OTPC

ONGC Tripura Power Company Limited

10th Floor, Core 4 and Central, SCOPE Minar, Laxmi Nagar, Delhi-110092, Phone : +91-11-22404700, Fax : +91-11-22017731, 22018831

Ref No: OTPC/Comml/T-8/2021-22/410 09th February 2022

Member Secretary,
North Eastern Regional Power Committee,
NERPC Complex, Dong Parmaw, Lapalang,
Shillong, Meghalaya – 793006

Sub: Supplementary PPA between OTPC and Power and Electricity Department, Government of Mizoram

Ref: NERPC/Committee/2021/1281-1285 dated 7th December 2021

Dear Sir,

Kind attention is invited to letter under reference wherein NERPC had advised OTPC to sign the supplementary PPA with the interested beneficiary states and to submit the same to NERPC for further needful action.

OTPC and Power and Electricity Department, Government of Mizoram have signed the supplementary PPA on 08th February 2022 and same is enclosed for your kind reference and further necessary action. The updated allocation of Mizoram from OTPC Palatana Project shall now be as below:

Mizoram Long Term Allocation as per Original PPA	Additional Long Term Allocation as per Supplementary PPA	Total Long Term Allocation of Mizoram from Palatana Project
22 MW	20 MW	42 MW

The revised percentage allocation of Mizoram from Palatana shall now be 5.785123%. Request NERPC to kindly allocate the additional power to Mizoram from OTPC Palatana Project on long term basis at CERC determined tariff so that this additional power may also be scheduled by Mizoram from 00:00 Hours of 15th February 2022.

Thanking you.

Yours faithfully,

Arup Ch. Sarmah
General Manager (Commercial)

C.C: The Engineer-in-Chief, Power and Electricity Department, Govt of Mizoram

Regd. Office: Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura-799 105, EPABX: 0381-2363714, Fax: 0381-2363716
CIN: U40101TR2004PLC007544, Website: www.otpcindia.in

भारत सरकार Government of India
विद्युत मंत्रालय Ministry of Power
उत्तर पूर्वी क्षेत्रीय विद्युत समिति
North Eastern Regional Power Committee
एन ई आर पी सी कॉम्प्लेक्स, डोंग पारमाओ, लापालाङ, शिल्लोंग-७९३००६, मेघालय
NERPC Complex, Dong Parmaw, Lapalang, Shillong - 793006, Meghalaya

सत्यमेव जयते

Ph. No: 0364 - 2534039
Fax No: 0364 - 2534040
Website: www.nerpc.nic.in

No. NERPC/Committee/2021/1281 - 1285

Dated: December 07, 2021

To:

1. The Chief Engineer (T&G), Department of Power, Govt. of Nagaland, Kohima - 797001.
2. The Chief Engineer, Commercial & CEI, Department of Power, Govt. of Arunachal Pradesh, Itanagar - 799111.
3. The Managing Director, MSPDCL, Imphal, Manipur - 795001.
4. The Engineer – In- Chief, Power and Electricity Department, Govt. of Mizoram, Aizawl-796001

Subject: Allocation of OTPC Merchant Power on Long Term Basis at CERC Determined Tariff – Reg.

Sir (s),

Pursuant to the decision of the 21st TCC/RPC forum regarding the subject matter, interested utilities were requested to submit expression of interest and details of quantum to avail from the Merchant Power of OTPC Palatana on long term basis at CERC determined tariff.

In response to which, NERPC Secretariat has received consent for 58 MW of OTPC Merchant power from some of the beneficiaries of Palatana. The details of the interested entities are as below:

Sl. No.	Constituent	Power Quantum Requested	Reference Letter
1	Arunachal Pradesh	3 MW	SE (COM)/SLDC/56/2020-21/2774-77 dated 11-10-2021
2	Manipur	10 MW	2/29/2018/MSPDCL(Comml)/168-71 dated 20-04-2021
3	Mizoram	20 MW	T11022/01/17-EC(P)/Com/15 dated 01-11-2021
4	Nagaland	25 MW	CEL/TB/NERPC/2009-10/205(A) dated 01-03-2021

In view of the above requests, OTPC is advised to approach the interested beneficiaries for signing of supplementary PPAs for allocation/scheduling of requested merchant power quantum on long term basis at CERC determined tariff.

The copies of the signed supplementary PPAs may be submitted to NERPC for further needful action.

Thanking you.

भवदीय / **Yours faithfully,**

B. Lyngkhoi
Member Secretary

Copy to:

1. The Managing Director, OTPC, 10th Floor, Core 4, Scope Minar, Lakshmi Nagar, New Delhi -110092.

Bhaskar Sen Choudhury

From:	Pappu, Srinivasarao <Srinivasarao.Pappu@voith.com>
Sent:	14 August 2024 09:26
To:	Vinod Madhusudhan (STEAG Energy Services India); Bhaskar Sen Choudhury
Cc:	Pintu Halder (STEAG Energy Services India); Prasad, Chelluboina; Pindiga, Harishanker; service, vtip; Manmohan Das (STEAG Energy Services India); CHAKRABORTI, KRISHNENDU; Salla, Venu
Subject:	Voith MOM dt: 13.08.20204 , VTC R 16K.1 (SN : 114-00213)- STEAG Energy Services (India) Pvt. Ltd. -OTPC Site, 2x 363.3 MW CCPP
Attachments:	MOM Steag- OTPC 1.jpg; MOM Steag OTPC MOM page 2 .jpg; Photo .jpg

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Dear Sir

Good Morning.

Thank you for kind support extended during our engineer recent visit to site.

Please refer attached MOM under note i.e, damage of Herringbone gear teeth app : 6 - 8 mm with sharp edge on outer side of gear .

As this is main power transmission torque from Input shaft herring bone gears to Primary shaft pinions , this gear teeth damage may create impact on other teeth's followed by damages & leads to operations issues like severe noise, vibrations etc.

So, in this regard, we suggest you to initiate the process of procurement of gear stage as below to meet any emergency conditions at site.

1. *Input shaft with herring bone gears - balanced set*
2. *Primary shaft with pinions including primary wheel & coupling shell - balanced set.*
3. *Additionally : may keep one set of secondary runner assembly like : secondary wheel with secondary shaft - balanced set.*

We also noticed that some of the bearing clearances are very close to replacement tolerances, request to procure all bearings & also consumable spares like O-rings & shaft seals etc. before each overhauling for replacement in such conditions.

Best Regards

Srinivasa Rao Pappu
Voith Group

Senior Manager -Industry AMB
Field Service India - tiyif
Group Division Turbo
Division Industry

Voith Turbo Private Limited
P.O. Industrial Estate, Nacharam
500 076 Hyderabad (A.P.), India

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PAHARPUR COOLING TOWERS LIMITED

Paharpur House, 8/1/B, Diamond Harbour Road, Kolkata - 700 027, INDIA
Ph: +91-33-40133000 • Fax: +91-33-40133499 • sales@paharpur.com • www.paharpur.com

Ref : 21-0B-0118
Date : 30.08.2021

O&M Solutions Pvt. Ltd
C/O ONGC Tripua Power Co. Ltd
Kakraban Road, PO-Palatana
PS-Kakraban
Dist. Gomati, Tripura-799116

Attn.: Mr. Ramashis Bhadra, DGM

Ref: Your Inspection Order no. WO 22-22Y-097 dated 04.08.2021

Sub: Inspection report of Cooling Tower model: 84848-4.0-08 x2 , Sl.No. 10-2I0008 and 10-2I0017

Dear Sir,

Thank you very much for the courtesy and hospitality extended to the undersigned by your goodselves during visit to your plant on 19th and 20th of August'2021 for inspection of the subject cooling towers. We are pleased to furnish our inspection report in Annexure-I and II for your perusal.

Assuring our best service always

Yours faithfully

for **Paharpur Cooling Towers Ltd.**

S.K.GHOSH
FEAP Marketing

Ref : 21-0B-0118
Date : 30.08.2021

Inspection Report
Annexure-I

- **Technical details of cooling towers:**

Description	Cooling Tower model: 84848-4.0-08 x2 , Sl.No. 10-2I-0008 and 10-2I0017A
1. Structure of cooling tower	RCC (Counterflow)
2. Gear Reducer	Spiral Bevel type Series 36 (Ratio 12.98:1)
3. Motor	MTR FTM 150HP/ 315M/4P /415V/50HZ
4. Drive shaft	Sr. 351 Class-III (D/S 351 CLI 4530 GB2.5/8 MB80)
5. Fan Assembly	10M dia type: HP-6-8 along with FRP hub cover
6. Distribution system	RCC main trough and PVC branch pipes fitted with spray nozzles
7. Distribution Nozzle	Type: NS5 (PP)
8. Fill	PCTL make single layer PVC fill pack (MC67 type)
9. Drift Eliminators	PCTL make PVC wave type

……cont. page 2

Ref : 21-0B-0118
Date : 30.08.2021

O&M Solutions Pvt. Ltd
C/O ONGC Tripua Power Co. Ltd

Annexure-I
Inspection Report

- **Our observations:**

Cooling tower is observed and inspected from outside as well as inside the cooling tower cell along with your Mr. Abhijit Debnath. Our observation is as follows.

1 **PVC Fills:**

PVC Fill packs have been damaged mostly in all cells in various locations inside cooling towers. In some locations, fill packs got totally damaged and worn out. Water is falling like thick channel instead of spraying. Please refer to the taken photographs of some damaged fill packs. Quantum of damages is more in cell no. 1,2 and 3 in both cooling towers of unit 1 and 2.

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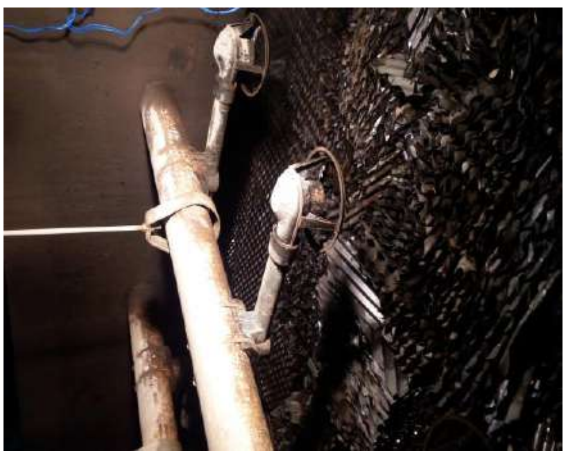
O&M Solutions Pvt. Ltd
C/O ONGC Tripua Power Co. Ltd

Annexure-I
Inspection Report

2. **Distribution system:**

It is observed that hot water spray nozzles are mostly in normal operating condition. In some locations, spray nozzles are found choked/broken. PVC branch pipes are found generally in good conditions. Hangers/studs are found damaged and branch pipes are opened out in some locations.



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Date : 30.08.2021

O&M Solutions Pvt. Ltd
C/O ONGC Tripua Power Co. Ltd

Annexure-I
Inspection Report

3. **Drift Eliminator:**

PVC drift eliminator blades are mostly in order and found good. In some locations, it is found damaged in small quantity.

4. **Mechanical equipment:**

Mechanical equipment support, fan assembly, drive shaft assembly, gear reducer are found in normal operating condition. No vibration or abnormal sound is observed.

Components	Observation
Gear Reducer	Physically found in normal condition. Outer casing and hardware are found good. Holding bolts and nuts are found good. Oil seal may be damaged in some gear boxes as spillage of gear oil is found in the surface of pinion cage cap. 

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O&M Solutions Pvt. Ltd
C/O ONGC Tripua Power Co. Ltd

Annexure-I
Inspection Report

Fan assembly	Blades are in good condition. Center hub and blade holding hardware are in good condition. Grommets are found damaged in various locations which may affect the fan blades. Hub cover is not found in the fan of unit-1 CT.
Drive Shaft	Physically found in good condition.
Gear and motor foundation support (weldment)	Gear and motor weldments are in good condition.
Lube Oil line	Physically found in good condition.
Motor	Physically seen okay. Please have it checked by your electrical expert periodically.

6. We have been informed from your end that you are not getting satisfactory performance from the cooling tower in term of approach and cold water temperature.

- **Our Recommendations:**

Damages of fill packs and improper spraying of hot water over fill area are the major factors behind lacking in performance of the cooling towers. This is the high time for replacing the damaged fill packs in all cells one by one. Considering the quantum of damages, we recommend for starting this fill replacement job in cell no. 1,2 and 3 in cooling towers of both units. This job may be carried out in other cells phase wise in subsequent years. Right now, we suggest for the following jobs in cell no. 1, 2 and 3.

1. Existing fill packs should be replaced with new ones in 100% quantity.
2. PVC branch pipes and adaptor arm assembly should be cleaned (up to maximum possible extent).
3. Damaged nozzles should be replaced by new ones.
4. Damaged hanger bars should be replaced.
5. Broken adaptor arm assembly/branch arm should be replaced.
6. For replacing fill packs, existing drift eliminator packs are required to be opened in certain locations. During handling, some eliminators may be damaged. Hence, it is recommended to keep 15-20 % eliminator blades and spacers in stock during work.
7. Mechanical equipment should be maintained in regular basis as per our recommended maintenance schedule and service manual.
8. Fan hub cover should be restored with the fan in all cells of unit -1 CT.
9. In connection to specification of gear oil, please go through our latest gear-oil manual attached with this report.

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O&M Solutions Pvt. Ltd
C/O ONGC Tripua Power Co. Ltd

Annexure-I
Inspection Report

Based on our above observations, BoM for above overhauling job is attached in Annexure-II. As discussed with you, we shall send our priced offer for materials and service on receipt of your further confirmation.

Thanking You

Yours faithfully

for **Paharpur Cooling Towers Ltd.**

S.K.GHOSH
FEAP Marketing

FINAL REPORT

PLANT PERFORMANCE AUDIT-2

For 2 x 363.3 MW Combined Cycle Power Plant, India

BV PROJECT NO. 410764

PREPARED FOR

ONGC Tripura Power Company Limited (OTPC)

12 JULY 2023

BLACK & VEATCH

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Acronym List

ACRONYM	DESCRIPTION
^oC	Degrees Centigrade
AC	Alternate Current
ACRT	Accelerated Creep Rupture Test
APS	Automatic Plant Start-up/Shutdown Control Scheme
ASME	American Society of Mechanical Engineers
AVR	Automatic Voltage Regulator
BHEL	Bharat Heavy Electrical Limited
BOP	Balance-of-Plant
BSI	Borescope Inspection
Btu	British Thermal Unit
Btu/kWh	British Thermal Unit per Kilowatt-Hour
CCPP	Combined Cycle Power Plant
CEMS	Continuous emission Monitoring System
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Commercial Operation Date
CRH	Cold Reheat
CT	Cooling Tower
CW	Circulating Water
DC	Direct Current
DCS	Distributed Control System
DGR	Daily Generation report
DLE	Dry Low Emission
DLN	Dry Low Nox
DM	Demineralized
EAF	Equivalent Availability Factor
EAF	Equivalent Availability Factor
EAF	Equivalent Availability Factor
ECR	Equipment Condition Report
ECT	Eddy Current Test

ACRONYM	DESCRIPTION
EFOR	Equivalent Forced Outage Rate
EHS	Environmental Health and Safety
ELCID	Electromagnetic Core Imperfection Detection
ESDV	Emergency Shutdown Valve
ETP	Effluent Treatment Plant
FFH	Factored Fired Hours
FOF	Forced Outage Factor
FOR	Forced Outage Rate
FSFL	Full Speed Full Load
FSNL	Full Speed No Load
GE	General Electric
GSU	Generator Step Up
GT	Gas Turbine
GTG	Gas Turbine Generator
HMBD	Heat and Mass Balance Diagram
HP	High Pressure
hp	Horsepower
HP	High-Pressure
HR	Heat Rate
HRSG	Heat Recovery Steam Generator
HSO	Hot Section Overhaul
HV	High Voltage
Hz	Hertz
I&C	Instrumentation and Control
I/O	Input/Output
IAF-II	India Alternative Fund- II
IL&FS	Infrastructure Leasing & Financial Services Limited
IP	Intermediate- Pressure
IR	Infrared
IRIS	Internal Rotary Inspection
Kcal	Kilocalories

ACRONYM	DESCRIPTION
kJ	Kilojoule
klb/h	Kilopounds per hour
kV	Kilovolt
kVA	Kilovolt-ampere
kVar	Kilovar
kW	Kilowatt
kWh	kilowatt-hour
LD	Liquidated Damage
LEAP	Life Expectancy Analysis Program
LED	Light Emitting Diode
LHV	Low Heating Value
LP	Low-Pressure
LTSA	Long Term Service Agreement
LV	Low Voltage
m/s	Meters per second
m^3/sec	Cubic meters per second
mA	Milliamperes
MO	Major Overhaul
MS	Main Steam
MT	Magnetic Particle Test
MTD	Month Till Date
MV	Medium Voltage
MW	Megawatts
MWh	Megawatt Hour
NCV	Net Calorific Value
NDT/ NDE	Non-Destructive Examination/ Non-Destructive Testing
NERC	North American Electric Reliability Corporation, USA
NOx	Nitrogen Oxides
O&M	Operations and Maintenance
O2	Oxygen
OAR	Operation Assessment Report

ACRONYM	DESCRIPTION
OEG	Operational Energy Group
OEM	Original Equipment Manufacturer
OMS	O&M Solutions Pvt. Ltd
ONGC	Oil and Natural Gas Corporation Limited
OTPC	ONGC Tripura Power Company Limited
P&ID	Process and Instrumentation Diagram
PCB	Pollution Control Board
PG Test	Performance Guarantee Test
PLC	Programmable Logic Controller
PM	Preventive Maintenance
PT	Dye Penetrant Test
PTC	Performance Test Codes
RCA	Root Cause Analysis
Rpm	Rotations per Minute
RT	Radiographic Test
RTD	Resistance Temperature Detector
RVI	Remote Visual Inspection
SMP	Standard Maintenance Procedure
SOP	Standard Operating Procedure
SOX	Sulphur Oxides
ST	Steam Turbine
STG	Steam Turbine Generator
TAT	Turn around time
TBC	Thermal Barrier Coating
TPH	Tons per hour
UTM	Ultrasonic Thickness Measurement
VGV	Variable Guide Vane
VI	Visual Inspection
VIGV	Variable Inlet Guide Vane
VMU	Vibration Monitoring Unit
YTD	Year Till Date

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1 Executive Summary

ONGC Tripura Power Company Limited (OTPC) is a joint venture of Oil and Natural Gas Corporation Limited (ONGC) and Govt. of Tripura. OTPC is operating a 726.6 MW (2X363.3 MW) Combined Cycle Power Plant (CCPP) at Palatana in the state of Tripura, India. The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015.

Black & Veatch has been contracted by OTPC to perform technical system audit, plant performance audit, and provide recommendations for improvement in plant performance, reliability, and safety of the plant. A list of **27** recommended performance improvement project is provided in ***Section 6.1.5.*** These recommendations are categorized based on “risk level”, “priority”, “CAPEX” and “On-line vs. Shutdown” planning. Few major upgrades specially for steam turbines such as steam seal upgrades, LP last stage modifications etc. are recommended to be analyzed in consultation with major retrofit package providers besides OEMs and planned during next capital overhauls at expected 100,000 Hrs.

1.1 Performance Analysis at Base Load

1.1.1 Heat Rate Analysis

Black & Veatch supported the conductance of site performance test with OTPC and OMS on 1st – 3rd of Feb-23 based on in-situ instrumentations. This assessment was part of 2nd audit cycle activity performed by Black & Veatch. The below table 0-1 compares the gross heat rate (Corrected) with PG test and [1]CERC norms.

Table 1-1 Gross Heat Rate Analysis

Unit	Perf. Test O/P (Uncorrected)	Perf. Test HR (Uncorrected)	PG Test		CERC	
			Output	HR	[1]HR	DIFF.
UOM	MW	kCal/kWh	MW	kCal/kWh	kCal/kWh	%
Block-1	335.70	1622.02	373.59	1504.9	1581	2.59
Block-2	339.19	1623.11	368.06	1505.5	1581	2.66

Both Block 1 and 2 were operated at base load. In Block-1, corrected heat rate for audit 2 was varying by 4.43% from OEM’s PG test value. In Block-2 performance test corrected heat rate was varying by 5.68% from OEM’s PG test results.

Overall, combined cycle heat rate (uncorrected) for Unit 1 and 2 are higher by 2.59% and 2.66% respectively from CERC’s permissible limit of 1581 kCal/kWh for base load operation.

[1] CERC tariff regulation 2019 specifies under u/s chapter 12; Norms of Operation to be 1.05 times of design gross heat rate for natural gas-fired combined cycle plant. The CERC value as applicable for OTPC is thereto derived by applying a 5% margin over the design heat rate of 1505.7 kCal/kWh.

1.1.2 Auxiliary Power Analysis

BLOCK	GROSS GENERATION (MW)	% OF RATED CAPACITY	AUX. ENERGY CONSUMPTION (%)	CERC NORMS (%)
Block-1 & 2	657.06	90.4	[2]3.446%	[3]3.30

APC is calculated at the station level based on EM data and deducting total hourly export (MWH) with hourly gross generation for the test period. The APC of station is around 4.4% higher than the CERC permissible limit for CCGT.

1.1.3 Performance Comparison with Other 9F Based Combined Cycle Units

S. NO	DESCRIPTION	UOM	BLOCK-1	BLOCK-2	[4]GLOBAL BENCHMARKS		
					Min	Max	Median
1	Gross Heat Rate (NCV basis)	kCal/kWh	1572.35	1591.27	1487	1766	1588
2	Plant Auxiliary Power Consumption	%	3.446		2.6	5.7	3.82

Black & Veatch compared OTPC heat rate and auxiliary power consumption with the industry standards. The data used for this assessment is referred using Black & Veatch's two decades of monitoring & diagnostic service of combined cycle plants. The performance of OTPC is shown graphically in the chart below. The chart shows that OTPC heat rate at 1581.82 (combined for block 1 and 2) is lower than the global median of 1584.81, however there are potential for average improvements inherent further up to 2-3% on the lower side duly accounting for machine's permanent degradation and its operating characteristics. Given Major Inspection (MI) for block 1 and block 2 are concluded in 2021 and 2022 respectively, the expected heat rate based on OEM supplied curve is reset at lower side to 1527.9 kCal/kWh and 1521.5 kCal/kWh respectively. The permanent degradation after 1 MI cycle is ~0.6-0.7% of design heat rate for both the blocks i.e., 10-12 kCal/KWh. With the considerations above, we expect that there is a potential for reduction of up to 2-3% in combined cycle heat rate by implementing the 27 recommendations outlined in section 6.1.5. ***Assuming overall reduction of 3%, a target heat rate of 1534 kCal/kWh or alternatively reduction of 45-50 kCal/kWh with respect to performance test heat rate can be targeted by OTPC in short to midterm.***

[2] Based on Energy Mater Data for the 2nd of February (15:00 -18:00 Hrs).

[3] Gas-based generating stations using electric motor driven Gas Booster Compressors, the Auxiliary Energy Consumption in case of Combined Cycle mode shall be 3.30%

[4] Following is the criterion used to ensure that comparison is justified in the context of OTPC.

- 10+ Combined cycle plants (9FA / 7FA) with block outputs in the range of approximately 300 to 1000 MW was considered.
- Operating history after COD for these plants are varying from 4 years to 12 years.
- Plants are in North America, China, Canada, and India.
- All plants are operated generally at either base load or sometimes at part load following grid dispatch instructions.

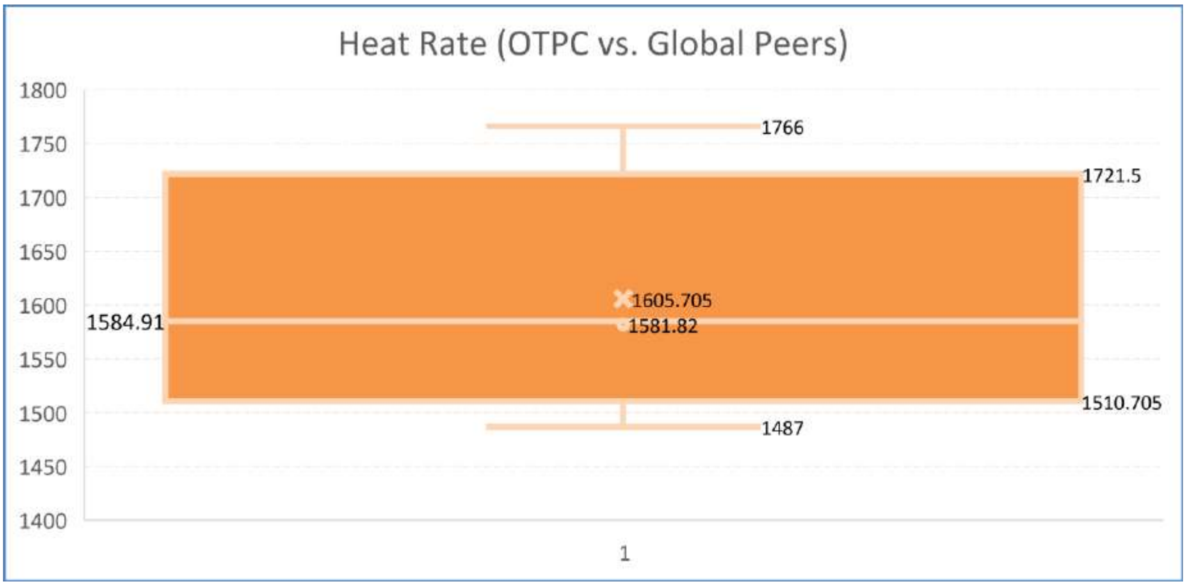
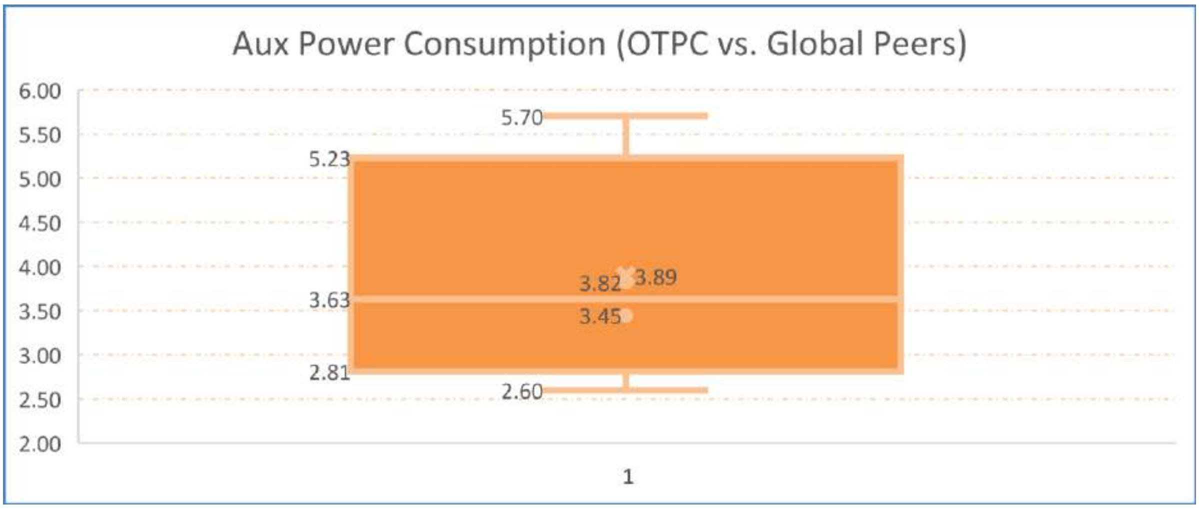


Figure 1 Box & Whisker Chart - OTPC vs. Global Peers

Figure 2 shows box and whisker plot of Aux power consumption. The OTPC auxiliary power consumption at 3.45% was lower than median of 3.82 and marginally higher than CERC norms of 3.30% respectively.



1.2 Recommended Improvement Actions

A list of 27 improvement project is provided in section 6.1.5 of the report and is reproduced below. These projects have each a potential of reducing heat rate and auxiliary power consumption varying with respect to severity of issues and measured adopted to rectify them including capital investment and technical support extended by OEMs and other equipment supplier. Please note that benefits of the projects are not additive and always complementary, hence heat rate improvement projects are required to be carefully evaluated to avoid double accounting or overstated expectations. We have classified these projects in two categories.

- Operational Adjustments
- System Modifications

Table 1-2 Heat Rate & APC Improvement Projects (1-5 Years)

Project ID	Project Description	Expected Heat Rate Reduction	Exp. APC Reduction	Type	CAPEX / Unit	Payback
1	HP/IP Section Internal Efficiency Improvement by Seal Upgrade	12-15 kCal/kWh	1.0-1.5 MW	System Modification (COH)	$1-1.5 million	<3 Years
2	Estimation of HP-IP Leakage by N2 Method (Services)	-	-	Operational Adjustment	$25-$35K	
3	LP Turbine efficiency Improvement by improving blade design and Increased annulus area (last stage blade replacement	10-30 kCal/kWh	Upto 1.0-2.0 MW	System Modification (COH)	$1.5-$2 million	3-5 Years
4	Addition of HP Exhaust pressure and temperature (Supply+ Service)	-	-	Operational Adjustment	$ 30-40K	
5a	Arrest Suspected Air Ingress in Condenser from Low Pressure Piping, LP turbine seals and diaphragm	5-10 kCal/kWh	-	Operational Adjustment	$ 30-40K	<1 Year
5b	Vacuum Pump “Under venting” Issue (Online Monitoring, Cleaning of Seal Water Cooler, Cavitation Avoidance)	5-10 kCal/kWh	-	System Modification (Minor)	$15-20K	<1 Year
5c	Condenser Cleaning (Online tube cleaning / Retubing with improved metallurgy	5-10 kCal/kWh	-	System Modification	$0.5-0.6 million	<2 Year
5d	Cooling Tower Projects (Fill pack replacements, CW flow equalization, Higher air flow using improved fan design, New Screen Design for CT basin)	10-15 kCal/kWh	Upto 0.5-1 MW, Condenser vacuum	System Modification	$0.8-1.2 million	<3 Year
6	Mitigate Inlet air filter choking and extend filter replacement cycle using Coalascer pads or Upgrade fine filter to EPA grade after cost benefit assessment with OEM	-	-	Operational Adjustment	$20-30K	<1 Year

Project ID	Project Description	Expected Heat Rate Reduction	Exp. APC Reduction	Type	CAPEX / Unit	Payback
7	Segregation of service air and instrument air usages (study)	-	Upto 100-150 KW	System Modification	$20-30K	<1 Year
8	Centralized controller for better loading / unloading frequency and average pressure band reduction	-	Upto 100 KW	System Modification	$80-100K	<1 Year
9	Arresting Leakages / Suspected Valve Passings CW Butterfly valve Plater Heat Exchanger BFP Recirculation IP Bypass Steam line	2-5 kCal/kWh	Upto 200 KW	Operational Adjustment	$50-80K	<1 Year
10	Real time monitoring of plant performance and continuous optimization	10-15kCal/kWh	Upto 0.5-1 MW	Operational Adjustment	$100-120K	<1 Year

A tabular and graphical representation for proposed recommendations and expected benefit is shown below.

Table 1-3 Heat Rate Improvement Strategy

Description	Units	Value[5]
Design Heat Rate	kCal/kWh	1505
Expected Heat Rate	kCal/kWh	1525
Target Heat Rate (Part Load, Gas Issues)	kCal/kWh	1534
Perf. Test Heat Rate	kCal/kWh	1582
Gap in Heat Rate (Target - Perf. Test)	kCal/kWh	48
Condenser Projects (5a,5b,5c)	kCal/kWh	-15
Cooling Tower Projects (5d)	kCal/kWh	-10
Steam Turbine Projects (1,2,3,5))	kCal/kWh	-20
Operational Adjustments (7,7,8,9)	kCal/kWh	-5
Predictive Analytics (10)	kCal/kWh	-10

[5] Values in negative indicates reduced gap between actual and target by project implementation. All improvement values are considered as median for representation purpose. Please refer 6.1.5 for range (minimum – maximum)

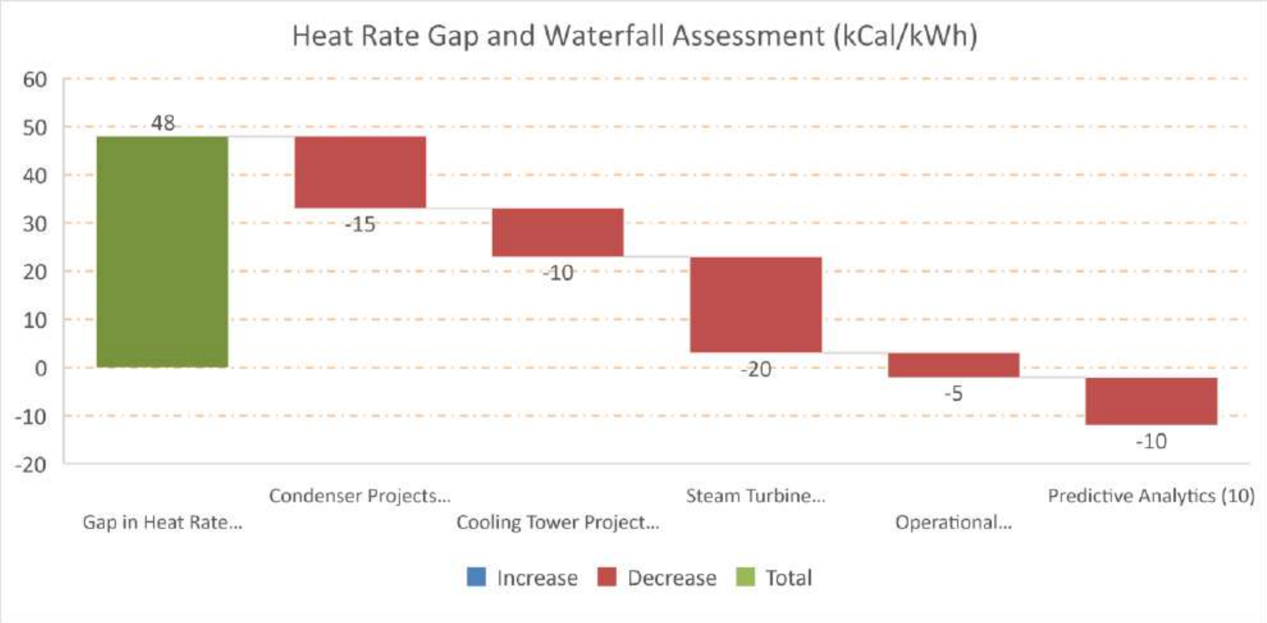


Figure 2 Heat Rate Gap and Waterfall Assessment

In conclusion, we have concluded two performance audits which were carefully organized between successive major inspections for Unit 2 and Unit 2 in 2021 and 2022 respectively. OTPC has implemented many upgrades and process improvements in the two units (ECP4 package upgrade for compressor, major retrofits in GT internals (nozzles, blades, shrouds, bearings replacement), IGV replacements, energy efficiency projects like CT fills replacements, new fan design, energy efficient lighting, insulation replacement etc. The focus for improvement is now required to be shifted towards bottoming cycle systems (HRSG, Steam turbine, Condenser and Auxiliaries) where we see considerable improvement potential through both system modification / upgrade strategy and operational adjustments. We are thankful to OTPC for giving opportunity to Black & Veatch to get associated in its decarbonization endeavor. Black & Veatch recommends systematic implementation of these projects in short-mid-term period for long-term efficient, reliable and safe plant operation achieving its environmental sustainability and decarbonization goals.

2 Facility Description

ONGC Tripura Power Company Limited (OTPC) is a joint venture of Oil and Natural Gas Corporation Limited (ONGC), and Government of Tripura. OTPC is operating a 726.6 MW (2X363.3 MW) Combined Cycle Power Plant (CCPP) at Palatana located about 60 (sixty) km from Agartala in the state of Tripura. The plant has 2 units each of 363. 3 MW on 1X1X1 configuration. Each unit consists of 1 GTG, 1 HRSG, and 1 STG along with associated plant auxiliaries supplied by BHEL.

The balance of plant system consists of Gas Booster Compressor house, river water intake system, fuel supply system, plant & fire water system, air supply system, hydrogen plant, nitrogen plant, 400 KV & 132 KV switchyard, etc.

The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015. The commissioning details of the station are shown below.

Table 2-1: Block-1 & 2 COD details

BLOCK NO	CAPACITY (MW)	TECHNOLOGY	DATE OF COMMISSIONING	DATE OF COMMERCIAL OPERATION
1	363.3	1X1 GE 9FA Combined Cycle	January 2013	4th Jan 2014
2	363.3	1X1 GE 9FA Combined Cycle	November 2014	24th Mar 2015

The plant receives gas from ONGC's gas fields located within 20-60 (twenty to sixty) km from the site. OTPC has entered into long term "Gas Sale and Purchase Agreement" (GSPA) with ONGC for purchase of fuel.

OTPC has entered into Operation and Maintenance Agreements with O&M Solutions Pvt. Ltd.(OMS) for providing operation and maintenance services including supply of consumables for the entire Plant. OTPC also has a maintenance services contract for services and supply of parts for Covered units of GT with General Electric International Inc and GE Energy Parts Inc respectively.

2.1 Equipment Design Information

Table 2-2: Equipment Design Information

DESCRIPTION	SPECIFICATION
Gas Turbine GT 2X363.3 MW	
Manufacturer	GE
Model ISO rated power Exhaust Temperature Speed Emission Control	9351FA Natural Gas Combustion turbine and Brush Generator 235400 KW 602.2 Deg. C 3000 RPM Dry Low NOx (DLN) 2.0
GT Turbine Generator (2 No)	

DESCRIPTION	SPECIFICATION
Manufacturer	BHEL, Haridwar
Terminal Voltage Stator Current Coolant Speed	15750 V 10022 A Hydrogen 3000 RPM
Heat Recovery Steam Generator (2 No)	
Manufacturer	BHEL
Features	Horizontal, natural circulation, water tube, top supported, fully drainable, modular design, Triple pressure with reheat type waste heat boiler
Maximum Capacity	289 TPH
Steam Turbine (2 No)	
Manufacturer	BHEL, Hyderabad
Type	Two Cylinder reheat Condensing turbine
Rated Speed	3000 RPM
Gas Booster Compressor [3 No]	
Manufacturer	BHEL
Model	BCL 406
Type	Centrifugal compressor
Drive Type	Electric Motor
Motor Power	3840 KW
Gas Heater	
Manufacturer	Not Availlable
Type Gas Flow	TEMA”AEL” 51520 kg/hr
GT Control System	
Type Model Make Control panel supply Monitor/Printer Supply	Electronic Speedtronic ™Mark VI/ Upgarded to Mark VIe M/S General Electric, USA 125 DC 240 AC
Plant Switchyard	400 kV and 132 kV switchyard with ICTs

3 Scope of Work and Audit Methodology

3.1 Scope of Performance Audit

The scope of Plant Performance Audit would be as follows

- Analyze the present key performance parameters of the plant and Identify reasons for variation/deviations of parameters, controllable losses, etc. and suggest ways to improve key performance indicators.
- Compare the plant performance parameters with design parameters.
- Compare the current plant performance parameters with performance targets.

3.2 Audit methodology

Black & Veatch team gathered available data to perform its assessment for this Report through the online data room. Black & Veatch conducted site visits to the OTPC site from 1st Feb – 4th Feb, 2023. The site visits involved meetings with representatives of OTPC and OMS. The purpose of the site was to assess the physical condition of the assets, to witness plant performance test and to gather additional information from operations personnel.

3.3 Performance Test Data Collection Guidelines

Black & Veatch has followed guidelines based on relevant ASME and PTC codes like PTC- 22, PTC -6, PTC -46, etc. for the performance evaluation. Some of the general guidelines are as below,

- Each unit shall be operated preferably in automatic mode and in a manner consistent with good utility practices.
- The total test duration comprises of the stabilization period, performance test period, and post-test period.
- The gas turbine shall be operating in baseload condition with IGV full open preferably.
- The test period will be preferably 120 minutes however, the test period shall not be less than 60 minutes if 120 minutes is not possible. ***Please refer table 3.1 for additional details***.

Table 3-1: Expected Minimum and Maximum Period for Performance Test

PERIOD	TIME	EXPECTED	MINIMUM
Stabilization period	Minutes	60	30
Test period	Minutes	120	60
Post-test period	Minutes	30	30
Total period	Minutes	210	120

- Before the start of the stabilization period, it shall be ensured that data is getting recorded at least for the parameters mentioned in the performance test data requirement section.

- The test shall not be carried out in conditions wherein there are expected major change in ambient parameters like ambient pressure, dry bulb temperature, and relative humidity.
- The test shall be repeated if there is starting/stopping of rain in between the test period.
- Following are critical stability conditions required per PTC 22. PTC 22 indicates sample standard deviation.

Table 3-2: Acceptable variations as per PTC 22

S.NO	VARIABLE	VARIATION ALLOWED PER PTC 22
1	Gross Power Output	0.65%
2	Air Temperature	1.3 DEGF (0.7 DEGC)
3	Fuel Flow	0.65%
4	Barometric Pressure	0.16%
5	Rated Speed	0.33%

- The test shall be restarted if there is a major disturbance or fluctuations during the performance test period.
- All drum blowdowns are to be kept closed.
- All drain /vent valves to be kept closed. Report if there are any water or steam leaks in the system.
- The electrical output from the combustion turbine shall be measured at the generator terminals with precision power meters.
- Fuel gas flow to the combustion turbine shall be measured using one or more calibrated orifice flow sections (designed in accordance with ASME MFC-3M), or other agreed-upon alternative meters (s) which meet the accuracy requirements of the test.
- Ambient conditions shall be measured with instrumentation that meets the accuracy requirements of the test.
- Upon completion of the test or during the test itself, the test data shall be reviewed to determine if any data should be rejected prior to the calculation of test results.
- All drain /vent valves to be kept closed. Report if there are any water or steam leaks in the system. All drum blowdowns were kept closed.
- The electrical output from the combustion turbine shall be measured at the generator terminals with precision power meters.

4 Principle Assumptions

In completing this assessment, Black & Veatch has used and relied upon certain information provided by OTPC and OMS. Black & Veatch believes the information provided is true and correct and reasonable for the purposes of this report. In preparing this report and the opinions presented herein, Black & Veatch has made certain assumptions with respect to conditions that may exist or events that may occur in the future. However, some events may occur, or circumstances change that cannot be foreseen or controlled by Black & Veatch and that may render these assumptions incorrect. To the extent that the actual future conditions differ from those assumed herein or provided to Black & Veatch by others, the actual results will differ from those that have been forecast in this report.

Throughout this report, Black & Veatch has stated assumptions and reported information provided by others, all of which were relied upon in the development of the conclusions of this report. Following is a summary of principal considerations and assumptions made in developing the opinions expressed herein:

- Natural gas and associated transportation will continue to be available in the quantities and qualities required by the plant throughout the remaining terms of agreements in place.
- The assets will be operated and maintained in accordance with good industry practices, with required renewals and replacements made in a timely manner.
- Equipment will not be operated in a manner to causes it to exceed the equipment manufacturer's ratings or recommendations.
- All contracts, agreements, rules, and regulations will be fully enforceable in accordance with their respective terms, and all parties will comply with the provisions of their respective agreements.
- All licenses, permits and approvals, and permit modifications (if necessary) will be obtained and/or renewed on a timely basis; and any such renewals will not contain conditions that adversely impact the operating and maintenance costs.

5 Plant Performance Test Result Analysis

Before the site visit, Black & Veatch has provided the formats and general guidelines for DCS data collection during stable operating conditions at baseload.

The baseload performance test data for Block-1 was recorded from 15:00 Hours to 17:00 Hours at 1 minute interval on 2nd of February. Similarly, Block-2 was kept at baseload operation from 15:00 Hours to 17:00 Hours on 3rd of February and performance test data was recorded for results evaluation.

5.1 Overall Plant Performance

5.1.1 Design Parameters

The plant's design parameters at base reference conditions provided by BHEL are shown in the below Table.

Table 5-1: Plant Parameters at Reference Design Condition

PARAMETERS	UNIT	VALUE
Block-1 & 2 Gross Output	MW	363.3
Block-1 &2 weighted average gross Heat Rate (NCV basis)	Kcal/kWh	1505.7
Auxiliary Power Consumption for the entire plant	%	3.41
NOx for each Block	PPM	50
Reference Condition		
Ambient Pressure	Bar (a)	1.0
Dry bulb Temperature	DEGC	27
Relative Humidity	%	77
LHV	KJ/KG	49328
CW inlet temperature	DEGC	32

5.1.2 Heat Rate Analysis

The table 5-2 describes the high-level results of the plant performance test conducted on 2nd and 3rd February.

Table 5-2 Gross Heat Rate Analysis

Unit	Perf. Test Output (Corrected)	Perf. Test HR (Corrected)	PG Test			CERC
			Output	HR	DIFF.	[6]HR
UOM	MW	kCal/kWh	MW	kCal/kWh	%	kCal/kWh
Block-1	344.62	1572.35	373.59	1504.9	4.43	1581
Block-2	344.7	1591.27	368.06	1505.5	5.68	1581

Table 5-3: Uncorrected & Corrected Heat Rate

DESCRIPTION	BASIS	UOM	DESIGN	BLOCK-1	BLOCK-2
Gross Load	Uncorrected	MW	363.3	335.70	339.19
	Corrected			344.05	344.70
Gross Heat Rate (NCV Basis)	Uncorrected	Kcal/kWh	1505.7	1622.02	1623.11
	Corrected			1572.35	1591.27

Table 5-4: Heat Rate Comparison between Expected (Degradation Curve) and Performance Test

UNIT	FIRED HOURS	EXPECTED HEAT RATE (KCAL/KWH)	TEST HEAT RATE (COR) (KCAL/KWH)	%DIFF. FROM EXPECT.	REMARKS
Block-1	70040.3	1527.9	1572.35	2.90	GT-1 Major inspection was done in 2021 at 56950 FFH
Block-2	60526.7	1521.5	1591.27	4.58	GT-2 Major Inspection is done in June 2022 at 55489 FFH.

Performance Analysis

The % difference from expected is higher in Block-2 due to following reasons.

- Lower bottoming cycle parameters in general specially pressure, temperature, flow rate at different sections of HRSG and ST cylinder
- Higher GT Inlet Filter DP i.e. 35 mm of H2O
- High back pressure

[6] CERC tariff regulation 2019; Gas plant having COD on or after 1.04.2009 - 1.05 X Design heat rate of unit/ block at 100% MCR and at site ambient conditions, zero percent make up, design cooling water temperature/back pressure

The expected heat rate derived from degradation curve supplied by OEM, are based on multiple assumptions i.e. operations within design conditions, Waterwash frequency (on-line and off-line), inspection intervals, steam turbine back pressure etc. The expected heat rate is placed in the table to support the benefits of MI in block 2 with degradation getting reset to new lower value trajectory after MI.

Table 1 Expected vs. Actual (% HR Degradation)

	Dec'21 (Block 1 - After MI)			Feb'23 (Block 2 -After MI)		
	Fired Hours	Expected Degradation	Actual Degradation	Fired Hours	Expected Degradation	Actual Degradation
Block 1	60619.5	1.03%	1.32%	70040.3	1.48%	2.90%
Block 2	51903.8	2.34%	4.55%	60526.7	1.05%	4.30%

Expected Degradation – Based on BHEL curve, Actual Degradation - Based on Performance Test Corrected Value

Black & Veatch has summarized the major equipment efficiencies calculated from the performance test results and compared the results with design.

Table 5-5: Performance Test Comparison with Design

Efficiency	UOM	Design	Performance Test Results	
			Block-1	Block-2
Overall Efficiency of CCPP	%	57.12	54.33	54.23
Compressor Efficiency	%	92.41	87.02	86.98
Gas Turbine Efficiency	%	35.14	34.98	35.49
HRSG Efficiency	%	83.3	89.18	88.20
STG Efficiency (Shaft O/P / Heat I/P)	%	33.91	29.69	30.08
HP Turbine Efficiency	%	89.1	**85.12**	**85.86**
IP Turbine Efficiency	%	95.8	**94.16**	**94.51**
LP Turbine Efficiency (UEEP)	%	89.1	**66.25**	**64.89**

- CCPP efficiency for blocks 1 and 2 are evaluated using PTC 46 standard and values are found to be around 54.33% and 54.23% respectively against the design value of 57.12%.
- Compressor polytropic efficiency is reported as 87.02% and 86.98% compared to design of 92.41%.
- HP turbine section internal efficiency is found to be 85.12% and 85.86% respectively.
- LP turbine efficiency (based on useful energy end point) is found to be 66.25% and 64.89% respectively.

5.2 Gas Turbine

The below table describes the performance output results of block 1 and 2 gas turbines compared against the design values.

Table 5-6: Block 1 &2 GT Performance against Design Values

Parameters	Unit	Index	Design	Performance Test	
				GT-1	GT-2
GT Load (Uncorrected)	MW	A	232.39	224.77	221.73
[7]GT Load (Corrected)	MW	Acor.	232.39	225.78	229.211
Fuel Flow	SM3/Hr	B	66738	65432.64	66157.85
LHV	Kcal/M3	C	8313.87	8321.773	8321.724
Ambient temperature	Deg C		27	27.67	27.44
GT Efficiency	%	860/[(BXC)/ AX1000]	35.14	36.09	35.94
GT Corrected Gross Heat Rate (LHV basis)	Kcal/kWh	D	2447.66	2382.76	2392.98
Specific Fuel Consumption	Kg/kWh	[BXRHO/AX1000]	0.21	0.211	0.209

[7] GT Load is corrected for ambient pressure, ambient temperature, RH, fired hours, frequency, LHV and power factor.

- GT efficiency is found to be 36.09% and 35.94% respectively and is within expected range. The calculation of efficiency is performed on GT corrected power output by direct method.
- Specific fuel consumption for blocks 1 and 2 at 0.211 and 0.235 kg/kWh respectively are noted to be higher than the design value of 0.21 kg/kWh.

5.3 Axial Compressor Performance

Parameters	Units	Index	Design	Block 1	Block 2
Compressor Inlet Pressure	kg/cm2	A	1.02	0.967	0.977
Compressor Discharge Pressure	kg/cm2	B	16.83	14.19	14.13
Compressor Inlet Air Temperature	Deg. C	C	27	27.67	27.44
Compressor Discharge Air Temperature	Deg. C	D	410	412.09	413.37
Air Flow	Kg/sec	E	602.59	596.42	586.71
IGV Angle	Deg	F		87.10	87.21
Combustion Turbine Gross Load (Site)	MW	G	232.39	224.77	221.73
Compressor Adiabatic Efficiency	%	F(PR,[8]Gc)	92.99	81.94	81.86
Polytropic Coefficient	-	K=[LN (PR)/LN(PR/TR)]	1.415	1.46	1.46
Polytropic Efficiency	%	F(K,Gc)	**95.13**	**87.02**	**86.98**
Compressor Pressure Ratio	-	PR=B/A	16.5	14.67	14.46
Compressor Temperature Ratio	-	TR=D/C	2.276	2.28	2.28

- GT compressor efficiency as per test data is found to be 87.02 % and 86.98% for block 1 and 2 respectively. During test, block 1 and 2 was operated at 224.77 MW and 221.73 MW respectively.
- The pressure ratio during test condition is calculated to be 14.67 and 14.46 respectively against design of 16.5. The air flow through compressor was calculated based on the difference in the flow of GT exhaust and natural gas mass flow rate.
- Overall, the performance of compressor is satisfactory.

During the site visit, Black & Veatch was informed about filter replacement cycle being twice in 1 year, generally 1 each in summer and winter cycle. This cycle of replacement is despite inlet air pulsation system being operational for the two units.

5.3.1 Recommendations:

5.3.1.1 Inlet Air Filter Replacement Cycle

Due to increase of fine dust in the ambient air, fine filters are getting exhausted within 4-6 months. This filter replacement requires shutdown of the unit. We recommend exploring the possibility of

[8] Gc – Gas Coefficient (Inlet and Outlet of Compressor)

installing Coalascer pad rolls before the prefilters. These Coalascer pads have good dust holding capacity. These pads can be changed online whenever these get choked.

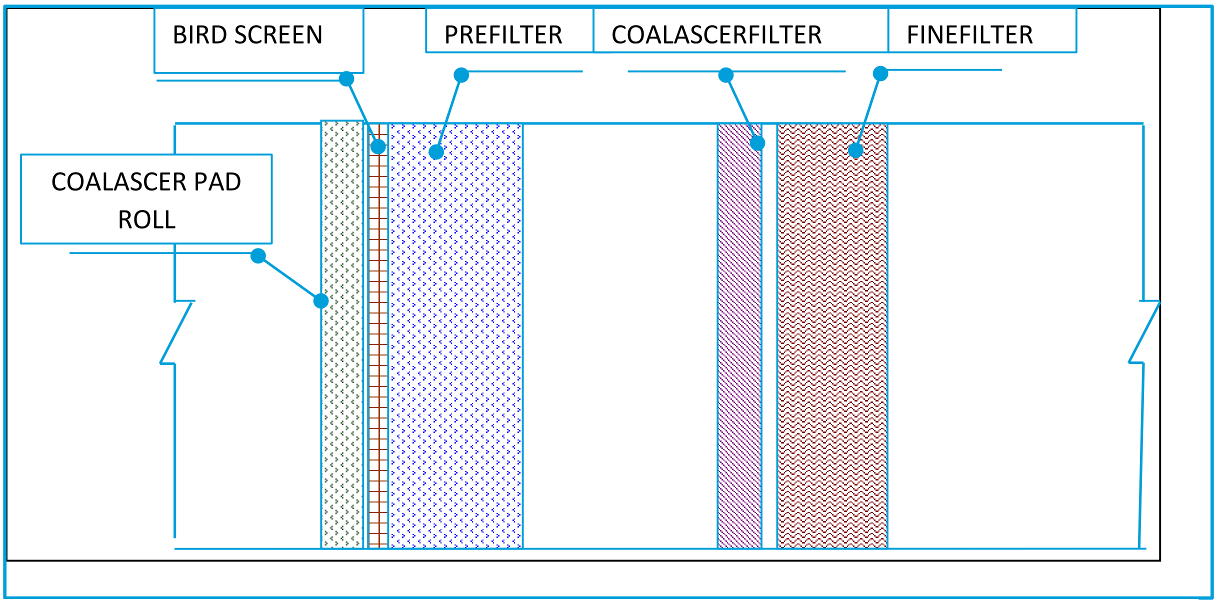


Figure 3 Coalascer Pad

The installation of coalescer pad rolls before bird screen will increase pressure drop (generally a pressure drops of 50 Pa impacts GT efficiency by 0.1%) but normally these pads are changeable on-line with ease and also extend filter replacement cycles. This modification is to be consulted with OEM and filter manufacturer before implementation for site specific environmental condition. The other possibility is upgrading / replacing fine filters to EPA grade (E10 or E11) without coalescer pad, but here also – there is a benefit-loss assessment with higher inlet air -dP (loss) and lower fouling in compressor (gain) as described above.

5.4 HRSG Performance

5.4.1 Design Parameters

The below table describes the design parameters of HRSG 1 & 2 as per the technical diary shared by OTPC.

Table 5-7: HRSG Design parameters

PARAMETERS	VALUES
HP Feed water Pressure, temperature, flow	158 kg/cm2, 152.1 DEGC, 289.6 TPH
HP Drum Pressure, temperature	145 kg/cm2, 339 DEGC
HP Main steam Pressure, temperature, flow	134 kg/cm22, 540 DEGC, 289.6 TPH
IP Feed water Pressure, temperature, flow	100 kg/cm2, 152.1 DEGC, 65 TPH
IP Drum Pressure, temperature	36.6 kg/cm2, 246 DEGC
IP SH outlet steam Pressure, temperature, flow	34.6 kg/cm22, 330 DEGC, 35.6 TPH
LP Feed water Pressure, temperature, flow	6.6 kg/cm2, 149.6 DEGC, 36.7 TPH
LP Drum Pressure, temperature	5.1 kg/cm2, 159 DEGC

PARAMETERS	VALUES
LP SH outlet steam Pressure, temperature, flow	4.4 kg/cm22, 230 DEGC, 36.7 TPH
CRH Inlet Pressure, temperature	34.8 kg/cm2, 345 DEGC
HRH outlet Pressure, temperature	33.2 kg/cm2, 540 DEGC
HRSG inlet pressure, Temperature, flow (flue gas)	266.71 mmWC, 700 DEGC, 2217.6 TPH

The below table describes the HRSG 1and 2 full load operating parameters compared against the design full load parameters and PG test DCS screenshot values (instantaneous).

Table 5-8: HRSG 1 and 2 full load parameters and comparison with design values

PARAMETERS	UOM	DESIGN	HRSG-1		HRSG-2	
			PG Test	Perf.Test	PG Test	Perf.Test
HP Main Steam Pressure,	Kg/cm2	134	129.09	126.0	126.80	122.84
HP Main Steam temperature	Deg C	540	536.05	530.6	541.00	534.6
HP Main Steam flow	TPH	289.6		292.3		286.9
IP Main Steam Pressure,	Kg/cm2	34.6	33.93	33.56	31.97	32.55
IP Main Steam Temperature	Deg C	330	312.76	312.2	326.27	327.06
IP Main Steam Flow	TPH	35.6		34.74		35.9
CRH Inlet Pressure,	Kg/cm2	34.8	33.61	35.98	30.97	34.22
CRH Inlet Temperature	Deg C	345	344.71	350.27	NA	353.22
HRH Outlet Pressure	Kg/cm2	33.2	32.71	35.02	31.90	33.30
HRH Outlet Temperature	Deg C	540	538.90	538.1	541.00	538.16
Feedwater outlet temperature	Deg C	152	147.45	149.73	149.44	149.12

5.4.2 HRSG Efficiency

The below table indicates the HRSG-1 & 2 main parameters and efficiency values from performance test output results at the GT baseload condition.

Table 5-9: HRSG Efficiency Results

PARAMETERS	UNIT	BLOCK-1	BLOCK-2
HP steam production / hr	TPH	290.9	286.9
HP steam Enthalpy	kcal/kg	818.3	821.7
IP steam production / hr	TPH	33.8	35.9
IP steam Enthalpy	kcal/kg	719.8	729.4
LP steam production / hr	TPH	36.9	36.5
LP steam Enthalpy	kcal/kg	699.7	699.0
HRSG inlet temp	Deg C	622.0	614.8

PARAMETERS	UNIT	BLOCK-1	BLOCK-2
HRSG outlet temp	Deg C	105.2	103.4
Air flow rate	TPH	2328.1	2366.6
HP Feedwater Enthalpy	kcal/kg	149.7	149.1
IP Feedwater Enthalpy	kcal/kg	147.7	146.6
LP Feedwater Enthalpy	kcal/kg	143.6	144.3
[9]HRSG (Eff)	%	89.18	88.20

- Black & Veatch has calculated the HRSG Efficiency by Input/Output method and noted that HRSG 1& 2 efficiencies are noted to be around 89.18% and 88.20% against the design value[10] of 83.35%.

5.4.3 LP Circuit Performance

The below table describes the performance of the LP circuit based on performance test results.

Table 5-10: LP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	TEST	
				HRSG-1	HRSG-2
LP Feed Water Pressure	Kg/cm2	10.4		13.4	13.6
LP Feed Water Temperature	Deg C	149.5	[A]	143.6	144.3
Enthalpy of LP Feed Water	Kcal/kg	150.7		144.6	145.3
Energy from LP FW	Kcal/sec	1536.43	[C]	1422.8	1455.0
LP Drum Pressure	Kg/cm2	5.1		4.8	4.8
LP Saturation Temperature	Deg C	158.92	[B]	157.4	157.5
LP Main Steam Flow	TPH	36.7	[E]	35.4	36.1
LP Main Steam Pressure	Kg/cm2	4.8		4.7	4.6
LP Main Steam Temperature	Deg C	229		235.5	234.5
LP Steam Enthalpy	Kcal/kg	696.9	[F]	699.5	699.0
Energy From LP Steam	Kcal/sec	7105.08	[D=E*F]	6881.8	7000.1
Energy Gain from LP Circuit	Kcal/sec	5568.65	[D-C]	5459.0	5545.1
Approach	Deg C	9.42	**[B-A]**	**13.7**	**13.2**

- The energy gain from the LP circuit is around 5459 and 5545 Kcal/sec for HRSG 1 & 2 respectively against the design values of 5568 Kcal/sec.

[9] HRSG Efficiency is based on ratio of heat pick up in HP, IP, and LP circuit (output) and heat input from fuel gas across the control volume. [HP Steam flow X HP Steam Enthalpy Gain + IP Steam Flow X IP Steam Enthalpy Gain + RH Steam Flow X RH Steam Enthalpy Gain + LP Steam Flow X LP Steam Enthalpy Gain] / [Flue Gas Flow Rate X (HRSG Inlet Temp – HRSG Outlet Temperature) X Cp of Gas] *100

[10] Design details are calculated based on the design data available in technical diary and heat balance diagram.

- LP circuit approach is found to be around 13.7 and 13.2 Deg C respectively for HRSG 1 and 2 against the design value of 9.42 deg C.

5.4.4 IP Circuit Performance

The below table describes the performance of the IP circuit based on performance test results.

Table 5-11: IP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
IP Feed Water Flow	TPH	65.16		55.62	70.09
IP Feed Water Pressure	Kg/cm2	43.6		54.44	52.73
IP Feed Water Temperature	Deg C	150.2		147.73	146.64
Enthalpy of IP Feed Water	Kcal/kg	121.7		149.42	148.28
Energy from IP FW	Kcal/sec	2202.91	G	2308.52	2886.81
IP Drum Pressure	Kg/cm2	36.6		37.02	35.77
IP Saturation Temperature	Deg C	244.01	[B]	247.40	245.46
IP Main Steam Flow	TPH	35.8	[D]	33.82	35.90
IP Main Steam Pressure	Kg/cm2	36.6		33.56	32.55
IP Main Steam Temperature	Deg C	246		312.20	327.06
IP Steam Enthalpy	Kcal/kg	730.2	[E]	719.80	729.39
Energy From IP Steam	Kcal/sec	7262.01	F=D*E	6762.11	7272.68
Energy Gain from IP Circuit	Kcal/sec	5059.1	H=F-G	4453.59	4385.87
IP Economizer Outlet Temp.	Deg C	231	[B]	228.69	231.11
[11]Approach	Deg C	13.01	**[B-A]**	**18.71**	**14.35**

- Energy gain from the IP circuit is around 4453.59 and 4385.87 Kcal/sec for HRSG 1 & 2 respectively against the design values of 5059 Kcal/sec.
- IP circuit approach is found to be around 18.71 and 14.35 Deg C respectively for HRSG 1 and 2 against the design value of 13.01 deg C.
- Higher approach signifies reduced hear transfer in the economizer section either due to internal/ external fouling or surface area constraints. The assumption is that upstream parameters of HRSG like feedwater pressure, temperature is close to expected range. Please note that before inferring heat transfer issues, it is important that a trend of degradation is established over time with correct measuring points.

[11] Approach = IP economizer feed water outlet temperature – Saturation temperature corresponding to IP drum pressure

- Heat pick-up in the HRSG -1 IP circuit is observed to be below the design (~9-10%). The difference is attributable to lower IP steam flow rate and enthalpy and higher IP feed water inlet enthalpy with the addition of 6.48 TPH spray in bypass.
- Heat pick-up in the HRSG-2 IP circuit is lower due to higher IP feed water flow caused by IP bypass spray flow of 19.46 TPH. This has also impacted reheat circuit energy gain.

5.4.5 HP Circuit Performance

The below table describes the performance of the HP circuit based on performance test results.

Table 5-12 HP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
HP Feed Water Flow	TPH	289.6	[H]	290.12	284.64
HP Feed Water Pressure	Kg/cm2	158		147.69	144.98
HP Feed Water Temperature	Deg C	152.1		149.05	147.91
Enthalpy of HP Feed Water	Kcal/kg	155.5	[I]	152.15	150.95
Energy from HP FW	Kcal/sec	12510.11	[G=H*I]	12261.64	11935.58
HP Drum Pressure	Kg/cm2	145		137.08	134.31
HP Saturation Temperature	Deg C	338.46	[B]	335.59	329.4
HP Main Steam Flow	TPH	289.6	[E]	300.15	291.95
HP Main Steam Pressure	Kg/cm2	135		125.97	122.84
HP Main Steam Temperature	Deg C	540		530.57	534.62
HP Steam Enthalpy	Kcal/kg	821.8	[D]	818.32	821.67
Energy From HP Steam	Kcal/sec	66114.53	[F=D*E]	68227.21	66635.59
Energy Gain from HP Circuit	Kcal/sec	53604.42	[F-G]	55965.57	54700.02
HP Economizer Outlet Temp.	Deg C	334.19	[A]	331.20	**318.2**
[12]Approach	Deg C	4.27	[B-A]	4.40	**11.2**

- Energy gain from HP circuit is around 55965.57 and 54700 Kcal/sec for HRSG 1 & 2 respectively against the design values of 53604 Kcal/sec.
- HP circuit approach is found to be around 4.40 and 11.20 Deg C respectively for HRSG 1 and 2 against the design value of 4.27 deg C. In general, steam parameters (pressure and temperature) in HP sections are observed to slightly lower if compared to design or Unit 1. Unit specific variation in operating characteristic within range is normal, however this variation should be continuously checked.

[12] Approach = HP economizer feed water outlet temperature – Saturation temperature corresponding to HP drum pressure

- Approach signifies heat transfer gain in the superheater section of HRSG from the fuel gases. HRSG for HP Circuit 2 is high as we see lower HP economizer outlet temperature i.e. 318.9 Deg. C as compared to design of 334.19 Deg. C. Please note in general HP -2 pressure and temperature parameters are lower during the test. As noted above, a single point deviation is only a snapshot and a trend over time is to be analyzed with correct measurement to check any fouling in the tube section.

5.4.6 Reheater Circuit Performance

The below table describes the performance of the RH circuit based on performance test results.

Table 5-13: Re-heater circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
CRH Flow	TPH	269.45	[D]	270.67	266.72
CRH Pressure	Kg/cm2	35.85		35.98	34.22
CRH Temperature	Deg C	347.5		350.27	353.22
Enthalpy of CRH	Kcal/kg	740.3	[E]	741.03	743.67
Energy from CRH	Kcal/sec	55413.83	[F=D*E]	55714.37	55098.50
IP Feed water Flow	TPH	35.8		40.30	**55.36**
IP Feed Water Pressure	Kg/cm2	36.6		33.56	32.55
IP Feed Water Temperature	Deg C	246		312.20	327.06
IP Bypass Spray	TPH	0		6.48	19.46
Enthalpy of IP Feed Water	Kcal/kg	730.2		719.80	729.39
Energy from IP FW	Kcal/sec	7262.01	[G]	8057.75	11216.12
HRH Flow	TPH	305.045	[A]	307.70	306.43
HRH Pressure	Kg/cm2	33.3		35.98	34.22
HRH Temperature	Deg C	540		538.14	538.16
Enthalpy of HRH	Kcal/kg	846	[B]	844.73	845.15
Energy from HRH	Kcal/sec	71739.49	[C=A*B]	72200.10	71938.46
Total Energy into Re-Heater	Kcal/sec	62675.85	[H=F+G]	63772.12	66314.62
Energy Gain from Re-Heater	Kcal/sec	9063.64	[C-H]	8427.98	**5623.84**

- Energy gain from the reheater circuit is around 8427.98 and 5623.84 Kcal/sec for HRSG 1 & 2 respectively against the design values of 9063.6413Kcal/sec.

[13] Design heat pick up is calculated based on the design data available in the technical diary and heat balance diagram the design values

- Heat picks up in the HRSG-2 reheater circuit is lower due to higher IP feed water flow caused by IP bypass spray flow of 19.46 TPH. This has also impacted reheat circuit energy gain adversely if compared to design heat gain.

5.4.7 Recommendations

5.4.7.1 Suspected IP Bypass System Steam Passing & Steam Valve Upgrade

IP bypass controllers are also not able to effectively contain the steam and even hair line cracks in control valve may lead to significant flow of steam to condenser impacting condenser vacuum adversely. Our test data shows that IP bypass spray valve for Unit 1 and 2 was 6.48 TPH and 19.4 TPH respectively which suggest that there may be suspected steam flow in the downstream pipe, even though bypass valve position is shown as fully closed. It is necessary that suspected steam leakage in IP steam pipe is quickly arrested in available opportunity.

Unlike traditional control valves, there are designs which uses multi-stage, multi-turn technology divides the pressure reduction into many smaller stages. The number of turns, or stages, is selected to ensure a specific fluid discharge velocity is achieved at the exit of the control element. This reduces the potential for cavitation and erosion, that would otherwise compromise the valve's ability to effectively control leakage.

5.4.7.2 CBD Tank Vents Open to Atmosphere

As per the design, the Continuous Blow-Down Tank (CBD) vent is routed to Deaerator however, based on site-visit discussions, it is understood that for both units, CBD vent lines are kept open to atmosphere. CBD vent should be routed to the Deaerator for fluid recovery and improved energy utilization.

5.5 Steam Turbine

The below table indicates the performance output results of ST-1 and 2 at the GT baseload condition.

Table 5-14: Steam Turbine Performance

Parameters	Unit	Design	Performance Test	
			ST-1	ST-2
Unit Load	MW	130.91	112.81	113.64
MS Pressure	Kg/cm2	133.88	125.97	122.84
MS Temperature	Deg C	537.8	530.57	534.62
HP Exhaust Pressure	Kg/cm2	37.03	34.12	32.33
HP Exhaust Temperature	Deg C	347.3	348.76	347.95
HRH Pressure (IP Turbine Inlet)	Kg/cm2	34.4	33.56	32.55
HRH Temperature (IP Turbine Inlet)	Deg C	539.6	538.14	538.16
IP Turbine outlet pressure	Kg/cm2	5.04	4.71	4.21
IP Turbine outlet temperature	Deg C	264.5	282.17	274.45
LP Turbine inlet pressure	Kg/cm2	4.96	4.63	4.21
LP Turbine inlet temperature	Deg C	261.2	235.58	233.60
LP Turbine outlet pressure	Kg/cm2	0.088	0.200	0.173
LP Turbine outlet temperature	Deg C	NA	58.41	56.39

Parameters	Unit	Design	Performance Test	
			ST-1	ST-2
HP FW Flow	TPH	289.6	290.12	284.64
HP SH Attemperation Flow	TPH	0.00	10.03	7.31
IP FW Flow	TPH	65.15	55.62	70.09
IP SH Attemperation Flow	TPH	0.00	6.48	19.46
RH Attemperation Flow	TPH	0.00	3.76	3.16
STG Thermal Efficiency (Design 36.66)	%	36.66	32.32	29.93
HP Turbine Cylinder Efficiency(design-89.1%)	%	89.79%	**85.12**	**85.86**
IP Turbine Cylinder Efficiency(design-95.8%)	%	95.78%	**94.16**	**94.51**
LP Turbine Cylinder Efficiency(design-89.1%)	%	89.04%	**66.25**	**64.89**

5.5.1 Recommendations:

5.5.1.1 HP/IP Section Internal Efficiency Improvement by Seal Upgrade

Leakage losses represent the greatest portion of turbine stage losses. The losses are magnified as the turbine packing and turbine diaphragm spill strips wear out progressively. A large amount of these losses is recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization.

New turbine blade cover and nozzle spill strip designs are available which greatly reduce turbine blade tip leakage losses. New interstage and end packing will reduce packing leakage losses, resulting in more steam available to power the turbine blades. Retractable packing and brush seal packing designs are available from various manufacturers, which aim to reduce leakage losses even further from original designs. This upgrade can be performed at the HP/IP turbine major inspection and should be performed after engineering analysis and in consultation with OEMs.

The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP and IP turbine efficiencies. Typical efficiency improvements up to 0.7-1.2 % in heat rate is reported in the past. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.

The retrofit requires checking the actual clearances of the seals with respect to manufacturer's design clearances[14]. This task will help assess the extent of wear in the seals or help to find out the deviation of clearances from manufacturer's design clearances.

Replacement of existing seals with superior quality seals[15]. A generally guideline for replacement of seals is provided in the table below.

[14] Manufacturer's design clearances were not available.

[15] Option is feasible only when the slots provided by manufacturer fit with new type of seal

Table 5-15 General Guideline for Seal Replacement

Seal	Type
HIP Inter stage	Double stepped
HP turbine seals	Stepped
IP Turbine seal	Stepped
LP turbine seal	Plain seal

Actual clearances if found to be deviating from design clearances, it is recommended to explore the replacement and upgrade of the seals during the capital overhaul at 100,000 hours of steam turbine operation. Following are recommended seal types and arrangements based on industry best practices.

Vernier labyrinth seal: Seals provide better leakage resistance. The gland is independent of differential expansion. Both the shaft and seal ring are finned, the pitch of the fins being slightly different on the two seal components. This has the advantage that some of the fins will always be directly opposite, providing a greater restriction.

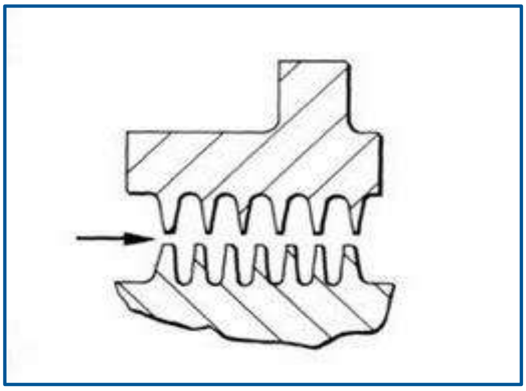


Figure 4 Vernier Labyrinth Seal

[16]**Spring backed labyrinth seal:** The radial clearance of the labyrinth gland is kept to minimum to minimize leakage across the gland (leakage is proportional to leakage area). The effects of rub are minimized in close clearance glands by making glands spring loaded.

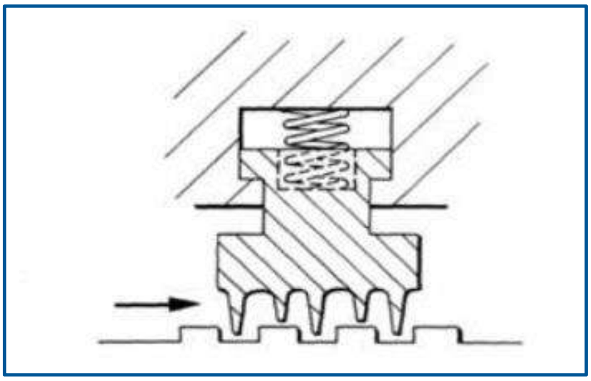


Figure 5 Spring Loaded Vernier Labyrinth Seal

[16]Power Plant Engineering, Black & Veatch

Labyrinth Glands with Fins in Radial & Axial Direction: The design increases the number of restrictions in a given gland length. The thickness of gland tip is kept minimum to avoid rubbing or if accidental rubbing happens, the heat generated is minimum.

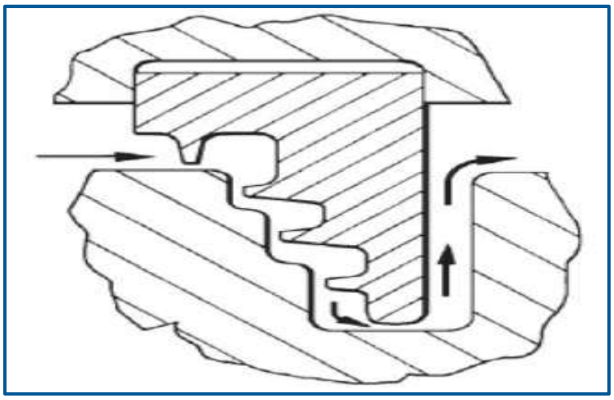


Figure 6 Labyrinth Glands with Axial and Radial Fins

5.5.1.2 Determination of HP to IP Leakage Flow (Temperature Inference Method)

The N2 packing leakage to IP turbine bowl is calculated using the temperature inference method. This method is an indirect method to determine the magnitude of leakage flow, since this leakage flow is inside the turbine, and it is impractical to directly measure it. Determination of the leakage flow shall also determine the true IP turbine efficiency. The leakage flow may be somewhat greater than or less than the actual design flows, depending upon the packing clearance and stage pressure.

A diagrammatic representation of available parameters for HP-IP turbine is shown below.

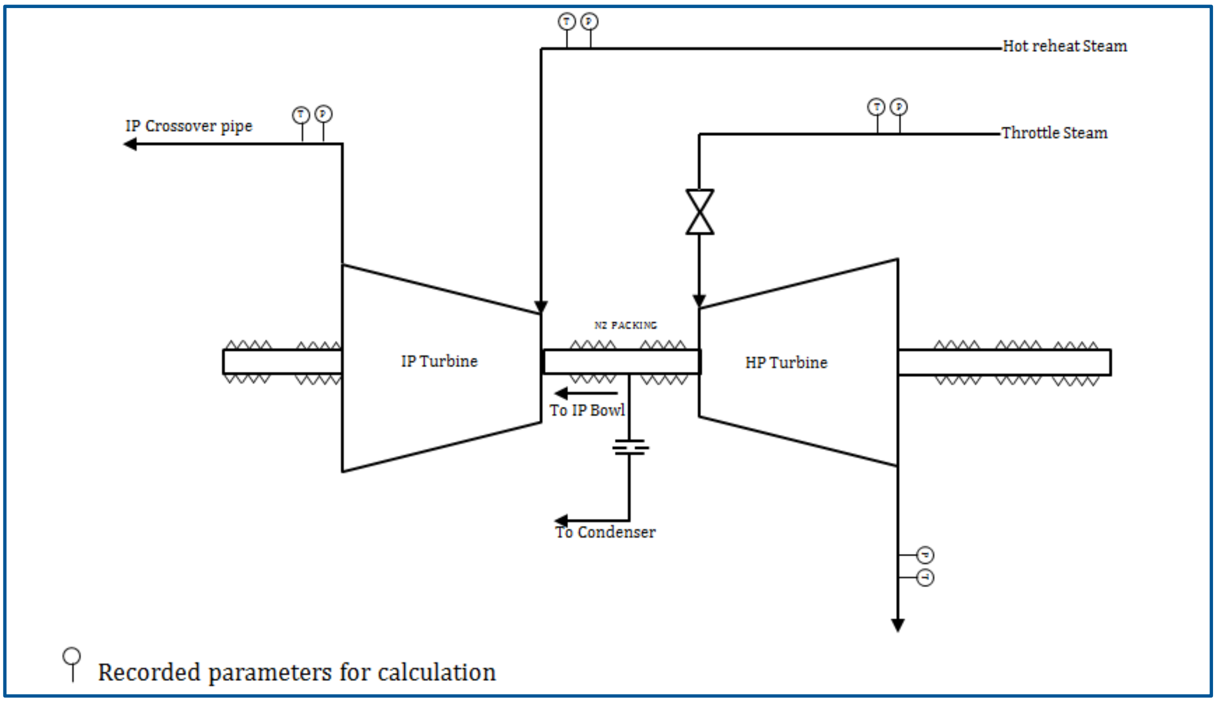


Figure 7 Determining HP-IP Leakage (Temperature Inference Method)

The basis of the temperature inference method is that IP section efficiency remains constant over the operating range. The method is based upon cooling effect that the internal HP to IP packing leakage on the apparent IP section efficiency.

The leakage from HP to IP section is generally cooler than the steam entering in the IP bowl, thereby yielding a reduced enthalpy condition at the IP exhaust and corresponding change in the "apparent" enthalpy efficiency drop.

The HP steam leaking to the IP cools the steam in the IP yielding an erroneously high value of measured IP efficiency, if not properly compensated. The amount of error in IP efficiency will vary according to the difference in enthalpy between the leakage steam and hot reheat steam. In this method, If initial temperature is raised and reheat temperature is decreased, this error will decrease and conversely it will increase if initial temperature is lowered and /or reheat temperature is increased.

In this method, at least three tests are run with variation in initial and reheat temperature. For each of the three tests, the measured IP efficiency for various assumed values of HP to IP leakage may be calculated. A curve of IP efficiency versus assumed leakage flow, as a percent of reheat flow is plotted. The lines for each test run will intersect at a point that indicates the actual HP to IP leakage and the actual IP turbine efficiency.

The temperature inference method is provided in **ASME PTC 6.2** code (***Please refer section C5 : Guiding Principle for Temperature Inference, IP Efficiency Plot and Ratio of Slopes Methods"***). In this method, at least three test runs are recommended with variation in main steam and reheat temperature.

For each of the three tests, the measured IP efficiency for various assumed values of HP to IP leakage may be calculated. A curve of IP efficiency versus assumed leakage flow as a percent of reheat flow is plotted. The lines for each test run will intersect at a point that indicates the actual HP to IP leakage and the actual IP turbine efficiency. An indicative methodology is provided, however please note that this is to be designed for individual units reviewing operational constraints and applicable temperature drop achievable without impacting the equipment adversely.

This test is to be carried out to estimate the N2 packing leakage between the HP and IP sections of the turbine. This is calculated by using the enthalpy drop test. Test procedure is as follows: -

- Maintain 100% load of the unit and main steam and hot reheat temperatures at base value. Once the parameters are stable test run will be carried out for 1 hour.
- Maintain MS temperature at base level and reduce the HRH temperature.
- Once the parameters are stable test run will be carried out for 1 hour.
- Bring the HRH temperature back to base value and then reduce MS temperature. Once the parameters are stable test run will be carried out for 1 hour.
- Retrieve the data for the steam parameters, estimate IP efficiency and perform the graphical analysis as described above for estimating HP-IP internal leakage.

5.5.1.3 Improving LP Turbine Efficiency by Improved Blade Design and Increased Annulus Area

The steam seal upgrade tends to decrease heat rate and increase LP turbine efficiency. The new gland seals also reduce the in-air leakage around the shaft. The improved gland seal reduces the amount of air that enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air in-leakage through improved seals can decrease (improve) back pressure by 4-12 KPa absolute with a corresponding heat rate improvement of nearly 1.0%.

Large OEMs globally also provide customized retrofit packages consisting of replacement of low-pressure turbine blades using improved blade design and increased exhaust annulus area to improve performance. The performance gain in the LP section based on industry experience is commendable with output increasing up to 1.00% and heat rate reduction up to 0.75% with only steam seal upgrades. The replacement is normally doable in capital overhaul, however the need for this retrofit to be carefully worked out evaluating turbine internal condition and aging of the machine.

The last stage buckets are responsible for approximately 10% of the turbine's total output. Redesign of the last stage buckets, including increasing length, reduces exhaust loss by increasing the amount of energy removed from the steam. This increases capacity and decreases heat rate. The project includes replacing the last stage LP turbine buckets or blades with new longer blades. Replacing the last stage diaphragm is also recommended to maximize efficiency gain. Longer last stage buckets reduce exhaust losses by maximizing the amount of energy extracted from the steam. This is done by increasing the area of the last stage to reduce exhaust velocity. Performance gains from replacing the last stage buckets is dependent on where the unit operates on the Exhaust Loss Curve. Combined with last stage bucket replacement, up to 3% improvement in output and 2.5% reduction in heat rate can be realized.

5.5.1.4 Performance Monitoring of HP Turbine Section & In-Situ Instrumentation for HP Exhaust Pressure and Temperature

One of the most critical measurements for analyzing HP turbine internal efficiency is HP turbine exhaust temperature. The ASME PTC test code 46 specifies this measurement to be close to HP turbine exhaust. Figure 5 below specifies the preferable location of measurement. Minimum 2 measurement of HPT exhaust temperature is recommended with instrument of 1 Deg. F or 0.56 Deg. C accuracy class for best results. HP exhaust pressure measurement is also recommended with an instrument of accuracy class 0.1%. The criterion for accuracy is stringent given the nature of calculations and its criticality to predict overall turbine internals condition.

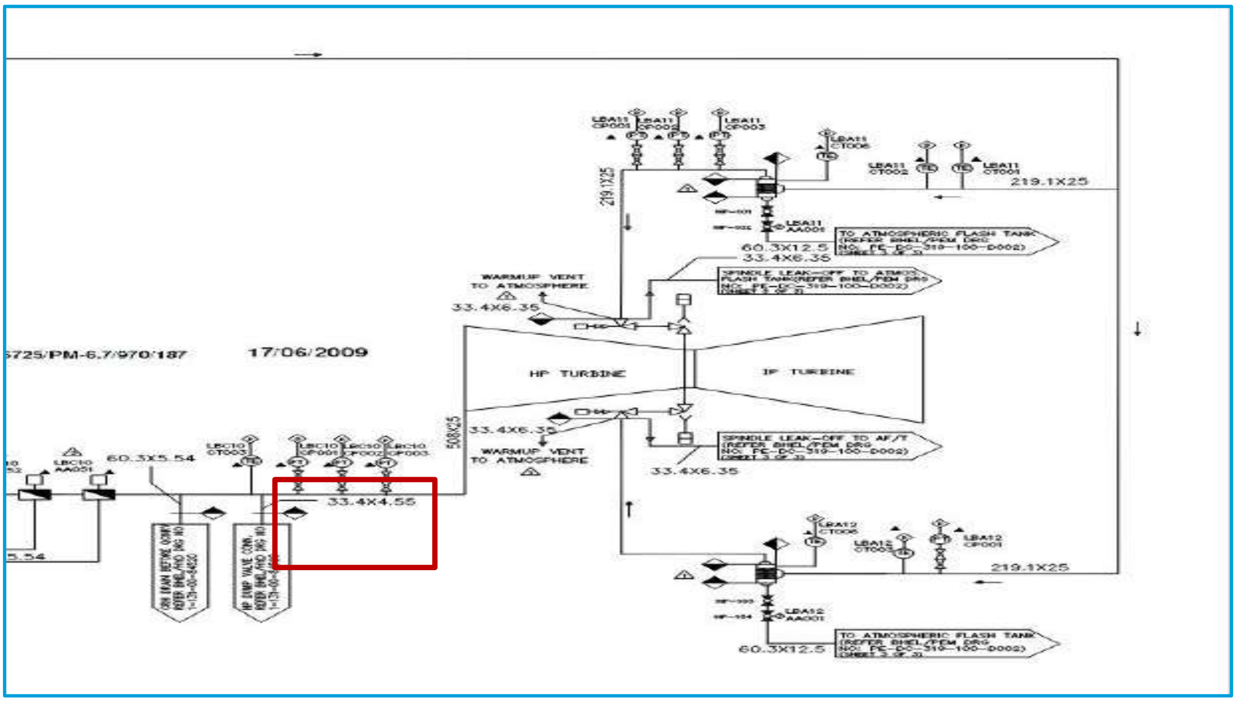


Figure 8 HP Exhaust Temperature Measurement

5.6 Condenser

The below table indicates the performance output results of Condenser-1 and 2 at the GT baseload condition against the design values.

Table 5-16:Condenser 1 & 2 Performance against Design performance

PARAMETERS	UNIT	DESIGN	INDEX	BLOCK -1	BLOCK-2
LP Exhaust Steam Flow	TPH	354.3		361.54	359.30
CW Inlet temperature	Deg C	32	[F]	34.33	31.18
CW outlet temperature	Deg C	41	[G]	44.30	40.57
Delta P (Difference) - LHS	mwc	**6**		**12.644**	
Delta P (Difference) - LHS	mwc	**6**		**12.972**	**12.380**
CW Flow	M3/hr	21000		23041	23044
Delta T (Difference)	Deg C	9	[H=G-F]	9.97	9.39
Vacuum	Kg/cm2(a)	0.095		0.200	0.1731
Saturation temperature	Deg C	44.43	[E]	59.64	56.56
Hot well temperature	Deg C	44.43		58.41	56.39
Sub-cooling	Deg. C	0		1.23	0.17
Dissolved O2 (Condensate)	ppb			17.86	3.13
TTD	Deg C	3.43	[E-G]	15.34	16.00

PARAMETERS	UNIT	DESIGN	INDEX	BLOCK -1	BLOCK-2
LMTD	Deg C	7.08	**H**	**19.9**	**20.3**
[17]Estimated Heat Duty	MW	**286.098**	**"U"*A*[H]**	**267.281**	**275.933**
Actual Heat Transfer Coefficient	kCal/hr-m2-C		[A]	1210.35	1154.12
Max. Possible Heat Transfer (100% Clean Tubes)	kCal/hr-m2-C		[B]	3718.91	3667.26
Cleanliness	-	0.8	**[A/B]**	**0.33**	**0.31**

- Condenser vacuum is reported as 0.200 kg/cm2 (a) and 0.173 kg/cm2 (a) at inlet CW temperature around 34.33 and 31.11 deg C in Unit 1 and 2 respectively.
- Condenser cleanliness is found to be around 0.33 and 0.31 respectively for condensers 1 and 2 against a design value of 0.80.

5.6.1 Back Pressure Deviation Check

Black & Veatch further analyzed the reasons for the higher back pressure in both units. The expected backpressure is calculated based on the design inlet parameters at clean condenser conditions.

Table 5-17: Unit 1 Condenser Spot back Pressure Check (Actual Vs Expected Analysis)

Back Pressure Check	UNIT	INDEX	Unit 1	Unit 2
Load	MW		112.81	113.64
Actual back pressure	bar	[F]	0.196	0.170
CW inlet temperature	Deg. C		34.33	31.18
CW outlet temperature	Deg. C		44.30	40.57
Hot Well Temperature	Deg. C		61.61	57.98
Barometric pressure	bar		1.006	1.005
Actual Back Pressure	kPa		**19.61**	**16.96**
Saturated Steam Temperature	Deg. C		59.64	56.54
Actual CW rise	Deg. C		9.969	9.39
Actual TTD	Deg. C		15.34	15.97
Expected back pressure	kPa	**[A]**	**10.24**	**9.00**
Optimum CW rise (From HBD @33 CW Inlet)	Deg. C		9.00	9.00
Optimum TTD (From HBD)	Deg. C		3.50	3.50
Back pressure due to CW inlet temp	kPa	[B]	15.71	14.25
Back pressure due to CW flow	kPa	[C]	16.17	14.42

[17] Condenser design heat duty – 246 mkCal/hr.
Estimated Heat Duty = Overall heat transfer coefficient*Surface Area of Condenser Tubes* LMTD

Back Pressure Check	UNIT	INDEX	Unit 1	Unit 2
Variation due to CW inlet temp. = Back Pressure due to CW inlet temp – Target Back Pressure	kPa	**[D=A-B]**	**5.47**	**5.25**
Variation due to CW flow = Back Pressure due to CW flow – Back Pressure due to CW inlet temp	kPa	**[E=C-B]**	**0.46**	**0.18**
Variation due to air/dirty tubes TTD = Actual Back Pressure – Back Pressure due to CW flow	kPa	**[F-C]**	**3.44**	**2.53**

Given the CW Inlet temperature of 34.33 Deg. C and 31.18 Deg. C for Condenser 1 and 2, If we consider design range of 9 deg. C (i.e. difference of CW inlet and outlet temperature) and [18]design TTD of 3.50 deg. C, we expect the back pressure to be 10.24 kPa and 9.00 kPa respectively. The back pressure measured at the test period was 19.61 kPa and 16.96 kPa respectively.

The deviation in back pressure due to CW inlet temperature is for Unit 1 is due to high CW inlet temperature (34.33Deg. C compared to design of 32 Deg. C) and high heat load. Please note that LP exhaust flow is higher by 7.24 TPH than design of 354.3 TPH with expected higher enthalpy steam entering condenser.

The gap in expected and actual vacuum is 9.37 kPa and 7.96 kPa respectively. The assessment shows that majority of back pressure deviation in Unit 1 (~37%) is attributable to impact of air ingress or dirty tubes. In Unit 2 (~32%) of back pressure deviation is attributable to air ingress / dirty tube.

Further evaluation of DP (delta pressure) across condenser suggests that delta P across both water boxes is much higher than design limits of 6 mwc. DO levels are also found to be higher in condensate water specially for Unit 1 which is 17.86 ppb.

Table 5-18 Condenser Parameters

PARAMETERS	UNIT	DESIGN	BLOCK-1	BLOCK-2
LP Exhaust Steam Flow	TPH	354.3	361.54	359.30
CW Inlet temperature	Deg C	32	34.33	31.18
CW outlet temperature	Deg C	41	44.30	40.57
Delta P (Difference) - LHS	mwc	**6**	**12.644**	**NA**
Delta P (Difference) - LHS	mwc	**6**	**12.972**	**12.380**
Dissolved O2 (In Condensate)	ppb	**-**	**17.86**	**3.13**
Condenser Cleanliness	-	**0.80**	**0.33**	**0.31**

5.6.2 Review of Condenser Cleanliness

The inspection was carried out on 21st June and 23rd June 2022 for Unit 2 during MI.

[18] Minor variation in TTD with CW inlet temperature is estimated based on HBDs. The HBD referred are PE-DC-319-100-D101, PE-DC-319-100-D106, PE-DC-319-100-D111 (100% CC load, 0% make up and 27 Deg. C, 9 Deg. C and 15 Deg. C ambient conditions respectively.

Observations After Opening of Condenser Water box :

- Tubes were choked from the slime and broken PVC fills.
- Tube sheet was not cleaned. Scales, depositions, slime and iron nodules were observed.
- Algae / organic growth was not concerning.
- No tube leakage observed while performing flood test.
- Issues found in water treatment (phosphate -zinc based compounds) for anti-scaling, bio-dispersion, corrosion inhibition, PH reduction and microbial control.

5.6.3 Condenser Instrumentation Adequacy

Plant operators and engineers require adequate instrumentation to continuously monitor plant operations, equipment health, and diagnostic of operation anomalies. As requested by OTPC, Black & Veatch has reviewed the instrumentation adequacy for calculating condenser performance.

5.6.3.1 Steam side Instrumentation:

Source: P&ID / 32-CONDENSATION SCHEME-21310084532-S00-R00

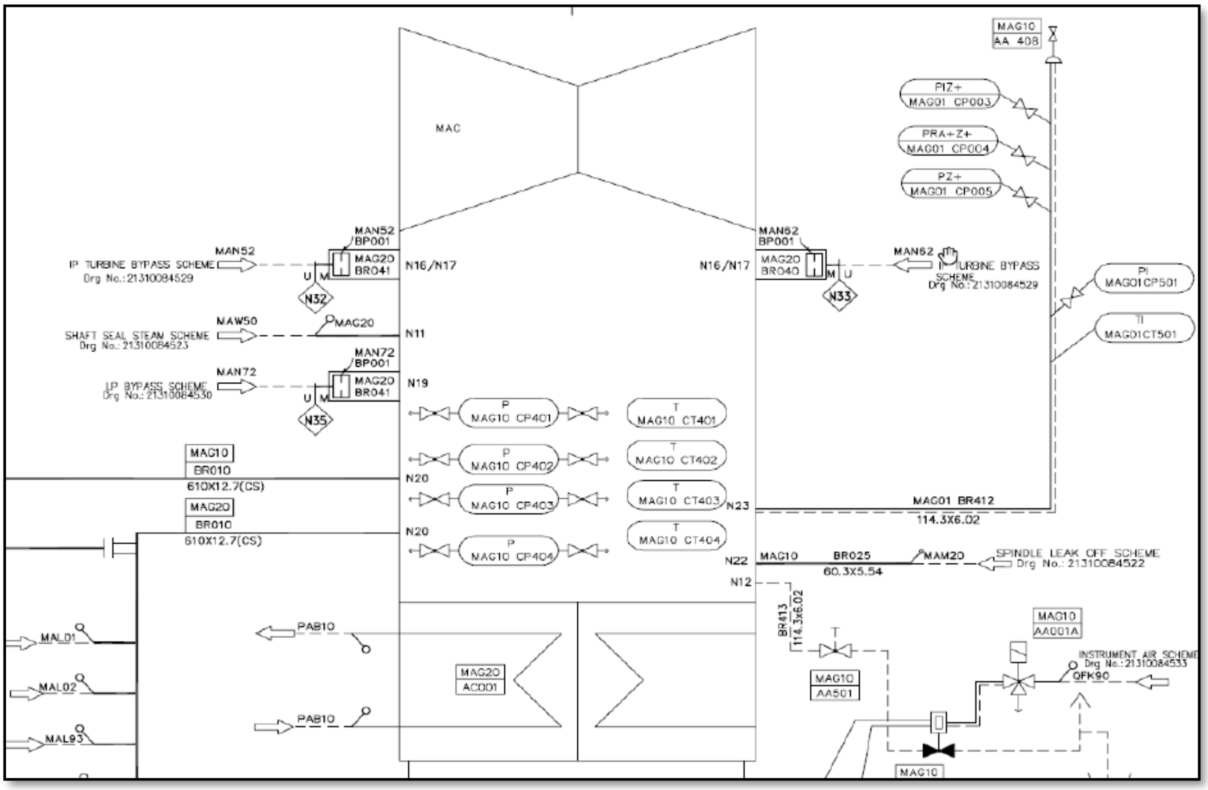


Figure 5-9: LP Turbine Steam Condensation System P&ID

As per the above P&ID and instrumentation schedule provided in the O&M manual (ONGC Steam Turbine/VOLUME-2 PART-2/Page no: 244), Black & Veatch understands that the following instrumentations are available for the condenser steam side measurements,

Table 5-19: Available Instruments for Condenser Steam Side Measurement

S.NO	MEASUREMENT	TAG NO
1	Condenser Pressure	MAG01 CP003

S.NO	MEASUREMENT	TAG NO
2	Condenser Pressure	MAG01 CP004
3	Condenser Pressure	MAG01 CP005
4	Condenser Pressure	MAG01 CP501
5	Condenser Pressure	MAG01 CP401
6	Condenser Pressure	MAG01 CP402
7	Condenser Pressure	MAG01 CP403
8	Condenser Pressure	MAG01 CP404
9	Condenser Temperature	MAG01 CT501
10	Condenser Temperature	MAG01 CT401
11	Condenser Temperature	MAG01 CT402
12	Condenser Temperature	MAG01 CT403
13	Condenser Temperature	MAG01 CT404
14	Vacuum Breaker Open	MAG10 CG051B
15	Vacuum Breaker Open	MAG10 CG051C

Black & Veatch opines that the instrumentation available for steam side measurements is adequate for calculating condenser performance. *The three condenser pressure instruments namely MAG01 CP003, CP004, and CP005 taken are used for the plant performance calculations.*

The below table describes the 2 hours average value of these three condenser pressure measurements taken during the performance test at full load conditions. ***Based on historian data made available to Black & Veatch, the sampling frequency of vacuum tags in DCS historian for Unit 1 are observed to be once every 60 minute which is very high. It is recommended to correct the tag sampling frequency in DCS to every minute interval.***

Table 5-20: Condenser Pressure Readings During Performance Test

BLOCK	TAG	AVERAGE VALUE IN
Block-1	11MAG01CP003XQ07.Out.Sample	0.2001
	11MAG01CP004XQ07.Out.Sample	0.1987
	11MAG01CP005XQ07.Out.Sample	0.2008
Block -2	21MAG01CP003XQ07.Out.Sample	0.1722
	21MAG01CP004XQ07.Out.Sample	0.1721
	21MAG01CP005XQ07.Out.Sample	0.1729

Black & Veatch recommend OTPC to ensure the calibration of all the instruments as recommended by OEM.

5.6.3.2 Waterside Instrumentation:

Source: P&ID/ PE-DG-319-165-N101 Rev 03 P&ID for CW-ACW SYSTEM

Black & Veatch has reviewed the instrumentation available in the CW waterside of the condenser for enabling condenser performance calculation as per the standards.

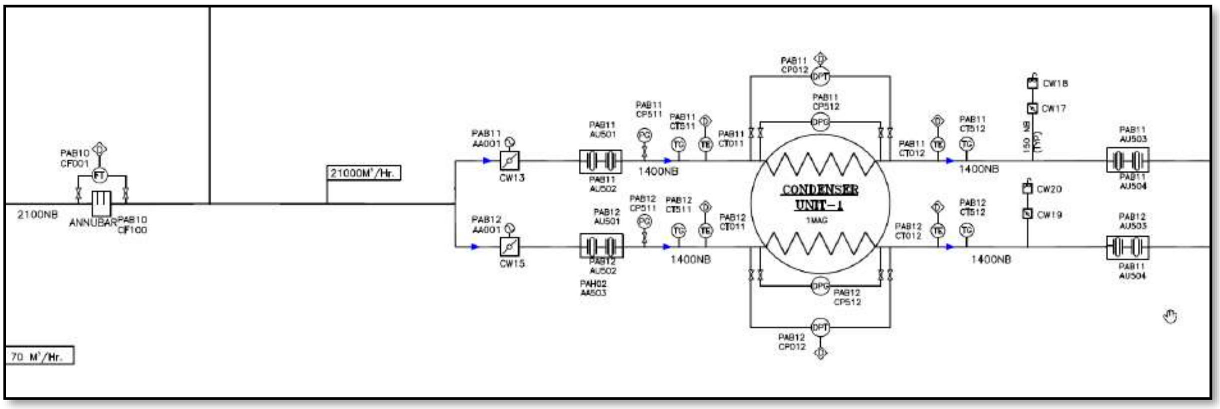


Figure 5-10: CW & ACW P&ID

As per the above P&ID, Black & Veatch understands that the following instrumentations are available at the condenser for waterside measurements.

Table 5-21: Available Instruments for Condenser Water Side Measurement

S.NO	MEASUREMENT	TAG NO
1	CW Flow (Annubar)	PAB10 CF001
2	CW Inlet Pressure Pass- 1	PAB11 CP511
3	CW Inlet Pressure Pass- 2	PAB12 CP511
4	CW Inlet Temperature Pass -1	PAB11 CT511
5	CW Inlet Temperature Pass -2	PAB12 CT511
6	CW Inlet Temperature Pass -1	PAB11 CT011
7	CW Inlet Temperature Pass -2	PAB12 CT011
8	DP Measurement Pass-1	PAB11 CP012
9	DP Measurement Pass-2	PAB12 CP012
10	DT Measurement Pass -1	PAB11 CP512
11	DT Measurement Pass -2	PAB12 CP512
12	CW Outlet Temperature Pass -1	PAB11 CT012
13	CW Outlet Temperature Pass -2	PAB12 CT012
14	CW Outlet Temperature Pass -1	PAB11 CT512
15	CW Outlet Temperature Pass -2	PAB12 CT512

It was observed that the CW (Annubar) (PAB10 CF001) flow measurement values of Unit-1 & 2 are around 23041.93 TPH and 33414.21 TPH. Black & Veatch validated the flow in Unit 2 using CW pump head and discharge characteristic and found the flow measurement to be erroneous. The calibration of this instrument is recommended in nearest opportunity.

CW Flow is the total flow measurement at the CW header which includes the CW flow to condenser circuit and ACW circuit. As per the P&ID (PE-DG-319-165-N101 Rev 03 P&ID for CW-ACW SYSTEM), there are separate flow meters to measure ACW flow to each PHE which also includes CW blowdown flow (flow meter is available to measure the blowdown) and HRSG blowdown tank flow.

Cross verification of the CW flow at the Cooling tower riser utilizing portable offline meter(like Ultrasonic flow meter) on a periodic basis is recommended once in every 6 months.

5.6.3.3 Air Extraction side Instrumentation:

Source: P&ID/ Vacuum Pump Manual/Chapter 5/ Drawings/Page no:2

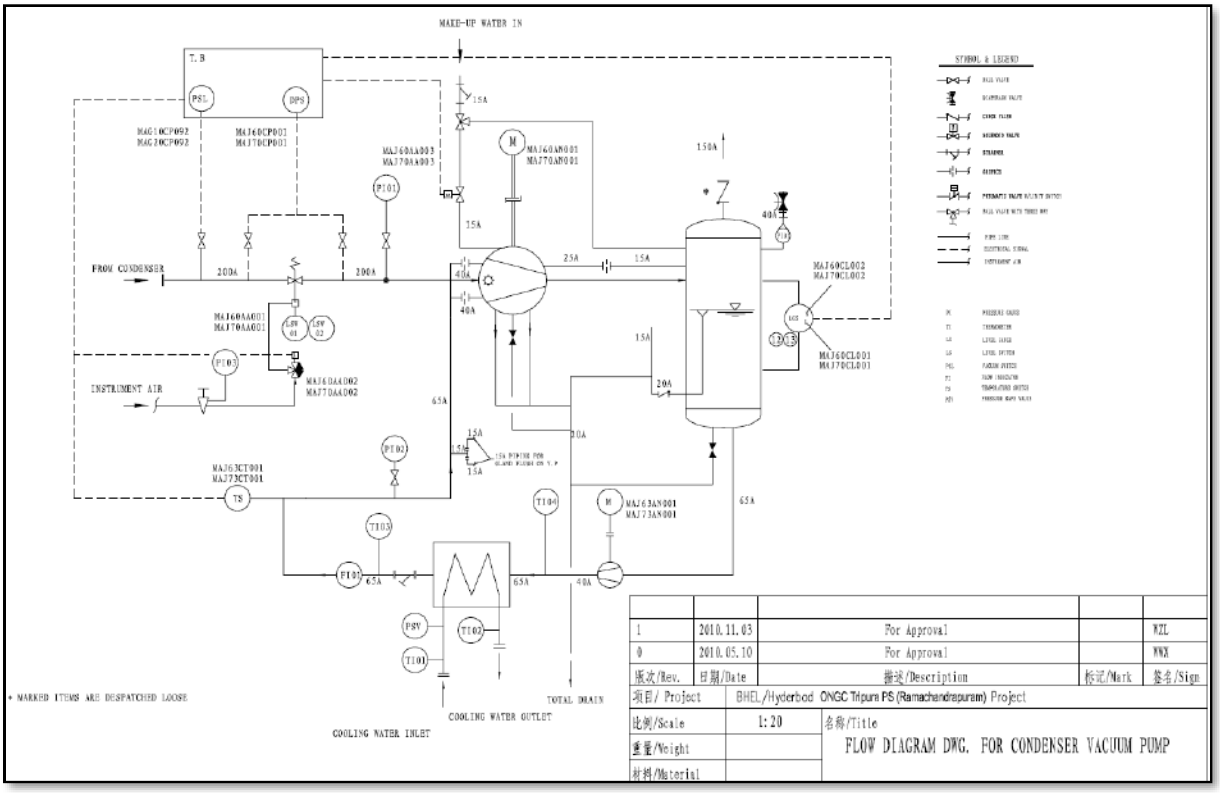


Figure 5-11: Air Extraction system P&ID

As per the above P&ID, Black & Veatch understands that Vacuum pumps are equipped with the following instruments,

- Inlet Air Pressure indicator at Inlet of main Vacuum Pump (PI01)
- Seal Water Pressure indicator at Inlet of main Vacuum Pump (PI02)
- Flow measurement Rota meter to measure Air outlet from Vacuum pump Separator (FI01)
- Seal Water Cooler Inlet Temperature Thermometer (T104)
- Seal Water Cooler Outlet Temperature Thermometer (T103)
- Cooling water inlet to seal cooler Temperature Thermometer (T102)
- Cooling Water Outlet from seal cooler Temperature Thermometer (T103)
- Separator Level Gauge and Level Switch

5.6.4 Recommendations:

5.6.4.1 On-Line Performance Monitoring of Vacuum Pump & Seal Water System

Black & Veatch opines that the instrumentation available at the air extraction system is adequate for calculating vacuum pump performance. However, as most of the readings are not readily available in DCS, Black & Veatch recommends following instruments for continuous monitoring of Vacuum pump and seal cooler performance in DCS.

Table 5-22 Vacuum Pump Performance and Recommended On-Line Measurements

PARAMETERS	STATUS	ON-LINE INDICATION	MONITORING
Seal Water Flow (Inlet to Seal Water Cooler)	Not Available	Not Available	Continuous
Seal Water Inlet and Outlet Temperature (Seal Water Cooler)	Gauge Available	Not Available	Continuous
Seal Water Inlet and Outlet Differential Pressure	Not Available	Not Available	Continuous
ACW Inlet and Outlet Temp. (Seal Water Cooler)	Gauge Available	Not Available	Continuous
Seal Water Temperature (Inlet to Vacuum Pump)	Gauge Available	Not Available	Continuous
Rota Meter Flow	Available	Not Available	Continuous

5.6.4.2 Investigate Suspected Air Ingress in Condenser Shell

Helium leak test is technology of choice due to availability, applicability (Can be done when unit is in operation) and detectability (Sensitivity of 10-6 mbar, fast (less than 20 seconds) , and ability to detect very fine leakages) of leakage points which are in condenser system but isn't useful for leakages which are under water up to condensate extraction pump (Downstream of hot well, flange joints, bellows, valves, suction strainer, and associated pipelines).

Infrared thermography has come to age as far as locating air ingress points are considered. Due to advancement of technology and drop in prices, good quality thermography cameras are available in reasonable rates in market today. But infrared thermography is best used when combined with other techniques like helium or acoustic technique to pinpoint areas of air ingress.

Ultrasonic acoustic leak detection system with high sensitivity is available which can be used for regular inspections to ensure near airtight condenser. In case of vacuum leak, air moves from a high-pressure side (outside condenser) to a low-pressure side (Inside condenser) and during its passage turbulent flow gets generated creating ultrasound frequencies (>20 KHz). This has strong ultrasonic components which are heard through noise attenuating headphones, the greater the leak, the greater would-be sound intensity. Ultrasonic acoustic leak detection when combined with Infrared thermography & Helium leak detection technique is proven to yield reliable and repeatable results with less false negatives. A typical helium leak set up is shown below.

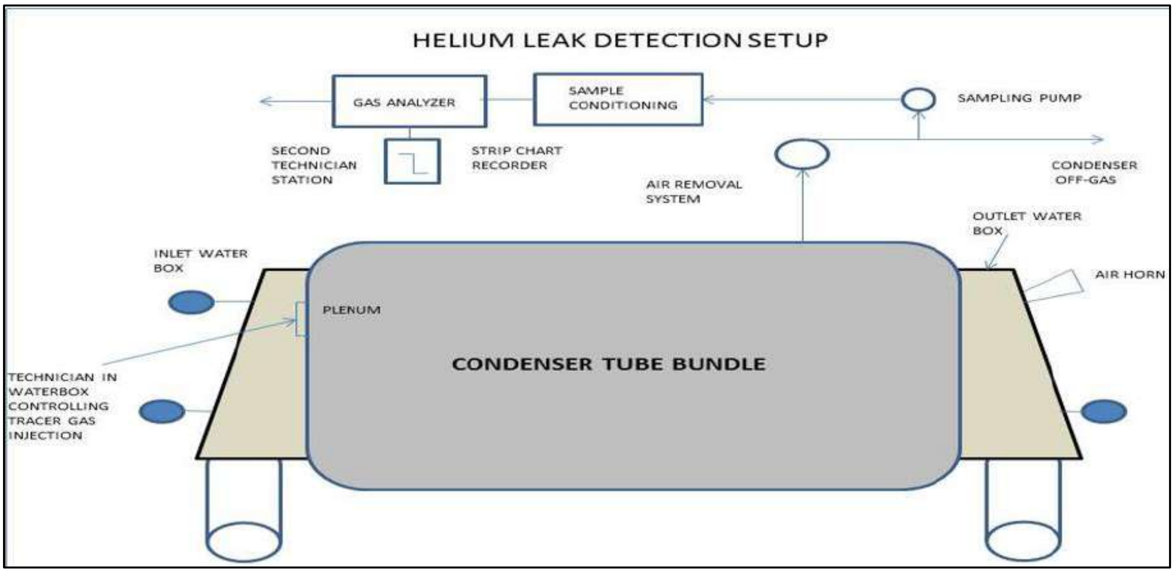
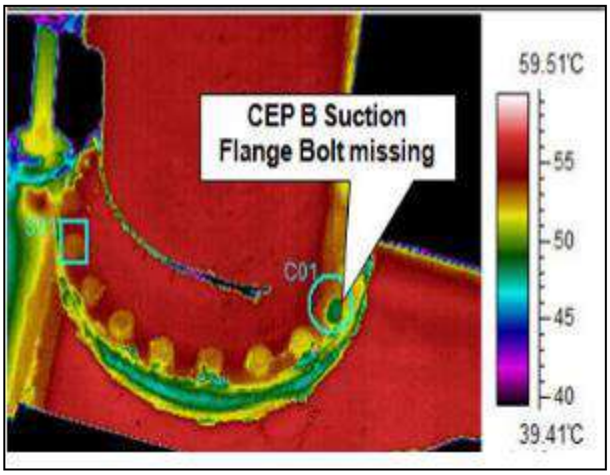


Figure 12 Helium Leak Set Up

Common primary source of leakages is generally listed as follows.

- Atmospheric relief valve or vacuum breakers
- Rupture disks
- Condenser Drains
- Turbine Seals
- Low Pressure Turbine Diaphragm / End Seals
- Turbine Instrumentation Lines
- Condenser Expansion Joint
- Tube sheet to Shell Joint
- Air removal suction component
- Condenser Instrumentations
- Low Pressure feed water heaters, associated piping, valves and instruments
- CEP strainers, vents, drains and seals
- Pipe flanges, Orifice flanges
- Valves
- Manholes

An assessment like infrared thermography often yields best results for wet sections after hot well. The two figures below suggest leakages observed which otherwise are difficult to detect by Helium leak test alone.



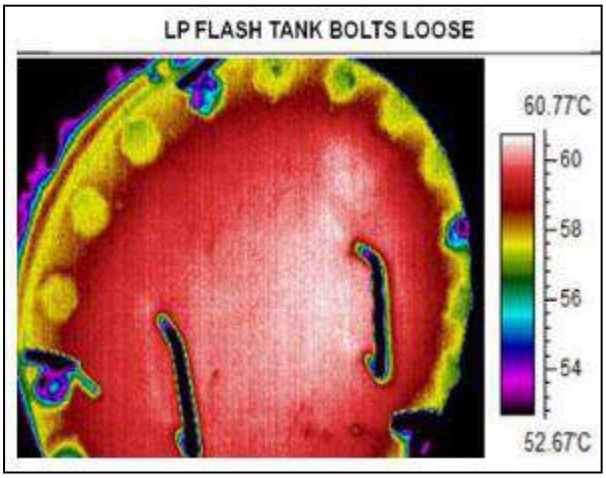


Figure 14 Infrared Thermography CEP Suction Flange **Figure 13 LP Flash Tank**

5.6.4.3 Online Tube Cleaning (OLTC) system

Black & Veatch recommends conducting a feasibility study for the installation of an Online Tube cleaning system for increasing heat-transfer effectiveness.

Online Tube Cleaning System facilitates continuous cleaning of the Condenser Tubes up with the Plant in operation. Cleaning is accomplished by passing slightly oversized Sponge Rubber Balls though the condenser tubes. Install a retrievable ball tube cleaning system to periodically remove bio fouling material from the inner surface of condenser tubes, keeping condenser tubes free of scale will maintain design heat transfer between the condensing steam and circulating water.

Major Components and Auxiliary Equipment of OLTC system are as follows.

- Ball Separator
- Ball Recirculating Skid
- Measuring and Control System
- Ball Monitoring System
- Ball Charger and Feeder

Ball charging is normally from the inlet to condenser and ball separator installed in the Condenser CW outlet pipe is ball catching equipment which separates the cleaning balls from cooling water for recirculation. The Ball Separator is fitted with single/double screens at a selected angle for the smooth collection of balls. The backwashing of the screens is initiated by DP measurement automatically. A ball recirculation system ensures these balls to be again routed to CW inlet pipe to condenser. The installation of ball cleaning system may be localized managed by a PLC or remotely using DCS. An HMI with audio/ visual alarms can also be provided.

5.6.4.4 Regular Replacement of Sacrificial Anodes

Black & Veatch recommends regular inspection of sacrificial anodes during every outage/condenser inspection if applicable. Sufficient stock of sacrificial anodes should be maintained for 100 percent replacement of damaged or worn-out anodes during every outage if Applicable For OTPC

5.7 Vacuum Pump

Table 5-23 Vacuum Pump Design Data

DESCRIPTION	PARTICULARS
Pump Design Point	1” of Hg (a)
Seal Water flow	13.6 m3
ACW Inlet (Design)	13 Deg. C
ACW Outlet	14.5 Deg. C
Seal Water Inlet (Cooler)	23.9 Deg. C
Seal Water Outlet (Cooler)	16.5 Deg. C
Condenser Design Pressure	2.84” of Hg(a)
Pump Capacity (HEI)	20 SCFM
Discharge Pressure	Atmospheric
Make Up Water	CEP Discharge
Design ITD	19 Deg. F

5.7.1 Condenser Performance and Vacuum System

Following section describes condenser performance in view of removal condensable and non-condensable gases in conjunction with vacuum pump operation. The analysis is based on data collected during the performance test.

Table 5-24 Condenser Performance and Vacuum System

Description	UOM	Expect.	Index	Unit 1		Unit 2	
				1A	1B	2A	2B
*Seal Liquid Temperature (Inlet to Cooler)	Deg. C	42.9	[A]	60.0	55.0	55.0	54.0
*Seal Liquid Temperature (Outlet to Cooler)	Deg. C	35.5	[B]	40.0	38.0	41.0	34.0
DT across Seal Cooler	Deg. C	**7.4**	**[A-B]**	**20.0**	**17.0**	**14.0**	**20.0**
Approach of Cooler	Deg. C	**3.5**	**[B-C]**	**4.0**	**5.0**	**7.0**	**4.0**
ACW Inlet Temperature	Deg. C	32	[C]	36.0	33.0	34.0	30.0
ACW Outlet Temperature	Deg. C	33.5	[D]	38.0	35.0	35.0	31.0

Description	UOM	Expect.	Index	Unit 1		Unit 2	
				1A	1B	2A	2B
Actual ITD (Tsat at Vac. Pump Suction Pres. - Seal Water Temp)	Deg. C	**10.6**	**Tsat(E)-B**	**15.0**	**17.0**	**10.3**	**17.3**
Vacuum Pump Air-Steam Inlet Temperature	Deg. C	-	-	53.0	54.0	51.0	51.0
Condenser Water Inlet Temperature	Deg. C	-	-	34.3	34.3	31.2	31.2
Condenser Water Outlet Temperature	Deg. C	-	-	44.3	44.3	40.6	40.6
Condenser Vacuum (Transmitter)	bar (a)	-	-	0.196	0.196	0.170	0.170
Vacuum Pump Inlet Pressure (Estimated)	bar (a)	[A]	[E]	0.158	0.158	0.131	0.131
Saturation Pressure Corresponding to Seal liquid Inlet Temperature	bar (a)	[B]	[F]	0.074	0.066	0.078	0.053
Cavitation Margin (Seal Liquid Inlet Temp.)	**bar (a)**	**[A-B]**	**[E-F]**	**0.084**	**0.091**	**0.054**	**0.078**

Note: Data marked in asterisk is measured locally by available gauge.

5.7.2 Review of Vacuum Pump & Seal Water Cooler Performance

Liquid Ring Vacuum Pump (LRVP) supports condenser operation by continually extracting the non-condensable gases (air) that enter the condenser to maximize the condensing capability and minimizes turbine exhaust back pressure. Surface condenser produces the vacuum while LRVP ensures sustenance of the condenser vacuum.

The LRVP should always operate in conjunction with the condenser. Under-venting of the condenser is caused when the LRVP cannot remove the non-condensable load entering the condenser. The condenser pressure will rise, and turbine operation is affected. This is caused when the high temperature of the seal water in the LRVP will not allow the pump to operate at the same pressure as the condenser. Based on local measurements performed during performance test, it is evident that the difference between seal water outlet temperature and ACW inlet temperature (also known as Seal water cooler approach) for pump 1A, 1B, 2A and 2B are 4-7 deg. C higher than expected.

Given the estimates for seal water cooler approach being based on temperature gauge readings which were not calibrated, we expect the seal water cooler approach to be much higher or possibly lower also in few cases than what is found during the test.

The seal cooler is used on LRVP systems where the service liquid is reused after it exits the LRVP. The service liquid is cooled to a lower temperature, so that desired vacuum and capacity of the LRVP can occur. The cooler is often overlooked when the LRVP system is maintained.

The proper heat transfer function of this heat exchanger is essential for trouble-free vacuum system operation. If the correct heat transfer between the two fluids is not taking place, the LRVP will operate in a different pressure range than the condenser. As stated previously, the condenser and the LRVP must operate in conjunction with one another using similar water temperatures.

Besides seal water cooler performance, there are two more suspect to vacuum pump underperformance.

- Increase in non-condensable heat load (Air -Ingress)
- Increase in condensable component of heat load (Higher steam loading likely caused due to inefficiency in LP turbine and last stage blades)
- Suspected Cavitation of Impeller & Cones
- Direction of Rotation (Check the pump Direction of Rotation (Normally clockwise if viewed from the drive end). Gas compression should be from the suction to the discharge port.

5.7.3 Recommendations

5.7.3.1 Develop and Implement Standard Maintenance Practice (SMP) for Cleaning of Seal Water Cooler

The seal water cooler may have to be cleaned to maintain its heat transfer capability. Ensure that the proper flow and temperature of cooling water is being supplied to the heat exchanger. If the temperature rise is low on the cooling water side and the seal water is not cold enough, fouling could be the problem. It is critical that the seal water cooler be cleaned at regular intervals and should be as closely scrutinized as the main condenser for proper operation. Proper system flushing after before any start up is also important to avoid fouling in tubes. Ensure that there is no place for air to accumulate inside the exchanger reducing its heat transfer surface. ***A SMP for Seal Water Cooler Cleaning is recommended to be adhered by maintenance personnel.***

Seal water flow and differential pressure measurements (On-line) are to be ensured for continuous monitoring of vacuum pump performance. Please refer table 4-14 for recommended on-line measurements of Vacuum pump. A cleaning cycle with frequency once every 6 month is preferable if feasible or as per recommendation of OEM whichever is earlier. A cooling with moderate chemical treatment is also feasible and is to be checked with OEM.

5.7.3.2 Cavitation Avoidance

High seal water inlet temp. may lead to pump cavitation. High seal water temperature in due course of two-stage compression may potentially exceed the corresponding saturation temp. (boiling point) causing cavitation. This problem can be mitigated if seal water flow and temperatures are made available for operators' guidance and seal water cooler performance is regularly audited. Table 4-21 provides recommendations for online measurements of vacuum pump performance.

Cavitation related damage of Vacuum pump internals was reported by M/s Millennium Enterprise in its report and MOM dated 26th April 2022. The recommendations as per the report are also to procure SS rotor and installing flow meters for seal water.

Another method is using acceleration, true peak detection, frequency banded vibration sensor which is sensitive only to those frequencies normally excited during cavitation. This loop powered sensor provides a 4-mA to 20-mA output signal proportional to the sensed vibration level. A 4-mA to 20-mA output sensor may extend its signal to DCS and alarm limits can be set for alerting the operator. Even if it is not possible to shut the pump down once cavitation is detected, the knowledge that it is occurring can be used by plant personnel for troubleshooting and addressing the issue in a planned manner.

5.8 Cooling Tower

The cooling towers' performance was tested when both units were operating at baseload. The below tables describe the design details of the cooling tower performance parameters.

Table 5-25: Cooling Tower Design Details

DESCRIPTION	UNITS	PARTICULARS
CT basin capacity	m3	7000
No of Cooling Towers		2 (one for each unit)
No of cells in each CT		8 (7W+1S)
Capacity of each cell	m3/hr	3428.57
CT inlet temperature	Deg C	31
CT Outlet temperature	Deg C	42
Design Wet Bulb Temperature	Deg C	27.25
Evaporation Efficiency	%	85
No of fans in each CT		8
No of blades in each Fan/type		8 blades / Aerofoil
Fan motor capacity	kW	110

The below table describes the performance test output of cooling tower values against the design values.

Table 5-26: Cooling Tower- 1&2 Performance Test output against Design Values

DESCRIPTION	UNIT	DESIGN	INDEX	CT -1	CT-2
No of Cells in Service	Nos	8(7W+1S)		8W	8W
Dry Bulb Temp	Deg.C	NA	[M1]	26.68	26.42
Relative Humidity	%	NA	[M2]	37.62%	53.66%
Wet Bulb Temperature	Deg C	27.25	[M3]	17.76	19.90
CT inlet temperature	Deg C	32.00	[A]	34.33	31.18
CT Outlet temperature	Deg C	41.00	[B]	44.30	40.57
CT Range	Deg C	9.00	**C=[B-A]**	**9.97**	**9.39**
CT Approach	Deg C	4.75	**D=[A-M1]**	**16.57**	**11.28**
CT Effectiveness	%	65.5%	[C/C+D]%	37.6%	45.4%

Based on Performance calculation

- Effectiveness of cooling tower is calculated as 37.6 % and 45.4 % respectively for CT-1 &2 against the design effectiveness of 65.5%
- Cooling tower Approach is calculated as 16.57 Deg C and 11.28 Deg C respectively for CT-1 &2 against the design Approach of 4.75 DEGC.
- Cooling Tower Range is calculated as 9.97 DEGC and 9.39 Deg C respectively for CT-1 &2 against the design Range of 8 Deg C.

5.8.1 Recommendations:

5.8.1.1 Fill pack replacement in CT 1 and CT 2

Black & Veatch was informed that a program for fill pack replacement is already underway. In Unit 1, 2 fill packs in 2 cells and in Unit 2, fill packs in 5 cells are replaced till Feb-23. The plan is to be progressively replace all the fill packs in the two cooling towers. It is also recommended to upgrade the design from existing MC67 PVS fills design with other cross-corrugated Fills such as C.10.19 folded end fills.

Another upgrade is use multi-layer combinations of fill packs (rather than single later) such as 2 layers of 600 mm of 19 mm flute size with 1 layer of 300 mm of 12 mm flute size at the top can be checked for feasibility. This will help in doing the cleaning of fills and also can improve the thermal performance.

5.8.1.2 Measurement of CT flow in Risers and Equalization of flow across CT Cells

In multi-cell CT design, the inlet flow to each cells differs greatly due to long pipe length. Part of this issue is addressed by reducing the diameter of pipe as water traverses from the front most cell to the rear cell. The flow in riser pipes is often required to be adjusted to ensure that flow / cell is even across the cooling towers. ***A measurement of CT riser flow once in 6 month or after any major shutdown is recommended to ensure improved L/G (liquid to gas ratio) for each cell.***

5.8.1.3 Develop SMP for CT Fills Cleaning

Review the preventive maintenance schedule of cooling towers fills cleaning. Given the concentration of suspended solids found during visual inspection, fills cleaning may be undertaken 1 cell/month by drawing out the fill packs, weighing the fill packs in dry condition before cleaning, cleaning it by pressurized jet of water, observing the weight drop and then repacking it correctly without affecting/damaging the edges and flute profiles or honeycomb structure. ***A SMP for CT fills cleaning is recommended to be adhered by maintenance personnel.***

5.8.1.4 Provision for higher air flow by improved design of fans airfoil (Improved L/G ratio)

Replacement of GRP blades with high grade Epoxy coated blades in the fan of improved aerodynamic design. The primary objective is to ensure higher air flow through the fills for lowering the CT water outlet temperature. A well design retrofits can provide benefits up to 20% increased air flow / cell then conventional design for same power consumption.

5.8.1.5 Improvement in Air-Water Distribution of CT Cells

CTs often undergo deterioration over the period of operation and need sufficient and effective maintenance periodically. We recommend the following activities to be performed in pre-defined scheduled maintenance intervals.

- Inspection of water distribution system, fills, drift eliminators during each monthly PM.
- Installation of water nozzles in dry patches after internal inspection.
- Check for any damage to the PVC water distribution pipes, their end covers, leakage from the joints, damaged nozzles, missing distribution rings of the nozzles, blockage of nozzles below RCC ducts, etc. to ensure proper spraying of water evenly throughout the fill surface.
- In situ cleaning of fills and drift eliminator with clarified water once in a quarter to remove loose dirt or sludge.

- Check of fan blade tip clearance and maintain it as per the OEM recommendation, typically it is less than 50mm.
- Blade angle can be adjusted to the max allowable value to increase air flow as recommended by OEM, typically it is maintained around 12 to 14 degrees. However, this needs to be validated through OEM.
- While inspecting the fills and water distribution, use wooden ply or sheets for walking to avoid damage of fill edges.

5.8.1.6 CT Basin Screen Design

If the CT outlet channel has two slots to put the two separate screens, then we recommend keeping the upstream screen size opening to around 1.5" – 2" to restrict the large size debris and 1/2" (12 mm- 15 mm) opening for the downstream screen to restrict the smaller size fills or debris.

After doing this modification more frequent cleaning of the downstream screen may be required otherwise the CT basin will overflow in case of heavy blockage. This design typically has benefit of less pass through of broken fills, debris, and other external materials into condenser water box and tube sheet. Please refer figure 7 for a typical CT forebay screen designed for a utility in North India.

Figure 15 CT Basin Screen Design

5.9 Miscellaneous Pumps

Measurements of all major HT motors of HRSG, turbine & BOP area were taken using the Power Analyzer, which measures Voltage, Current, kW, and P.F., etc. The parameters were measured to measure the hydraulic efficiency of pumps. The measurements taken are tabulated and presented below Table.

Table 5-27: Block-1 & 2 Pump Parameters

HT PUMPS	DESIGN MOTOR RATING (KW)	VOLTAGE (KV)	CURRENT (AMPS)	POWER FACTOR	[19]HYDRAULIC POWER (KW)[A]	ELECTRICAL POWER (KW)[B]	EFFICIENCY [A/B*100] (%)
HP/IP BFP-1A	4000	6.77	232	0.862	1490.4	2344.9	63.60
HP/IP BFP-2A	4000	6.79	228	0.850	1443.4	2279.1	63.30
CEP 1B	600	6.77	46.9	0.834	275.9	458.6	60.20
CEP 2B	600	6.79	48.1	0.851	265.8	480.8	55.40
[20]DMCW 1B	300	6.75	26.0	0.851	157.6	257.5	61.20
DMCW 2B	300	6.79	26.2	0.850	184.3	261.9	70.40
CW Pump- 1A	1150	6.80	106.0	0.756	682.1	974.2	70.02
CW Pump- 1B	1150	6.80	109.9	0.760	681.2	957.8	71.12
CW Pump- 2A	1150	6.80	106.1	0.756	758.1	944.2	80.29
CW Pump- 2B	1150	6.80	109.9	0.760	734.2	983.2	74.66

[19] (Pump TDH X Flow X Density X g)/3600/1000

[20] DMCW Pump 1B was running at 1495 TPH and DMCW Pump 2B flow as 1840 TPH. Design flow rate is 1730 m3/hour and design pump efficiency is 84%.

The major pumps performance parameters do not indicate any major deviation except few cases where pumps operating point and design duty points are deviating large. There is a potential energy saving for pumps specially CEPs (continuous duty) if they are operated under VFD control.

OPTC has already implemented VFDs in low pressure BFP in Unit 2 and is under service.

5.10 Condensate Extraction Pump

Following tables provides performance assessment of CEP.

Table 5-28 CEP Performance

PARAMETERS	UNITS	DESIGN	INDEX	CEP 1B	CEP 2B
Discharge Pressure	Bar			24.66	24.37
Suction Pressure	Bar			0.196	0.170
Suction Temperature	Deg C	49.2		58.41	56.39
Discharge Temperature (Estimated)	Deg C			61.71	58.08
Discharge flow	m3/hr.	660.0		413.41	401.85
Speed	RPM	1484.0			
Voltage	KV	6.6	[A]	6.77	6.78
Current	A	65.0	[B]	46.9	48.1
Power Factor			[C]	0.83	0.85
Power	KW	600.0	[F=SQRT (3)*A*B*C]	458.6	480.1
Hydraulic Power	KW	466.0	[E]	275.9	265.8
Specific Weight	kg/m3	988.4		984.0	985.0
Pump TDH	mwc	210.0		**249.3**	**246.7**
Hydraulic Efficiency (TDH)	%	80.0	**[E/F]**	**60.20**	**55.40**

- The difference in pump design and operating efficiency is attributable due to operating point deviating from design considerably.
- Pump actual TDH is higher than design, suggesting higher power consumption as higher head increases the power consumption proportionately.
- Assessment of deaerator level control valve system shows potential for lowering the head by opening of the level control valve to full and operating pump at reduced speed using VFD.

5.10.1 Recommendations:

5.10.1.1 Retrofit of MV VFD for Power Saving in CEP

Under operating conditions, the deaerator level control valve remains throttled to maintain the deaerator inlet pressure of 4 kg/cm2. The power consumed by CEP at full load is about 460-480 kW (based on performance test data). The CEP discharge pressure is about 24Kg/cm2 which reduces to around 20 kg/cm2 at the inlet of deaerator level control valve (~ pressure drop of 20 kg/cm2 at valve throttling of 72%). Deaerator level control valve is throttling the condensate pressure from 20

kg/cm2 to around 4 kg/cm2 at the inlet of deaerator. Please refer snapshot of CEP operation during the performance test of Unit 1. Similar observation is reported for Unit 2 also.

Given the present operation of CEPs away from design efficiency point, it is recommended to retrofit the pump motor with a VFD to reduce the speed and thereby its discharge pressure adequately to avoid deaerator level controller valve throttling, while still meeting the pressure requirement of its duty points. A careful design review and performance analysis will result in the potential power saving is in the tune of minimum 100-120 KW at full load after adjusting for the increased HVAC auxiliary load of VFD. A detailed review of this retrofit is outside the scope, however industry experience suggests a pay back period typically of less than 3 years for such retrofit.

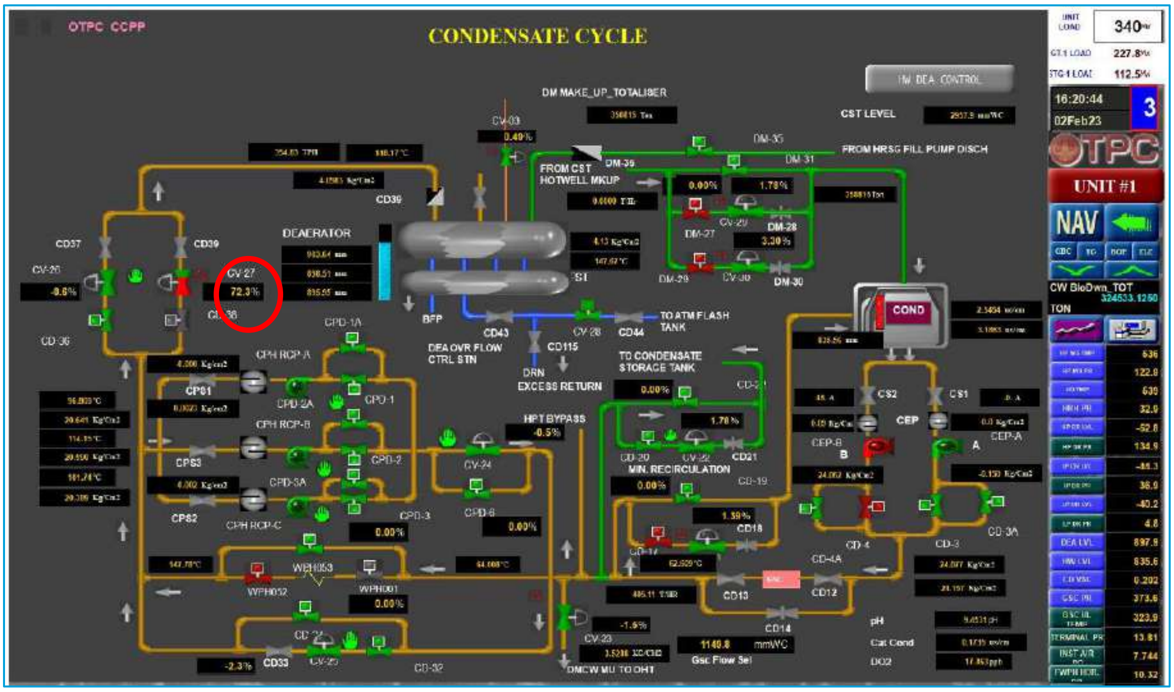


Figure 16 CEP Operation in Unit 1

- Deaerator at a pressure of 4.0 bar.
- HP/LP Bypass spray.
- LP Turbine Exhaust cooling sprays.
- Gland steam de-super heater
- Condenser drain flash box
- Condensate dozing (if applicable)

5.10.1.2 Retrofit of CEP Gland Packing to Mechanical Seals

Mechanical seal OEMs such as Eagle Burgmann, Borg Warner, etc. can be consulted for converting the gland packing to mechanical seal. This will help in increasing the life of shaft seal and reducing the dissolved oxygen content in the condensate. The performance data suggest significantly high DO level in Unit 1 (17.86 PPB).

5.11 Circulating Water Pump

Following tables provides performance assessment of CW Pumps.

Table 5-29 CW Pump Performance Evaluation

Parameters	Units	Design	INDEX	CW-1B	CW-1C	CW-2A	CW-2B
Discharge Pressure	Bar	NA		3.0303	3.0744	3.1235	3.0450
Suction Pressure (Estimated)	Bar	NA		0.9614	0.9614	0.9614	0.9614
Discharge Temperature	Deg C	NA		34.33	34.33	31.18	31.18
Suction flow	m3/hr.	12000	[G]	11648.0	11395.0	**12400.0**	**12450.0**
Voltage	KV	6.60	[A]	6.76	6.76	6.80	6.799
Current	A	108.6	[B]	110.0	107.6	106.0	109.9
Hydraulic Power	KW	865.0	[E=G*H]	682.1	681.2	758.1	734.2
Power Factor		0.8	[C]	0.7564	0.760	0.7564	0.76
Input Power	KW	1018.0	F=[SQRT(3)*A*B*C]	974.2	957.8	944.2	983.3
Pump Total Dynamic Head (Bowl)	mwc	22.0	[H]	21.59	22.04	22.54	21.74
Hydraulic Efficiency (Bowl)	%	85.0	**[E/F*100]**	**70.02**	**71.12**	**80.29**	**74.66**

5.11.1 Recommendations:

5.11.1.1 Measures for High CW Flow and for Arresting Suspected Passing in Butterfly Valve

In a parallel pump operation, passing of CW discharge valve of standby pump will lead to short circuiting of CW flow to the forebay. It is practically difficult to identify the short circuiting, but this issue leads to lower CW flow across the condenser, hence it is recommended to inspect all the valves internally and replace the elastomeric seals, seal retaining segments, metallic seals of valve disc, etc. Gearbox of the actuator should be adjusted to close the valves properly and should be crosschecked internally for its full closer.

5.11.1.2 Plate Heat Exchanger Isolation

Plate heat exchangers are often designed to operate as (1W + 1S) configuration, however many times, PHE are charged from ACW side for quick line up in case a changeover is warranted. This compromises standby PHE cleaning and effectiveness while adding to ACW power consumption. Standby PHE is recommended to be closed from both DMCW and ACW side as far as feasible to save unnecessary use of pumping power while keeping a close watch on in-service PHE differential pressure.

5.12 HP/IP Boiler FEED Pump

Table 5-30 HP/IP Boiler Feed Pump Performance Evaluation

Parameters	Units	Design	Index	HP BFP 1A	HP BFP 2A
Discharge Pressure	Bar	179.9		146.15	144.19
Suction Pressure	Bar	14.4		15.50	15.47
Suction Temperature	Deg C	149.5		146.66	146.40
Discharge Temperature	Deg C	149.5		149.73	149.12
Suction flow	m3/hr.	420	[G]	446.31	438.60
Voltage	KV	6.6	[A]	6.77	6.79
Current	A	405	[B]	232	228
Power Factor		0.89	[C]	0.862	0.85
Shaft Power	KW	3112.0	F=[SQRT(3)*A*B*C]	2344.9	2279.1
Hydraulic Power	KW	2490.0	[I=G*H]	1490.4	1443.4
Pump TDH	mwc	2000	[H]	1331.8	1312.2
Hydraulic Efficiency (TDH)	%	80.0	**[F/I*100]**	**63.60**	**63.30**

- The HPBFP efficiencies are observed to be within expected range. The deviation in efficiency can be explained based on pump design and operating duty point differences

5.13 DMCW Pump

Parameters	UOM	Design	Index	DMCW-1B	DMCW-2B
Discharge Pressure	Bar			7.08	6.91
Suction Pressure	Bar			3.25	3.27
Suction Temperature	Deg C	49.2		0.00	0.00
Discharge Temperature (Estd)	Deg C			40.35	41.15
Discharge flow	m3/hr.	1760.0	[G]	**1495.0**	**1840.1**
Speed	RPM	1486.0		NA	NA
Voltage	KV	6.6	[A]	6.75	6.79
Current	A	33.0	[B]	26.0	26.2
Power Factor			[C]	0.85	0.85
Power	KW	294.0	F=[SQRT(3)*A *B*C]	257.5	261.9
Hydraulic Power	KW	246.8	[I=G*H]	157.6	184.3
Pump TDH	mwc	44.0	[H]	39.0	37.1
Hydraulic Efficiency (TDH)	%	83.9	**[F/I*100]**	**61.20**	**70.40**

- The DMCW Pump efficiencies are observed to be within expected range. The deviation in efficiency can be explained based on pump design and operating duty point differences.

- DMCW Pump 1B was running at 1495 TPH and DMCW Pump 2B flow was 1840 TPH. Design flow rate is 1730 m3/hour and design pump efficiency are 84%. Given the pump 2B, being operated at higher than design flow (1840 TPH), a passing is suspected either via PHE (if standby PHE is isolated) or DMCW common recirculation line.

5.13.1 Recommendations:

5.13.1.1 Measures for Arresting Higher Flow Rate in DMCW 2B

A flow measurement using ultrasonic flow meter is required to adjust the pump operating points near the design duty point. Any suspected passing either in common recirculation valve or stand by PHE can be ascertained and arrested. Pump 1B and 2B are found to operate at different flow rate (difference by 345 TPH) which shall be corrected.

5.14 Compressed Air System

OTPC plant has two instrument air screw compressors with the capacity of 15 m3/min for the compressed air requirement. The operating pressure of the compressor is 8.5bar. The rated KW of drive motor is 132 KW. The input KW of compressor at rated condition is 119 KW and at unloaded condition, it is 27 KW. We have collected half hourly power consumption data for the compressor for 2.5 hours. Please refer below table for the details. The pressure at air drier outlet is 8.0 bar.

Description	Voltage (Volt)	Current (Load)	Current (Unload)	PF	Electrical Power (KW)
IAC -1A	435	185	56	NA	NA
IAC-1B	434	-	52	NA	NA
IAC-2A	438	184	55	NA	NA
IAC -2B	442	-	53	NA	NA

The power measurement for IAC was not available for Black & Veatch to conclude, however analyzing historical data suggest that power consumption of compressor at unload and load conditions are typically in the range of 22-25 KW and 100-110 KW respectively. The loading/ unloading cycle of IAC suggested few optimizations as evident in the table below.

Description	15:00	15:30	16:00	16:30	17:00	Instrument Air Pressure (bar)
IAC-1A	Unload	Unload	Load	Load	Unload	7.78
IAC-1B	**Unload**	**Unload**	**Unload**	**Unload**	**Unload**	
IAC-2A	Unload	Unload	Unload	Load	Load	7.72
IAC-2B	**Unload**	**Unload**	**Unload**	**Unload**	**Unload**	

IAC -1B and 2B are found to be completely unloaded for the period of performance test, while IAC 1A and 2A operated cyclically to maintain instrument air header pressure. Load/unload compressors

have two pressure setpoints: an upper setpoint and a lower setpoint. The compressor regulates the pressure between these two setpoint. When the lower pressure is reached, the compressor starts 'pumping air'. This setpoint is called the 'loading setpoint'. To avoid an ever-last uncontrolled rise in pressure, the compressor has an upper setpoint, called the 'unload setpoint' - where the compressor stops pumping air. There is various microprocessor-based control for Improved Loading / Unloading of Compressor which also reduces overall power consumption of the compressed air system.

5.14.1.1 Service Air and Instrument Air Segregation

Segregating the plant service and operating air and instrument air system can result in energy savings. In past assessments, Black & Veatch has seen plants that combine their service, operating, and instrument air system into a single system. In OTPC also, compressors are operated to meet both service air and instrument air requirements. Utilizing instrument air for service and controls together will result in higher energy demands specially for air-drying application.

5.14.1.2 Centralized Controller for Equalizing the Run-Hours of Two Parallel Compressors & Energy Saving

Normally, the load/unload pressure of each unit are set to react to changes in air demand. If the system pressure drops, an additional compressor will switch to loaded running. However, the sequence will always be the same, and this leads to a higher pressure than required. Central controllers can be set to prevent unequal wear of compressors, equalizing the running hours on multiple machines for more efficient service scheduling and reduced cost. Another advantage of centralized controller is that they reduce the average pressure band (load and unload set points). It also reduces the operating pressure of machines. By reducing the pressure by 1 bar (or 14.5 psi), energy usage gets lowered by 5-10%, while reducing the pressure by 1 bar (or 14.5 psi) decreases air leakages by average 10-15%.

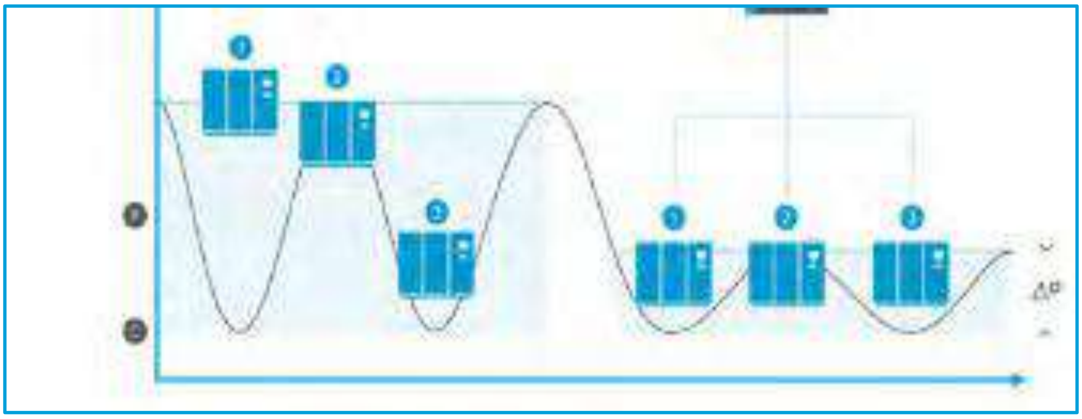


Figure 17 Average Pressure Band Trend for Parallel Compressor Operation

6 Recommendations

6.1 Based on Plant Performance Audit

The recommendations related to performance impact are categorized based on Risk, Priority, Capex requirement, and shutdown requirement. The assumed criteria and basis for these categorizations are provided below.

6.1.1 Risk Categorization:

The identified recommendations are further categorized into different risk levels based on the threats and hazards involved with the recommendations in the system. The different risk categorizations are as below

- Low
- Minor
- Moderate
- Major
- Critical

6.1.2 Priority Categorization:

The identified recommendations are further categorized into different priority levels based on the period the recommendation is expected to be planned for the reliable operation of the plant. The different priority categorizations and their criteria are as below

Table 6-1: Priority Categorization

PRIORITY	CRITERIA
Immediate	Important and urgent
Short term	Important and urgent but can be delayed
Long term	Important, not urgent
Good to have	Not important, not urgent

6.1.3 Capex Requirement Categorization:

The identified recommendations are categorized into different CAPEX requirements based on the high-level Capex estimate required to implement the recommendations. The different CAPEX requirements and their range considered are as below,

Table 6-2: Priority Categorization

CAPEX REQUIREMENT	RANGE (INR LAKHS)
High	> 100 lakh
Medium	25 to 100 lakh

CAPEX REQUIREMENT	RANGE (INR LAKHS)
Low	< 25 lakh
Not Applicable	

6.1.4 Shutdown Requirement Categorization:

The recommendations are further analyzed and shutdown requirements to implement the recommendations are identified. The shutdown requirement is based on the time period expected to implement the recommendations. The different shutdown requirements considered are as below,

Table 6-3: Priority Categorization

SHUTDOWN REQUIREMENT	RANGE (DAYS)
No	0
Minor Outage	15-30 days
Major Outage	30-45 days

6.1.5 Recommendation Summary

Black & Veatch has utilized information gathered at various stages during the execution of this Performance system Audit and assessments carried out in the above sections as a basis for identifying recommendations. Black & Veatch has identified around 10 recommendations for plant performance improvement and reliable plant operation. The below table describes the number of identified recommendations with respect to each categorization explained above.

Table 6-4: Recommendations Under Different Categories

PRIORITY	RISK CATEGORY	CAPEX REQUIREMENT	SHUTDOWN REQUIREMENT
Immediate - 4 no's	Low - 1 no	High -4 no's	No -4 no's
Short term - 21 no's	Minor - 1 no	Medium - 4 no	Minor Outage -14 no's
Long term - 1 no's	Moderate - 14 no's	Low - 15 no’s	Major Outage -2 no's
Good to have -1 no	Major -1 no	NA - 4 no's	No Outage -11 no’s
	Critical - 10 no's		

The recommendations to improve the plant performance are provided in the below table.

Table 6-5: Plant Performance Improvement Recommendations

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
1	Compressor	5.3.1.1	Inlet Air Filter Choking	Due to increase of fine dust in the ambient air, fine filters are getting exhausted within 4-6 months. This filter replacement requires shutdown of the unit. We recommend exploring the possibility of installing Coalascer pad rolls before the prefilters. These Coalascer pads have good dust holding capacity. These pads can be changed online whenever these get choked. Alternatively OTPC may also explore upgrading / replacing fine filters to EPA grade (E10 or E11) without coalescer pad after cost benefit assessment.	Moderate	Good to have	Low	Minor Outage	-	-
2	IP Turbine Bypass System	5.4.7.1	Suspected IP Bypass System Steam Passing & Steam Valve Upgrade	Test data shows that IP bypass spray valve for Unit 1 and 2 was 6.48 TPH and 19.4 TPH respectively which suggest that there may be suspected steam flow in the downstream pipe. It is necessary that suspected steam leakage in IP steam pipe is quickly arrested in available opportunity.	Minor	Short term	Low	Minor Outage	1-3	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				Unlike traditional control valves, there are designs which uses multi-stage, multi-turn technology divides the pressure reduction into many smaller stages. The number of turns, or stages, is selected to ensure a specific fluid discharge velocity is achieved at the exit of the control element. This reduces the potential for cavitation and erosion, that would otherwise compromise the valve’s ability to effectively control leakage.						
3	HRSG	5.4.7.2	CBD Tank Vents Open to Atmosphere	As per the design, the Continuous Blow-Down Tank (CBD) vent is routed to Deaerator however, based on site-visit discussions, it is understood that for both units, CBD vent lines are kept open to atmosphere. CBD vent should be routed to the Deaerator for fluid recovery and improved energy utilization.	Moderate	Short term	Low	Minor Outage	-	-
4	Steam Turbine	5.5.1.1	HP/IP Section Internal Efficiency Improvement by Seal Upgrade	Leakage losses represent the greatest portion of turbine stage losses. The losses are magnified as the turbine packing and turbine diaphragm spill strips	Critical	Immediate	High	Major Outage		

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				wear out progressively. A large amount of these losses is recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization. The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP and IP turbine efficiencies. Typical efficiency improvements up to 0.7-1.2 % in heat rate is reported in the past. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.						
5	Steam Turbine (HP/IP Section)	5.5.1.2	Suspected high HP to IP Leakage Flow (Temperature Inference Method)	The N2 packing leakage to IP turbine bowl is calculated using the temperature inference method. This method is an indirect method to determine the magnitude of leakage flow,	Critical	Short Term	Medium	No	12-15	1.0-1.5

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				since this leakage flow is inside the turbine, and it is impractical to directly measure it. Determination of the leakage flow shall also determine the true IP turbine efficiency.						
6	Steam Turbine (LP)	5.5.1.3	Improving LP Turbine Efficiency by Improved Blade Design and Increased Annulus Area	The steam seal upgrade tends to decrease heat rate and increase LP turbine efficiency. The new gland seals also reduce the in-air leakage around the shaft. The improved gland seal reduces the amount of air that enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air in-leakage through improved seals can decrease (improve) back pressure by 4-12 KPa absolute with a corresponding heat rate improvement of nearly 1.0%.	Moderate	Long Term	High	Major Outage	10-30	1.0-2.0
7	Steam Turbine (HP Section)	5.5.1.4	Performance Monitoring of HP Turbine Section & In-Situ Instrumentation for HP Exhaust Pressure and Temperature	One of the most critical measurements for analyzing HP turbine internal efficiency is HP turbine exhaust temperature. The ASME PTC test code 46 specifies this measurement to be	Moderate	Short Term	Low	Minor Outage	-	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				close to HP turbine exhaust. A minimum 2 measurements of HPT exhaust temperature is recommended with the instrument of 1 Deg. F or 0.56 Deg. C accuracy class for best results. HP exhaust pressure measurement is also recommended with an instrument of accuracy class 0.1%.						
8	Vacuum Pump	5.6.4.1	On-Line Performance Monitoring of Vacuum Pump & Seal Water System	Black & Veatch opines that the instrumentation available at the air extraction system is adequate for calculating vacuum pump performance. However, as most of the readings are not readily available in DCS, Black & Veatch recommends the following instruments for continuous monitoring of Vacuum pump and seal cooler performance in DCS. •Seal Water Flow (Inlet to Seal Water Cooler) •Seal Water Inlet and Outlet Temperature (Seal Water Cooler) •Seal Water Inlet and Outlet Differential Pressure	Critical	Immediate	Low	Minor Outage	5-10	

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				•ACW Inlet and Outlet Temp. (Seal Water Cooler) •Seal Water Temperature (Inlet to Vacuum Pump) •Rota Meter Flow						
9	Condenser	5.6.4.2	Investigate Suspected Air Ingress in Condenser Shell	Helium leak test is technology of choice due to availability, applicability (Can be done when unit is in operation) and detectability (Sensitivity of 10-6 mbar, fast (less than 20 seconds) , and ability to detect very fine leakages) of leakage points which are in condenser system but isn't useful for leakages which are under water up to condensate extraction pump (Downstream of hot well, flange joints, bellows, valves, suction strainer, and associated pipelines).	Critical	Immediate	Low	No	5-10	
10	Condenser	5.6.4.3	Online Tube Cleaning (OLTC) system	Black & Veatch recommends conducting a feasibility study for the installation of an Online Tube cleaning system for increasing heat-transfer effectiveness.	Major	Short Term	Medium	Minor	5-6	
11	Condenser	5.6.4.4	Regular Replacement of Sacrificial Anodes	Black & Veatch recommends regular inspection of sacrificial anodes during every	Low	Short term	Low	Minor	-	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				outage/condenser inspection if applicable. Sufficient stock of sacrificial anodes should be maintained for 100 percent replacement of damaged or worn-out anodes during every outage if Applicable For OTPC						
12	Vacuum Pump	5.7.3.1	Develop and Implement Standard Maintenance Practice (SMP) for Cleaning of Seal Water Cooler	The seal water cooler may have to be cleaned to maintain its heat transfer capability. Ensure that the proper flow and temperature of cooling water is being supplied to the heat exchanger.	Critical	Immediate	NA	No	Included in ID 8	-
13	Vacuum Pump	5.7.3.2	Cavitation Avoidance	High seal water inlet temp. may lead to pump cavitation. High seal water temperature in due course of two-stage compression may potentially exceed the corresponding saturation temp. (boiling point) causing cavitation. This problem can be mitigated if seal water flow and temperatures are made available for operators' guidance and seal water cooler performance is regularly audited.	Critical	Short Term	Low	Minor Outage	Included in ID 8	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				Another method is using acceleration, true peak detection, frequency banded vibration sensor which is sensitive only to those frequencies normally excited during cavitation. This loop-powered sensor provides a 4-mA to 20-mA output signal proportional to the sensed vibration level. A 4-mA to 20-mA output sensor may extend its signal to DCS and alarm limits can be set for alerting the operator.						
14	Cooling Tower	5.8.1.1	Fill pack replacement in CT 1 and CT 2	Black & Veatch was informed that a program for fill pack replacement is already underway. In Unit 1, 2 fill packs in 2 cells and in Unit 2, fill packs in 5 cells are replaced till Feb-23. The plan is to be progressively replace all the fill packs in the two cooling towers. It is also recommended to upgrade the design from existing MC67 PVS fills design with other cross-corrugated Fills such as C.10.19 folded end fills.	Critical	Short Term	High	No	15-20	0.5-1

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
15	Cooling Tower	5.8.1.2	Measurement of CT flow in Risers and Equalization of flow across CT Cells	In multi-cell CT design, the inlet flow to each cells differs greatly due to long pipe length. Part of this issue is addressed by reducing the diameter of pipe as water traverses from the front most cell to the rear cell. The flow in riser pipes is often required to be adjusted to ensure that flow / cell is even across the cooling towers. A measurement of CT riser flow once in 6 month or after any major shutdown is recommended to ensure improved L/G (liquid to gas ratio) for each cell.	Critical	Short Term	Low	No	Included in ID 14	-
16	Cooling Tower	5.8.1.3	Develop SMP for CT Fills Cleaning	Review the preventive maintenance schedule of cooling towers fills cleaning. Given the concentration of suspended solids found during visual inspection, fills cleaning may be undertaken 1 cell/month by drawing out the fill packs, weighing the fill packs in dry condition before cleaning, cleaning it by pressurized jet of	Critical	Short Term	NA	No	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				water, observing the weight drop and then repacking it correctly without affecting/damaging the edges and flute profiles or honeycomb structure. A SMP for CT fills cleaning is recommended to be adhered by maintenance personnel.						
17	Cooling Tower	5.8.1.4	Provision for higher air flow by improved design of fans airfoil (Improved L/G ratio)	Replacement of GRP blades with high grade Epoxy coated blades in the fan of improved aerodynamic design. The primary objective is to ensure higher air flow through the fills for lowering the CT water outlet temperature. A well design retrofits can provide benefits up to 20% increased air flow / cell then conventional design for same power consumption.	Moderate	Short Term	Low	No	Included in ID 14	-
18	Cooling Towers	5.8.1.5	Improvement in Air-Water Distribution of CT Cells	CTs often undergo deterioration over the period of operation and need sufficient and effective maintenance periodically. •Inspection of water distribution system, fills, drift eliminators during each monthly PM.	Critical	Short Term	Low	No	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				•Installation of water nozzles in dry patches after internal inspection. •Check for any damage to the PVC water distribution pipes, their end covers, leakage from the joints, damaged nozzles, missing distribution rings of the nozzles, blockage of nozzles below RCC ducts, etc. •In situ cleaning of fills and drift eliminator with clarified water once in a quarter to remove loose dirt or sludge. •Check of fan blade tip clearance •Blade angle adjustment						
19	Cooling Towers	5.8.1.6	CT Basin Screen Design	If the CT outlet channel has two slots to put the two separate screens, then we recommend keeping the upstream screen size opening to around 1.5" – 2" to restrict the large size debris and 1/2" (12 mm- 15 mm) opening for the downstream screen to restrict the smaller size fills or debris.	Moderate	Short Term	Low	Minor Outage	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
20	Condensate Extraction Pump	5.10.1.1	Retrofit of MV VFD for Power Saving in CEP	Given the present operation of CEPs away from design efficiency point, it is recommended to retrofit the pump motor with a VFD to reduce the speed and thereby its discharge pressure adequately to avoid deaerator level controller valve throttling, while still meeting the pressure requirement of its duty points. A careful design review and performance analysis will result in the potential power saving is in the tune of minimum 100-120 KW at full load after adjusting for the increased HVAC auxiliary load of VFD.	Moderate	Short Term	High	Minor Outage	-	120-150 KW
21	Condensate Extraction Pump	5.10.1.2	Retrofit of CEP Gland Packing to Mechanical Seals	Mechanical seal OEMs such as Eagle Burgmann, Borg Warner, etc. can be consulted for converting the gland packing to mechanical seal. This will help in increasing the life of shaft seal and reducing the dissolved oxygen content in the condensate. The performance data suggest significantly high DO level in Unit 1 (17.86 PPB).	Moderate	Short Term	Medium	Minor Outage	-	10-150 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
22	CW Pump	5.11.1.1	Measures for High CW Flow and for Arresting Suspected Passing in Butterfly Valve	In a parallel pump operation, passing of CW discharge valve of standby pump will lead to short circuiting of CW flow to the forebay. It is practically difficult to identify the short circuiting, but this issue leads to lower CW flow across the condenser, hence it is recommended to inspect all the valves internally and replace the elastomeric seals, seal retaining segments, metallic seals of valve disc, etc. Gearbox of the actuator should be adjusted to close the valves properly and should be crosschecked internally for its full closer.	Moderate	Short Term	Low	Minor Outage	-	100-150 KW
23	Plate Heat Exchanger	5.11.1.2	Plate Heat Exchanger Isolation	Plate heat exchangers are often designed to operate as (1W + 1S) configuration, however many times, PHE are charged from ACW side for quick line up in case a changeover is warranted. This compromises standby PHE cleaning and effectiveness while adding to ACW power consumption. Standby PHE is	Moderate	Short Term	NA	No	-	15-25 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				recommended to be closed from both DMCW and ACW side as far as feasible to save unnecessary use of pumping power while keeping a close watch on in-service PHE differential pressure.						
24	DMCW	5.13.1.1	Measures for Arresting Higher Flow Rate in DMCW 2B	A flow measurement using ultrasonic flow meter is required to adjust the pump operating points near the design duty point. Any suspected passing either in common recirculation valve or stand by PHE can be ascertained and arrested. Pump 1B and 2B are found to operate at different flow rate (difference by 345 TPH) which shall be corrected.	Moderate	Short Term	NA	No	-	Included in ID 23
25	Instrument / Service Air Compressor	5.14.1.1	Service Air and Instrument Air Segregation	Segregating the plant service and operating air and instrument air system can result in energy savings. In past assessments, Black & Veatch has seen plants that combine their service, operating, and instrument air system into a single system. In OTPC also, compressors are operated to meet both service	Moderate	Short Term	Low	Minor Outage	-	Upto 50-100 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				air and instrument air requirements. Utilizing instrument air for service and controls together will result in higher energy demands specially for the air-drying applications.						
26	Instrument/ Service Air Compressor	5.14.1.2	Centralized Controller for Equalizing the Run-Hours of Two Parallel Compressors & Energy Saving	Normally, the load/unload pressure of each unit are set to react to changes in air demand. If the system pressure drops, an additional compressor will switch to loaded running. However, the sequence will always be the same, and this leads to a higher pressure than required. Central controllers can be set to prevent unequal wear of compressors, equalizing the running hours on multiple machines for more efficient service scheduling and reduced cost. Another advantage of centralized controller is that they reduce the average pressure band (load and unload set points). It also reduces the operating pressure of machines. By reducing the pressure by 1 bar (or 14.5 psi), energy usage gets lowered by 5-10%, while	Moderate	Short Term	Low	Minor Outage	-	Upto 50-100 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				reducing the pressure by 1 bar (or 14.5 psi) decreases air leakages by average 10-15%.						
27	Real Time Performance Monitoring	-	Performance Monitoring Using Real Time Data and Predictive Analytics Approach	Machine learning-based predictive maintenance plan detects any failure event significantly quicker, compared to the traditional approaches. The strategy utilizes the following sequential steps: • Real-time data fetching, organizing, stacking, and classifying. • Process data may be temperature, current, flow, pressure, vibration, level or calculated variables. • Using engineering knowledge and the machine learning approach, develop a predictive model of the variable and save as the operating baseline • Detect process anomalies and diagnose / mitigate the issue before its occurrence	Moderate	Short Term	Low	No	10-15	0.5-1

7 Conclusion

Black & Veatch is thankful to OTPC for providing the opportunity to perform the Plant Performance Audit of its Combined Cycle Plant.

In this report, we have provided our observations and recommendations on –

- Major performance audit observations of individual equipment and system
- Comparative assessment with similar peer units.
- Performance improvement recommendations for sustainable operation.

Black & Veatch has reviewed the past reports and provided recommendations in ***section 6.1.5*** along with expected heat rate and aux power consumption benefits.

A summary of these recommended improvement project is tabulated as follows.

Table 7-1 List of Performance Improvement Projects Including Key Decision Metrics

PRIORITY	RISK CATEGORY	CAPEX REQUIREMENT	SHUTDOWN REQUIREMENT
Immediate - 4 no's	Low - 1 no	High -4 no's	No -4 no's
Short term - 21 no's	Minor - 1 no	Medium - 4 no	Minor Outage -14 no's
Long term - 1 no's	Moderate - 14 no's	Low - 15 no's	Major Outage -2 no's
Good to have -1 no	Major -1 no	NA - 4 no's	No Outage -11 no's
	Critical - 10 no's		

Black & Veatch recommends systematic implementation of these projects in short-mid-term period for long-term efficient, reliable, and safe plant operation achieving its environmental sustainability and decarbonization goals.

125V GT-1 Main Battery Bank – (630Ah Ni-Cd Battery, 169 Nos.).

TPC Charger Voltage : 136 V Charger Current : steag

Battery Bank Voltage : 136.5 V Date : 23.11.22

Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2	Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2
1	1.42			35	1.40		
2	1.40			36	1.42		
3	1.42			37	1.41		
4	1.42	1200	1200	38	1.42		
5	1.40			39	1.40		
6	1.33			40	1.42		
7	1.39			41	1.42		
8	1.37			42	1.33		
9	1.40			43	1.40		
10	1.40			44	1.39	1200	1175
11	1.42			45	1.37		
12	1.40			46	1.42		
13	1.41			47	1.41		
14	1.42	1200	1200	48	1.34		
15	1.42			49	1.40		
16	1.40			50	1.42		
17	1.42			51	1.40		
18	1.42			52	1.42		
19	1.40			53	1.42		
20	1.42			54	1.40	1200	1175
21	1.40			55	1.42		
22	1.42			56	1.40		
23	1.40			57	1.42		
24	1.42	1200	1200	58	1.40		
25	1.40			59	1.42		
26	1.42			60	1.40		
27	1.40			61	1.42		
28	1.42			62	1.40		
29	1.42			63	1.42		
30	1.40			64	1.40	1200	1200
31	1.42			65	1.42		
32	1.42			66	1.42		
33	1.40			67	1.40		
34	1.34	1200	1200	68	1.42		

Battery Racks : Ventilation :

Pilot Cell Temp : Floor Cleaning :

Electrolyte Level : Room Temperature

Checked by : Reviewed by :

Name : Uttam Name :

TPC

Charger Voltage :

Battery Bank Voltage :

Charger Current :

Date :

steag

Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2	Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2
69	1.40						
70	1.42						
71	1.39						
72	1.40						
73	1.37						
74	1.40	1200	1200				
75	1.42						
76	1.40						
77	1.42						
78	1.34						
79	1.39						
70	1.40						
81	1.41						
82	1.42						
83	1.40						
84	1.33	1200	1175				
85	1.34						
86	1.30						
87	1.40						
88	1.40						
89	1.39						
90	1.37						
91	1.40						
92	1.42						
93	1.40						
94	1.42	1175	1200				
95	1.40						
96	1.32						
97	1.40						
98	1.42						

Battery Racks :

Pilot Cell Temp :

Electrolyte Level :

Ventilation :

Floor Cleaning :

Room Temperature

Checked by :

Name :

Reviewed by :

Name :

TPC Charger Voltage :

Battery Bank Voltage :

Charger Current :

steag

Date : 26-12-2022

Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2	Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2
1	1.46			35	1.39	1200	1200
2	1.45			36	1.37		
3	1.36			37	1.35		
4	1.46			38	1.36		
5	1.36	1200	1200	39	1.35		
6	1.43			40	1.45		
7	1.34			41	1.35		
8	1.34			42	1.44		
9	1.35			43	1.39		
10	1.36			44	1.42		
11	1.34			45	1.36	1200	1200
12	1.43			46	1.38		
13	1.43			47	1.37		
14	1.44			48	1.41		
15	1.34	1200	1200	49	1.40		
16	1.37			50	1.41		
17	1.33			51	1.38		
18	1.33			52	1.36		
19	1.40			53	1.38		
20	1.43			54	1.43		
21	1.36			55	1.44	1200	1200
22	1.42			56	1.38		
23	1.36			57	1.38		
24	1.34			58	1.43		
25	1.36	1200	1200	59	1.41		
26	1.38			60	1.40		
27	1.34			61	1.38		
28	1.39			62	1.35		
29	1.45			63	1.39		
30	1.38			64	1.39		
31	1.46			65	1.39	1200	1200
32	1.35			66	1.38		
33	1.39			67	1.44		
34	1.36			68	1.38		

Battery Racks :

Pilot Cell Temp :

Electrolyte Level :

Ventilation :

Floor Cleaning :

Room Temperature

Checked by :

Name :

Reviewed by :

Name :

TPC Charger Voltage :

Battery Bank Voltage :

Charger Current :

Date : 26-12-2022

steag

Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2	Cell No.	Volts	Electrolyte Sp. Gravity-1	Electrolyte Sp. Gravity-2
69	1·38						
70	1·46						
71	1·38						
72	1·33						
73	1·45	1200	1200				
74	1·37						
75	1·37						
76	1·38						
77	1·39						
78	1·40						
79	1·40						
80	1·35						
81	1·46						
82	1·44						
83	1·38						
84	1·48						
85	1·39	1200	1200				
86	1·40						
87	1·34						
88	1·35						
89	1·34						
90	1·41						
91	1·33						
92	1·45						
93	1·37						
94	1·45						
95	1·38	1200	1200				
96	1·34						
97	1·36						
98	1·34						
	1·						
	1·						
	1·						
	1·						

Battery Racks :

Pilot Cell Temp :

Electrolyte Level :

Ventilation :

Floor Cleaning :

Room Temperature

Checked by :

Name :

Reviewed by :

Name :

125V GT-1 Auxiliary Battery Bank — (3[illegible] Ah Ni-Cd Battery, 98 Nos.)

TPC | steag

Charger Voltage : 146 V   Charger Current :

Battery Bank Voltage : 127 V   Date : 24-11-22

Cell No.	Volts	Electrolyte Sp. Gravity	Cell No.	Volts	Electrolyte Sp. Gravity	Cell No.	Volts	Electrolyte Sp. Gravity
1	1.42		35	1.41		69	1.42	
2	1.42		36	1.44	1200	70	1.40	
3	1.40		37	1.36		71	1.40	
4	1.43		38	1.41		72	1.40	
5	1.34		39	1.41		73	1.40	
6	1.40	1200	40	1.42		74	1.41	
7	1.40		41	1.42		75	1.41	
8	1.33		42	1.36		76	1.43	1200
9	1.39		43	1.34		77	1.41	
10	1.39		44	1.26		78	1.41	
11	1.41		45	1.42		79	1.40	
12	1.41		46	1.34	1200	80	1.41	
13	1.43		47	1.38		81	1.43	
14	1.31		48	1.41		82	1.41	
15	1.42		49	1.42		83	1.41	
16	1.34	1200	50	1.43		84	1.42	
17	1.40		51	1.43		85	1.41	
18	1.42		52	1.40		86	1.43	1200
19	1.41		53	1.34		87	1.42	
20	1.41		54	1.41		88	1.42	
21	1.41		55	1.45		89	1.41	
22	1.44		56	1.34	1200	90	1.41	
23	1.42		57	1.40		91	1.32	
24	1.42		58	1.41		92	1.41	
25	1.41		59	1.40		93	1.40	
26	1.42	1200	60	1.44		94	1.39	
27	1.40		61	1.41		95	1.30	
28	1.42		62	1.40		96	1.38	1200
29	1.41		63	1.43		97	1.41	
30	1.42		64	1.41		98	1.42	
31	1.41		65	1.44				
32	1.41		66	1.41	1200			
33	1.40		67	1.38				
34	1.35		68	1.41				

Battery Racks : ok   Ventilation : ok

Pilot Cell Temp :   Floor Cleaning : cleaning done

Electrolyte Level : ok   Room Temperature

Checked by :   **Reviewed by :**

Name : R. [illegible]   **Name :**

OTPC

steag

Charger Voltage :

Charger Current :

Battery Bank Voltage : 137.8VDC

Date : 22/12/22

Cell No.	Volts	Electrolyte Sp. Gravity	Cell No.	Volts	Electrolyte Sp. Gravity	Cell No.	Volts	Electrolyte Sp. Gravity
01	1.44		35	1.41		69	1.41	
02	1.44		36	1.44		70	1.41	
03	1.40		37	1.36	1225	71	1.40	
04	1.44		38	1.41		72	1.40	
05	1.34		39	1.41		73	1.40	
06	1.40		40	1.42		74	1.41	
07	1.40	1250	41	1.41		75	1.41	
08	1.33		42	1.42		76	1.44	
09	1.38		43	1.49		77	1.41	1250
10	1.39		44	1.35		78	1.41	
11	1.42		45	1.43		79	1.40	
12	1.40		46	1.34		80	1.42	
13	1.44		47	1.38	1225	81	1.44	
14	1.30		48	1.40		82	1.40	
15	1.43		49	1.42		83	1.41	
16	1.34		50	1.42		84	1.43	
17	1.40	1225	51	1.44		85	1.41	
18	1.42		52	1.40		86	1.44	
19	1.42		53	1.34		87	1.42	1225
20	1.41		54	1.40		88	1.43	
21	1.41		55	1.44		89	1.40	
22	1.44		56	1.35		90	1.42	
23	1.42		57	1.40	1225	91	1.34	
24	1.42		58	1.41		92	1.40	
25	1.41		59	1.40		93	1.39	
26	1.42		60	1.44		94	1.38	
27	1.40	1225	61	1.42		95	1.29	
28	1.42		62	1.40		96	1.38	
29	1.42		63	1.43		97	1.41	1225
30	1.42		64	1.41		98	1.43	
31	1.42		65	1.44				
32	1.41		66	1.41				
33	1.40		67	1.37	1175			
34	1.35		68	1.41				

Battery Racks :

Ventilation :

Pilot Cell Temp :

Floor Cleaning :

Electrolyte Level :

Room Temperature

Checked by :

Name : Tapas Bonik

Reviewed by :

Name :

Stand proposal

Project name	New Project 2
Project reference	P_20Dec22_Arnab_b
System name	SYS_00000 - Layout
System reference	SYS_00000
Customer	
Customer reference	

Battery

Cell type	KPH 630 P
Cells number	169
Stand number	1
Cell container material	PP
Handle	No
Electrolyte	Type-II
Wiring principle	Crosswise
Battery terminal access	Conventional
Connector between rows	Cable

Part number	Description	Quantity
W2314900	KPH 630 P	169

Proposed stand

Stand N°	Stand details	Page
1	169 cell(s) KPH 630 P - 1 tier 1 step (32,955 mm x 0 mm)	2

Options

Terminal Connection End Lug - Dow-M10_70 : A=70 (mm²) : M20

Cables

End lugs are used to connect the external cables to the cells.

Summary of the system :

Electrolyte volume	2,200 L
System volume	10.59 m³
System weight	5,995 Kg

SAFT URJA

Tuesday, December 20, 2022

Layout Proposal

Battery

Cell type	KPH 630 P
Cells included in this stand	169
Cell container material	PP
Handle	No
Electrolyte	Type-II
Wiring principle	Crosswise

Part number	Description	Quantity
W2314900	KPH 630 P	169

Proposed Layout

Stand type	1 tier 1 step	
Stand dimensions (including cells)	Length (L)	32,955.00 mm
	Width (W)	345.00 mm
	Total height (H)	554.00 mm
	Total weight	7,965.0 Kg
Cells volume	10.59 m³	

SAFT URJA

Tuesday, December 20, 2022

Battery layout

1 tier 1 step (32,955 mm x 345 mm)
Battery : 169 x KPH 630 P

Cell 1 starts from Positive pole

Number of steps	1
Number of tiers	1
Step height	150

Connector between blocks

End Lug

Collecting bar

Tuesday, December 20, 2022

Stand proposal

Project name	New Project 2
Project reference	P_20Dec22_Arnab_b
System name	SYS_00000 - Layout
System reference	SYS_00000
Customer	
Customer reference	

Battery

Cell type	KPH 353 P
Cells number	98
Stand number	1
Cell container material	PP
Handle	No
Electrolyte	Type-II
Wiring principle	Crosswise
Battery terminal access	Conventional
Connector between rows	Cable

Part number	Description	Quantity
W2310800	KPH 353 P	98

Proposed stand

Stand N°	Stand details	Page
1	98 cell(s) KPH 353 P - 1 tier 2 steps (9,555 mm x 0 mm)	2

Options

Terminal Connection End Lug - Dow-M10_70 : A=70 (mm²) : M20

Cables

End lugs are used to connect the external cables to the cells.

Summary of the system :

Electrolyte volume	1,050 L
System volume	4.65 m³
System weight	2,056 Kg

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URJA

Tuesday, December 20, 2022

Layout Proposal

Battery

Cell type	KPH 353 P
Cells included in this stand	98
Cell container material	PP
Handle	No
Electrolyte	Type-II
Wiring principle	Crosswise

Part number	Description	Quantity
W2310800	KPH 353 P	98

Proposed Layout

Stand type	1 tier 2 steps	
Stand dimensions (including cells)	Length (L)	9,555.00 mm
	Width (W)	522.00 mm
	Total height (H)	704.00 mm
	Total weight	3,068.4 Kg
Cells volume	4.65 m³	

SAFT URJA

Tuesday, December 20, 2022

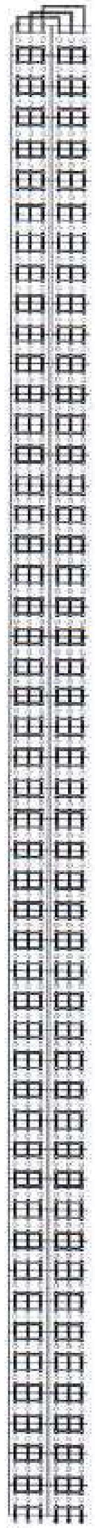
Battery layout

1 tier 2 steps (9,555 mm x 522 mm)
Battery : 98 x KPH 353 P

Cell 1 starts from Positive pole

Number of steps	2
Number of tiers	1
Step height	150

Connector between blocks
End Lug
Collecting bar
Cable between steps/rows, inside-outside



Tuesday, December 20, 2022

KPH 630 P - Cell data sheet

Classification

Brand	Saft Urja
Cell type	KPH 630 P
Cell P/N	W2314900
Capacity at 5 hours rate	630 Ah
IEC Designation	KH 630 P
According to IEC 60623	

Wiring principle: Crosswise

Physical data

Overall height	405 mm		
Cell height	405 mm		
Width	195 mm	Weight per cell	47.1 Kg
Length	345 mm		

Construction

Container material	Polypropylene	No. of terminals/polarity	4
Separator type	Grid	Terminal material	Steel
Connection torque	32.0 +/- 1.0 Nm	Vent type	VBYF (RAL 5005)
Terminal size	M20		
		Handle	No

Plates

Positive		Negative	
Type of plates	Pocket	Type of plates	Pocket

Electrolyte

Electrolyte type: Renewal		Max/Min	66 mm
Electrolyte type: Initial	Type-II	Vent oil quantity	
Electrolyte per cell: Liquid	12.4 liters		

Connection

Cable area of internal connection cables	70 mm²	End-lug (and external cable)	70 mm²

saft

URJA™

Tuesday, December 20, 2022

KPH 630 P - Cell data sheet

Charging

Float voltage	1.4 V/Cell	High rate voltage (min)	1.45 V/Cell
Single-level voltage	1.45 V/Cell		

Resistance/Short circuit

Internal resistance	0.11 mOhm	Short circuit current	18670 A

Performance data

Current discharge

After prolonged float charge of fully charged cells. Available amperes at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	63.5	79.2	126	207	307	403	592	1,073	1,435	1,613	1,821	2,149	2,974	3,355	4,083	4,342
1.05	62.3	77.8	123	204	301	394	573	1,018	1,232	1,341	1,505	1,750	2,431	2,812	3,393	3,545
1.1	61.1	76.1	121	198	291	381	542	825	938	1,039	1,147	1,342	1,987	2,264	2,692	2,826
1.14	59.0	73.4	116	190	277	360	473	632	727	800	874	1,066	1,581	1,813	2,136	2,214
1.16	58.2	73.9	114	183	260	327	427	544	638	684	756	905	1,365	1,572	1,810	1,956

Engine starting performance

For a fully charged cell by a constant current charge according to IEC 60623 standard at +20°C +/- 5°C (+68°F +/- 9°F), 30 seconds discharge down to 0,85 V

Available amperes 5,459 A

Power discharge

Available power (W), after prolonged float charged of fully charged cells at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	76.8	95.8	151	245	362	457	643	1,115	1,469	1,639	1,835	2,149	2,974	3,355	4,083	4,342
1.05	75.4	94.1	148	241	355	452	637	1,098	1,315	1,423	1,588	1,838	2,553	2,954	3,563	3,723
1.1	73.9	92.1	144	234	344	441	616	922	1,041	1,151	1,266	1,476	2,186	2,490	2,962	3,110
1.14	71.4	88.9	139	225	327	421	549	726	833	915	998	1,216	1,802	2,067	2,436	2,524
1.16	70.4	89.5	136	216	307	384	500	634	741	795	878	1,049	1,584	1,824	2,100	2,269

Engine starting performance

For a fully charged cell by a constant current charge according to IEC 60623 standard at +20°C +/- 5°C (+68°F +/- 9°F), 30 seconds discharge down to 0,85 V

Available amperes 5,459 A

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KPH 630 P - Cell data sheet

Kt Factor

Current discharge

After prolonged float charge of fully charged cells. Kt factor at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	9.9	7.96	5.00	3.05	2.06	1.56	1.06	0.59	0.44	0.39	0.35	0.29	0.21	0.19	0.15	0.15
1.05	10.1	8.10	5.10	3.10	2.09	1.60	1.10	0.62	0.51	0.47	0.42	0.36	0.26	0.22	0.19	0.18
1.1	10.3	8.28	5.23	3.18	2.16	1.66	1.16	0.76	0.67	0.61	0.55	0.47	0.32	0.28	0.23	0.22
1.14	10.7	8.58	5.42	3.32	2.27	1.75	1.33	1.00	0.87	0.79	0.72	0.59	0.40	0.35	0.29	0.28
1.16	10.8	8.52	5.55	3.45	2.42	1.93	1.47	1.16	0.99	0.92	0.83	0.70	0.46	0.40	0.35	0.32

Engine starting performance

For a fully charged cell by a constant current charge according to IEC 60623 standard at +20°C +/- 5°C (+68°F +/- 9°F), 30 seconds discharge down to 0,85 V

Available amperes 5,459 A

Power discharge

Kt factor power, after prolonged float charged of fully charged cells at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	8.20	6.58	4.18	2.57	1.74	1.38	0.98	0.56	0.43	0.38	0.34	0.29	0.21	0.19	0.15	0.15
1.05	8.35	6.70	4.27	2.61	1.77	1.39	0.99	0.57	0.48	0.44	0.40	0.34	0.25	0.21	0.18	0.17
1.1	8.53	6.84	4.37	2.69	1.83	1.43	1.02	0.68	0.61	0.55	0.50	0.43	0.29	0.25	0.21	0.20
1.14	8.83	7.09	4.54	2.80	1.92	1.50	1.15	0.87	0.76	0.69	0.63	0.52	0.35	0.30	0.26	0.25
1.16	8.94	7.04	4.64	2.91	2.05	1.64	1.26	0.99	0.85	0.79	0.72	0.60	0.40	0.35	0.30	0.28

Engine starting performance

Kt factor power, after prolonged float charged of fully charged cells at +20°C +/- 5°C (+68°F +/- 9°F)

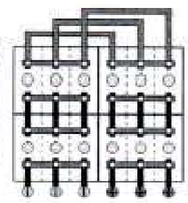
Available amperes 5,459 A

Tuesday, December 20, 2022

KPH 353 P - Cell data sheet

Classification

Brand	Saft Urja	Wiring principle	Crosswise
Cell type	KPH 353 P		
Cell P/N	W2310800		
Capacity at 5 hours rate	353 Ah		
IEC Designation	KH 353 P		
According to IEC 60623			



Physical data

Overall height	405 mm		
Cell height	405 mm		
Width	195 mm	Weight per cell	31.3 Kg
Length	261 mm		

Construction

Container material	Polypropylene	No. of terminals/polarity	3
Separator type	Grid	Terminal material	Steel
Connection torque	32.0 +/- 1.0 Nm	Vent type	VBYF (RAL 5005)
Terminal size	M20		
		Handle	No

Plates

Positive		Negative	
Type of plates	Pocket	Type of plates	Pocket

Electrolyte

Electrolyte type: Renewal		Max/Min	66 mm
Electrolyte type: Initial	Type-II	Vent oil quantity	
Electrolyte per cell: Liquid	10.2 liters		

Connection

Cable area of internal connection cables	70 mm²	End-lug (and external cable)	70 mm²

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URJA

KPH 353 P - Cell data sheet

Charging

Float voltage	1.4 V/Cell	High rate voltage (min)	1.45 V/Cell
Single-level voltage	1.45 V/Cell		

Resistance/Short circuit

Internal resistance	0.20 mOhm	Short circuit current	10461 A

Performance data

Current discharge

After prolonged float charge of fully charged cells. Available amperes at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	35.6	44.4	70.6	116	172	226	331	601	804	904	1,020	1,204	1,667	1,880	2,288	2,433
1.05	34.9	43.6	69.2	114	169	221	321	570	691	751	843	981	1,362	1,576	1,901	1,986
1.1	34.2	42.6	67.6	111	163	213	303	462	525	582	643	752	1,113	1,268	1,509	1,584
1.14	33.0	41.2	65.1	106	155	202	265	354	408	448	490	597	886	1,016	1,197	1,240
1.16	32.6	41.4	63.6	102	146	183	239	305	357	383	424	507	765	881	1,014	1,096

Engine starting performance

For a fully charged cell by a constant current charge according to IEC 60623 standard at +20°C +/- 5°C (+68°F +/- 9°F), 30 seconds discharge down to 0,85 V

Available amperes 3,059 A

Power discharge

Available power (W), after prolonged float charged of fully charged cells at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	43.0	53.7	84.4	137	203	256	360	625	823	918	1,028	1,204	1,667	1,880	2,288	2,433
1.05	42.3	52.7	82.7	135	199	253	357	615	737	798	890	1,030	1,430	1,655	1,997	2,086
1.1	41.4	51.6	80.7	131	192	247	345	517	583	645	709	827	1,225	1,395	1,660	1,742
1.14	40.0	49.8	77.8	126	183	236	307	407	467	513	559	681	1,010	1,158	1,365	1,414
1.16	39.5	50.1	76.0	121	172	215	280	355	415	446	492	588	888	1,022	1,177	1,272

Engine starting performance

For a fully charged cell by a constant current charge according to IEC 60623 standard at +20°C +/- 5°C (+68°F +/- 9°F), 30 seconds discharge down to 0.85 V

Available amperes 3,059 A

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URJA

KPH 353 P - Cell data sheet

Kt Factor

Current discharge

After prolonged float charge of fully charged cells. Kt factor at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	9.9	7.96	5.00	3.05	2.06	1.56	1.06	0.59	0.44	0.39	0.35	0.29	0.21	0.19	0.15	0.15
1.05	10.1	8.10	5.10	3.10	2.09	1.60	1.10	0.62	0.51	0.47	0.42	0.36	0.26	0.22	0.19	0.18
1.1	10.3	8.28	5.23	3.18	2.16	1.66	1.16	0.76	0.67	0.61	0.55	0.47	0.32	0.28	0.23	0.22
1.14	10.7	8.58	5.42	3.32	2.27	1.75	1.33	1.00	0.87	0.79	0.72	0.59	0.40	0.35	0.29	0.28
1.16	10.8	8.52	5.55	3.45	2.42	1.93	1.47	1.16	0.99	0.92	0.83	0.70	0.46	0.40	0.35	0.32

Engine starting performance

For a fully charged cell by a constant current charge according to IEC 60623 standard at +20°C +/- 5°C (+68°F +/- 9°F), 30 seconds discharge down to 0,85 V

Available amperes 3,059 A

Power discharge

Kt factor power, after prolonged float charged of fully charged cells at +20°C +/- 5°C (+68°F +/- 9°F)

V/Cell	10h	8h	5h	3h	2h	1.5h	1h	30m	20m	15m	10m	5m	1m	30s	5s	1s
1	8.20	6.58	4.18	2.57	1.74	1.38	0.98	0.56	0.43	0.38	0.34	0.29	0.21	0.19	0.15	0.15
1.05	8.35	6.70	4.27	2.61	1.77	1.39	0.99	0.57	0.48	0.44	0.40	0.34	0.25	0.21	0.18	0.17
1.1	8.53	6.84	4.37	2.69	1.83	1.43	1.02	0.68	0.61	0.55	0.50	0.43	0.29	0.25	0.21	0.20
1.14	8.83	7.09	4.54	2.80	1.92	1.50	1.15	0.87	0.76	0.69	0.63	0.52	0.35	0.30	0.26	0.25
1.16	8.94	7.04	4.64	2.91	2.05	1.64	1.26	0.99	0.85	0.79	0.72	0.60	0.40	0.35	0.30	0.28

Engine starting performance

Kt factor power, after prolonged float charged of fully charged cells at +20°C +/- 5°C (+68°F +/- 9°F)

Available amperes 3,059 A

GE Renewable Energy
Grid Solutions – Grid Automation

St Leonards Building
Harry Kerr Drive
Stafford
ST16 1WT

T +44 1785 223251
www.gegridsolutions.com

To Whom it May Concern

7th February 2024

Dear Customer,

Multilin F650 – Feeder Protection & Bay Controller – Transition from Ring to Pin Terminals

I write to advise you regarding a change planned in the terminal blocks used for terminating digital I/O and the auxiliary power supply in F650 relays and CIO modules. As of today, those terminal blocks on the rear of the product have a ring lug connection format.

Within the same 650 family as the F650 and CIO we have the C650 bay controller, which today is equipped with pin terminal connectors. These connectors have equally secure pin terminal connectors, which take bootlace ferrules as opposed to ring lugs.

As the 650 family is often used for applications which require protection and control together, the density of wiring can be high. For this reason, it is beneficial to use terminations where the wires naturally emanate perpendicular to the rear of devices, permitting an uncluttered and manageable wiring loom. This objective is satisfied using the pin terminals long-proven in the C650 section of the family. We therefore have decided to standardize on pin terminals for digital input, digital output and power supply connections for the entire 650 range. No changes are proposed to the existing ring terminal blocks for connecting CTs and VTs.

To summarize the changes:

Applicable models:
F650 Feeder Protection & Bay Controller, **CIO** Remote CAN bus I/O Module

Terminal Block	Current offering (F650/CIO)	Will become (F650/CIO)
CT/VT	Ring terminal	Ring terminal (no change)
Inputs, Outputs, Power Supply	Ring terminal	**Pin terminal (change)**
Serial Comms	Pin terminal	Pin terminal (no change)

The pictures on the next page show the before and after solutions.

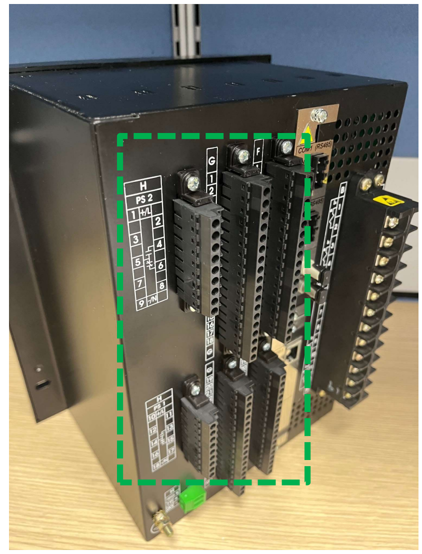
F650 and CIO orders for shipment **before 1st May 2024** will be satisfied with the current solution for terminal blocks. Shipments **from 1st May 2024 will be satisfied with the new terminal blocks** as per the right-hand column of the table.

Please note that attaching the revised terminal blocks does not change any of the internal structure of the product. In terms of compliance with norms and standards this is a benign mechanical change, which requires no modification of conformance claims. Similarly, any homologation/approval file that you hold for our product should still remain valid, perhaps with a copy of this letter stored as a note attached to it.

Pictures of the before and after scenarios:

Existing product with ring terminal I/O today

Harmonized solution from 1st May 2024



At this exciting time of evolution in our portfolio we wish to keep you up to date with all changes and the timelines on which they will occur. Particularly for the 650, it underlines how we are simplifying the engineering of your substation projects.

Yours faithfully,

Himanshu Bhatia
Senior Product Manager
Distribution, Industry & Power Generation – Grid Automation

Dinesh Laha

From: Mukherjee, Angsu (GE Vernova) <angsu.mukherjee@ge.com>
Sent: 14 February 2024 10:45
To: Subhajit Ganguly
Cc: Narendra Kumar Gupta
Subject: RE: Budgetary Price offer for Multilin F650 Relays
Attachments: f650 notifcation.pdf

Dear Sir,

Further to this, please note that your existing relay models are obsolete& offered models are one is to one replacement .

Please also note that the Multilin F650 – Feeder Protection & Bay Controller – Transition from Ring to Pin Terminals

F650 Feeder Protection & Bay Controller, **CIO** Remote CAN bus I/O Module

Terminal Block	Current offering (F650/CIO)	Will become (F650/CIO)
CT/VT	Ring terminal	Ring terminal (no change)
Inputs, Outputs, Power Supply	Ring terminal	**Pin terminal (change)**
Serial Comms	Pin terminal	Pin terminal (no change)

F650 and CIO orders for shipment **before 1st May 2024** will be satisfied with the current solution for terminal blocks. Shipments **from 1st May 2024 will be satisfied with the new terminal blocks** as per the right-hand column of the table.

Thanks & Regards,
Angsu Mukherjee

M +91 9163315765

angsu.mukherjee@ge.com

GE T&D India Limited
(Formerly Alstom T & D India Limited)
6th Floor, Tower 2A, Unit 602, Flex Work
ECOSPACE Business Park,
New Town, Rajarhat, Action Area II
Kolkata – 700156

From: Mukherjee, Angsu (GE Vernova)
Sent: Sunday, February 11, 2024 8:28 PM
To: Subhajit Ganguly <subhajit.ganguly@otpcindia.in>
Cc: Narendra Kumar Gupta <nk.gupta@otpcindia.in>
Subject: RE: Budgetary Price offer for Multilin F650 Relays

Dear Sir,

We confirm that the new relays will be exact one to one replacement with the previous models in terms of size, wiring, protection and controls and communications etc
F650 connection drawing is attached FYR.

Regards,
Angsu

From: Subhajit Ganguly <subhajit.ganguly@otpcindia.in>
Sent: Thursday, February 8, 2024 4:01 PM
To: Mukherjee, Angsu (GE Vernova) <angsu.mukherjee@ge.com>
Cc: Narendra Kumar Gupta <nk.gupta@otpcindia.in>
Subject: EXT: RE: Budgetary Price offer for Multilin F650 Relays

WARNING: This email originated from outside of GE. Please validate the sender's email address before clicking on links or attachments as they may not be safe.

Dear Sir

Kindly confirm that the new relays will be exact one to one replacement with the previous models (shared with you) in terms of size, wiring, protection and controls and communications etc
Also share connection drawing of the proposed relay model.

Regards
Subhajit Ganguly

From: Subhajit Ganguly
Sent: 08 February 2024 12:10
To: 'Mukherjee, Angsu (GE Vernova)'
Cc: Narendra Kumar Gupta
Subject: RE: Budgetary Price offer for Multilin F650 Relays

Dear Sir

Kindly confirm, offered item is interchangeable for all the applications (With or Without CBCT Provision) I have shared with you in enquiry mail.

Regards
Subhajit Ganguly

From: Mukherjee, Angsu (GE Vernova) [mailto:angsu.mukherjee@ge.com]
Sent: 06 February 2024 09:56
To: Subhajit Ganguly

Cc: Narendra Kumar Gupta
Subject: RE: Budgetary Price offer for Multilin F650 Relays

CAUTION: This email originated from outside of the OTPC Domain Network. Do not click links or open attachments, unless you recognize the sender and know the content is safe.

Dear Sir,

Please find the offer , one common model offered for all the existing F650 models , bye back is not possible .

F650-B-A-G-F-2-G-1-HI-6H-E
Configuration Details :
Display: B - Basic display (4 x 20 characters)
Serial Comm. Board 1 (ModBus): A - Redundant RS485
Ethernet Comm. Board 2 (DNP): G - 1588, 10/100 Base TX + 100 Base TX
I/O Board 1: 2 - 8 Inputs + 8 Outputs, 2 trip coil supervision
I/O Board 2: 1 - I/O Board with 16 Inputs + 8 Outputs
Auxiliary Voltage: HI - Source: 110-250 VDC (range:88~300); Source: 120-230 VAC (range:88~264)
Communication Protocol: 6 - IEC 61850, Modbus ® RTU & TCP/IP, DNP 3.0 Level 2
Environmental Protection: H- - Harsh (Chemical) Environment Conformal Coating
Enhance Display: E - Enhanced Display with USB

Special Options :
Language: English/English
Firmware: 8.50 (Firmware Revision)
No MOD's

Schedule I: Bill of Quantity and Prices

S. No	Proposed Model #	Qty	Unit EX-Works Price (in ₹)
1	F650-B-A-G-F-2-G-1-HI-6H-E	Min 20 Nos	225,000

(*All Prices are in INDIAN Rupees)

Commercial Terms & Conditions

Terms of Payment	:	100% advance payment including Tax & Duties against Performa Invoice before dispatch.
Prices	:	Ex-works
Freight & Insurance	:	2% Extra
Warranty	:	12 months from the Date of Material dispatch.
Delivery	:	16 weeks from the date of GE acceptance of techno-commercially clear

		order and receipt of relay at factory
Labour Cess	:	NOT APPLICABLE
Validity	:	30 days from the Date of Offer.
SD/PBG	:	NOT APPLICABLE
Contract Agreement	:	NOT APPLICABLE
LD	:	NOT APPLICABLE
GST	:	18% Extra

Note:

- Consequential Damages: Consequential damages will not be applicable for the above Supply offer.
- This above offer is only for SUPPLY; however, the SERVICE portion will be done on chargeable basis.

Schedule II: Address for PO creation & Entity details:

In the event of an order, pl place it on our authorized channel whose address is given below

Shree Narayan Sales & Services

219B, Old China Bazar Street,
1st Floor, Room No. F-1,
Kolkata-700 001.
Ph : +91 33 4007 7671
E-Mail : snss.anil@gmail.com/sales@mysnss.com
Website : http://www.mysnss.com/

Kind attn: Mr. Anil Kumar Khemka
+919831000165

Thanks & Regards,
Angsu Mukherjee

M +91 9163315765

angsu.mukherjee@ge.com

GE T&D India Limited
(Formerly Alstom T & D India Limited)
6th Floor, Tower 2A, Unit 602, Flex Work

ECOSPACE Business Park,
New Town, Rajarhat, Action Area II
Kolkata – 700156

From: Subhajit Ganguly
Sent: 02 February 2024 10:17
To: 'Mukherjee, Angsu (GE Vernova)'
Cc: Narendra Kumar Gupta
Subject: RE: Budgetary Price offer for Multilin F650 Relays

Reminder-2

Dear Sir

Awaiting for the offer.

Regards
Subhajit Ganguly

From: Subhajit Ganguly
Sent: 30 January 2024 09:46
To: 'Mukherjee, Angsu (GE Vernova)'
Cc: Narendra Kumar Gupta
Subject: RE: Budgetary Price offer for Multilin F650 Relays

Dear Sir

Awaiting for the offer.

Regards
Subhajit Ganguly

From: Subhajit Ganguly
Sent: 23 January 2024 16:20
To: 'Mukherjee, Angsu (GE Vernova)'
Cc: Narendra Kumar Gupta
Subject: Budgetary Price offer for Multilin F650 Relays

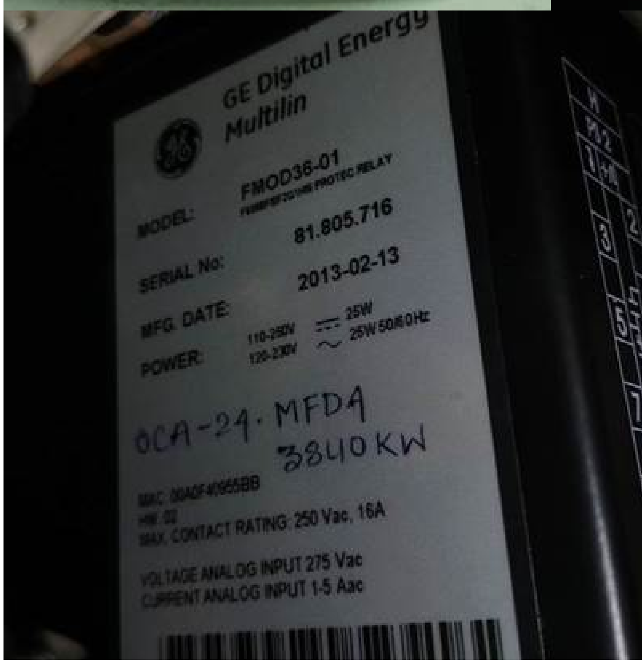
Dear Sir

Kindly send Budgetary Price offer for supply of following Multilin F650 Relays:

1. **GE Multilin 650 Relay for Motor protection (6.6KV MV System)**
   Protection Against: Motor Fault(99)
   02 Types:
   Type 1 (Below 1000KW): Without CBCT Provision. Required Quantity-10nos
   Type 2 (Above 1000KW): With CBCT Provision. Required Quantity-10nos


ESC
F2
F1
LOCAL
REMOTE
OFF
GE Multilin
650


GE Digital Energy
Multilin
2013-02-13
0CA-24-MFDA
3840 KW
H
PS 2


GE Digital Energy
Multilin
MODEL: FMOD36-01
PROTEC RELAY
SERIAL No: 81.805.716
MFG. DATE: 2013-02-13
POWER: 110-250V 25W
120-230V 25W 50/60Hz
0CA-24-MFDA
3840 KW
HW: 02
MAX. CONTACT RATING: 250 Vac, 16A
VOLTAGE ANALOG INPUT 275 Vac
CURRENT ANALOG INPUT 1-5 Aac

2. **GE Multilin 650 Relay for Line Incomer Protection (6.6KV MV System)**
   Protection Against: IDMT INSTANTENEOUS OVER CURRENT/EARTH FAULT (50/51/50N/99)
   Required Quantity:05nos

3. **GE Multilin 650 Relay for Transformer Protection (6.6KV MV System)**
Protection Against: IDMT INSTANTENEOUS OVER CURRENT/EARTH FAULT (50/51/50N/99)
With CBCT Provision
Required Quantity: 05nos

4. **GE Multilin 650 Relay for Motor Differential Protection (6.6KV MV System)**
Protection Against: MOTOR DIFFERENTIAL (87) Fault
Only for Motor feeders above 1000KW.

Required Quantity: 02nos

5. **GE Multilin 650 Relay for Under Voltage/No Voltage Protection (6.6KV System)**
   Protection Against: Under Voltage/No Voltage Fault (27/27N)
   Required: 02nos


MODEL
F650BABF2G0HI3
DIGITAL BAY CONTROLLER
SERIAL No.
81.109.605
MFG. DATE
NOV 19.2010
POWER
MAC:
HW: 02
MAX. CONTACT RATING: 250 Vac 16A general pu
VOLTAGE ANALOG INPUT 275 Vac
CURRENT ANALOG INPUT 1-5 Aac
81.109.605
MADE IN SPAIN


VOLTAGE
GE Multilin
650
UNDER VOLTAGE & NO
VOLT RELAY-27/27N

6. GE Multilin 650 Relay for Motor Protection System (415VAC LV System)

Required Quantity: 02nos

7. GE Multilin 650 Relay for Incomer Protection (415VAC)
Required Quantity: 02nos

8. **GE Multilin 650 Relay for DG Incomer Protection (415VAC)**
Required Quantity: 02nos

9. **GE Multilin 650 Relay for Bus Coupler Protection (415VAC)**
Required Quantity: 02nos

SCOPE of JOB of M/s GE: The same to be considered for submitting the offer.

1. Supply of New Model of F650 Relay compatible with presently installed F650 Relays for Motor/Line and Transformer Protection Application. (Technical Details of existing Relays are provided above).
2. Offer to be submitted on BUY BACK Policy to buy out the existing relays.
3. Deputing expert Manpower for Supervision and job execution at site.
4. Installation of the relays at designated feeder panels.
5. De-Installation of existing Relays from Panels.
6. Freight, Insurance and P&F of new relays from factory to our main Store at site and shifting of new relays from our store to job site.
7. Shifting of old relays from job site to our main store and Freight, Insurance and P&F from our main Store to your factory of old relays.
8. Testing of New Relays.
9. Preparation of Standard Operating Practices for our O&M team.
10. Demonstration of working of IED's to O&M Team.
11. Tool and Tackles for job execution.
12. Testing Tools for testing of new relays.

With best regards,

Subhajit Ganguly
Assistant Manager-Electrical Maintenance | ONGC TRIPURA PO
Palatana, Gomati Tripura, Pin-799105|Mobile: + 91 798001025
Phone: +91 381 236 3884|Email: subhajit.ganguly@otpcindia.i

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TECHNICAL INFORMATION LETTER

LCI WATER – COOLED BUS LEAKS

APPLICATION

Innovation Series Static Starter, LS2100 and LS2100e products (except 8.5MVA and 11MVA LS2100 and LS2100e)

PURPOSE

Leakage of the water- cooled bus has been detected in some static starters which have been in service for 10 or more years. Such leakage may result in the loss of coolant and the inability to start. Leakage may further result in failure of the static starter with an arcing fault within the enclosure.

REASON FOR REVISION

Additional parts required to implement the TIL. Scope of work is amended.

Compliance Category

M - Maintenance	Identifies maintenance guidelines or best practices for reliable equipment operation.
C - Compliance Required	Identifies the need for action to correct a condition that, if left uncorrected, may result in reduced equipment reliability or efficiency. Compliance may be required within a specific operating time.
A - Alert	Failure to comply with the TIL could result in equipment damage or facility damage. Compliance is mandated within a specific operating time.
S – Safety	Failure to comply with this TIL could result in personal injury. Compliance is mandated within a specific operating time.

Timing Code

1	Prior to Unit Startup / Prior to Continued Operation (forced outage condition)
2	At First Opportunity (next shutdown)
3	Prior to Operation of Affected System
4	At First Exposure of Component
5	At Scheduled Component Part Repair or Replacement
6	Next Scheduled Outage

BACKGROUND DISCUSSION

Static starters (LCI) are used in gas turbine power plants to start a gas turbine generator set by adjusting its speed. By operating the generator as a synchronous motor, it accelerates the turbine to a specific speed profile and helps in starting the gas turbine. LCI bridges comprising of SCRs and bus bars are water cooled and have a coolant circuit.

Leaks have been reported in water-cooled bus of some static starters after 10 or more years of service. All leaks have been observed at the ends of the tubing, near the right-angle fittings. This bus is used in both source and load bridges. A 6-pulse source or load bridge will have 6 water cooled bus pieces and the 12-pulse source or load bridge will have 12 water cooled bus pieces per bridge.

Figure 1: 6 pulse Load bridge water-cooled bus ends with SCR and Capacitor installed

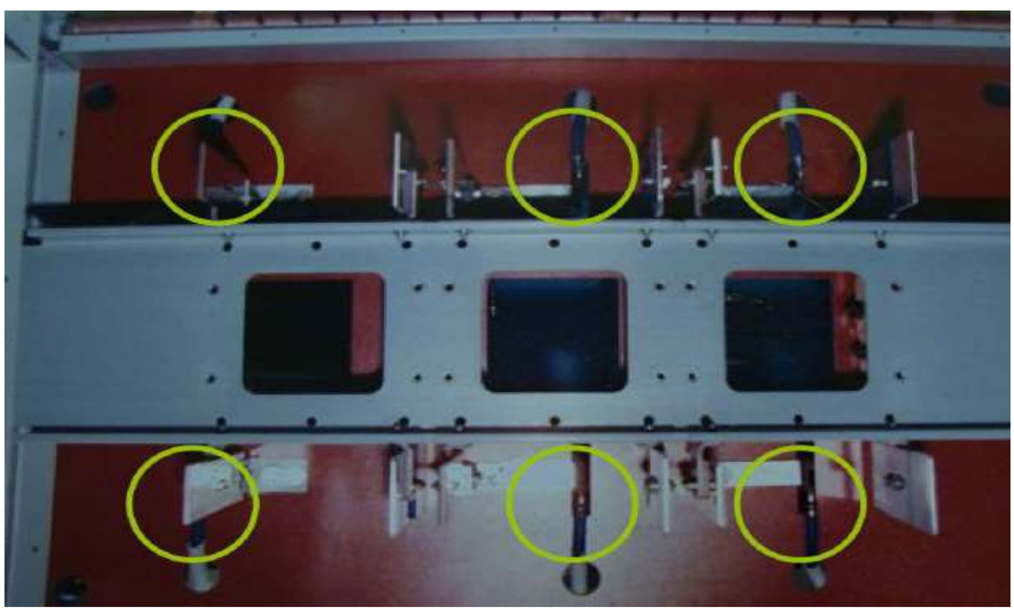


Figure 2: 6 pulse Load bridge water-cooled bus ends without SCR and Capacitor installed

Electrochemical and mechanical erosion is the primary mechanism for these failures, caused by high flow velocities in the water-cooled bus bars. Units using pure water rather than a water/glycol mix appear to be more susceptible to this erosion. Also, units that run at heavier loads and longer periods of time, such as industrial drives, have been observed to experience more erosion.

Figure 3: Cross section of eroded pipe removed from water cooled bus bar

Leaks in the water-cooled bus may result in loss of coolant and the exposure of an energized bus to this coolant may result in arc flashover event and equipment failure.

RECOMMENDATIONS

1. LCI in service (with coolant circulating) for less than 5 years or on which TIL 1755 has already been implemented (only bus bar replacement):
    - Replace six nylon tee connectors with stainless steel tee flow restrictors - GE # 151X1238WP01MG07 in the source bridge section.
    - Add six stainless steel straight flow restrictor - GE# 277A9696P7S in the load bridge section.

2. LCI in service (with coolant circulating) for more than 5 years:
    - Replace six nylon tee connectors with stainless steel tee flow restrictors - GE # 151X1238WP01MG07 in the source bridge section.
    - Add six stainless steel straight flow restrictor - GE# 277A9696P7S in the load bridge section.
    - Replace the water-cooled bus bars since, the water-cooled bus bars will have already experienced significant internal erosion due to excessive flow velocities. This should be done before the bus bars see eight years of flow duty.

Units which have already implemented TIL 1755-R1 and new LS2100e having stainless steel flow restrictors are not affected and this TIL is not applicable. Refer Appendix A for flow restrictor locations.

Following the recommendations of the TIL and routine inspection of the static starter bridge may prevent unscheduled outages and equipment failure due to coolant leak.

This TIL can be considered complete upon implementing the recommendations mentioned above. Please contact your local GE representative for assistance or additional information.

PLANNING INFORMATION

Compliance

- Compliance Category: **C**
- Timing Code: **6**

Manpower Skills

A GE Electrical TFA and craft technician. It is recommended that the TFA should have experience in implementing the TIL.

Parts List

For recommendation 1:

GE# 151X1238WP99BK01, which includes:

GE Part #	Description	Quantity
151X1238WP01MG07	Flow Restricted Splitter	6
277A9696P7S	Flow Restrictor, Long Orifice	6
305A6482P2	Hose crimper/pincer tool	1
305A6482P5	Hose clamp, 11/16-inch	120
278A2175PUP1	Blue hose, 5/8 OD, 3/8 ID	25 feet
342A4933CPP1	Temporary hose cut-off clamp tool	5

For recommendation 2, following additional parts are required.

Type of bridge	**GE Part #**	**Quantity**	**Description**
Typical 12 pulse source bridge	246B9953BAG1	2	WATER-COOLED BUS
	246B9953BAG2	2	WATER-COOLED BUS
	246B9953BAG3	8	WATER-COOLED BUS
Typical 6 pulse load bridge	246B9980ALG1	1	WATER-COOLED BUS
	246B9980ALG2	1	WATER-COOLED BUS
	246B9980AMG1	2	WATER-COOLED BUS
	246B9980AMG2	2	WATER-COOLED BUS
Common	305A6482P2	1	PINCER TOOL
	305A6482P5	150	BLUE HOSE CLAMP
	278A2175PUP1*	150 ft	BLUE HOSE
	305A4108P1¶	1	G-322L VERSILUBE SILICONE GREASE 8 OZ TUBES

GE Part Number	Description	Quantity*
N722JP21016B6	SCREW, TAPTITE, 1/4 X 1.00	8
N657P25036B6	BOLT, CARRIAGE, 3/8 X 2.25	16
N657P25024B6	BOLT, CARRIAGE, 3/8 X 1.50	16
N657P29024B6	BOLT, CARRIAGE, 1/2 X 1.50	16
N657P29020B6	BOLT, CARRIAGE, 1/2 X 1.25	4
N657P25016B6	BOLT, CARRIAGE, 3/8 x 1.00	4
N22P25020B6	SCREW, HEX HEAD CAP, 3/8-16 X 1.25	18
N51P23020B6	FHMS, 5/16-18 X 1.25	16
N657P25020B6	BOLT, CARRIAGE, 3/8 X 1.25	18
N657P29036B6	BOLT, CARRIAGE, 1/2- 13 x 2.25	12
N269P29B6	Nut & washer 1/2 – 13	12
N22HP25024B6	SCREW, HEX HEAD CAP, FULL THD, 3/8-16 X1.50	2
N26P21016B6	SCREW, SLOTTED HEX CAP, 1/4-20 X 1.00	2
N722JP23016B6	SCREW, TAPTITE, 5/16 X 1.00	16
N269P25B6	NUT, KEPS, 3/8-16	74
N269P21B6	1/4-20 KEPS NUT	2
N269P29B6	NUT, KEPS, 1/2-13	20
N269P23B6	NUT, KEPS, 5/16-18	16
N402AP43B6	3/8 REGULAR, STEEL, PLAIN WASHER	36
N402AP42B6	5/16 REGULAR, STEEL, PLAIN WASHER	32
N402AP41B6	1/4 REGULAR, STEEL, PLAIN WASHER	10
N402AP72B6	5/16 WIDE, STEEL, PLAIN WASHER	8

*Necessary amount of blue hose may vary, please assess the required length before ordering.

Special Tooling

- Chainfall for heavy lifting
- Standard ratchet set
- Flathead screwdriver
- Isopropyl alcohol
- Level indicator
- Torque wrenches (small enough to deliver 5-40 Nm force)
- Feeler gauge
- Snapon Stack Clamp Nut Wrench
- Heatsink Spreader Tool – 246B9953BPG1
- Wrench, Open End, 1 5/16" - PDMH1516WRENCHO
- Tubular Handle, 24" – PDM1024TUBHNDL
- Masking tape, marker pens, zip-lock bags and medium cardboard boxes.

Reference Documents

GEH-6373, GEH-6680, GEH-6799

Previous Modifications

Implementation of TIL 1755

Scope of Work

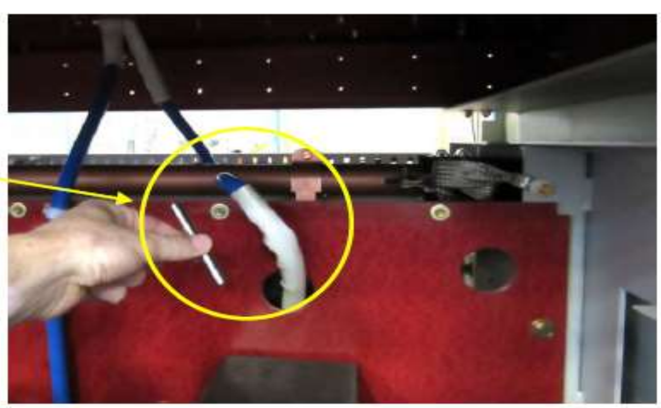
Recommendation 1: GE Electrical TFA and 1 x craft technician for 2 x 8 hours shift
Recommendation 2: GE Electrical TFA and 2 x craft technicians for 6 x 8 hours shift

Appendix A

1. Load bridge rear view and locations where flow restrictors need to be added.

Only two locations visible out of Six

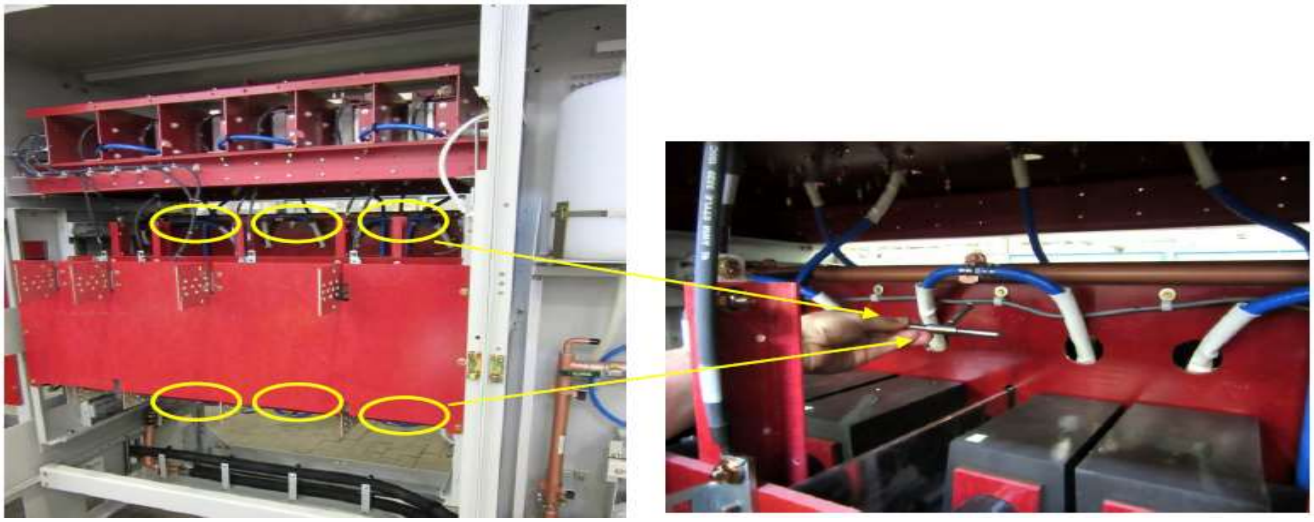
Stainless Steel Straight Flow restrictor GE # 277A9696P7S



2. Source bridge rear view and locations where flow restrictors need to be added.

All Six locations

Stainless Steel Tee Flow restrictor GE #151X1238WP01MG07



TIL DISPOSITION

Disposition of TILs should be entered in local records and also in GE Power ServiceNow. Follow the below instructions for entering the disposition record;

- Log into the Power ServiceNow at https://gepowerpac.service-now.com/til_new/ using your GE SSO number and password.
- Select "TIL Disposition".
- Click on the TIL for the serial number you want to update.
- Choose the most appropriate “Disposition Status” and enter “Disposition Notes”.
- Click "Save".

Contact your local GE service representative for assistance or for additional information.

GE Power
POWER SERVICES ENGINEERING
PRODUCT SERVICE

TIL 1755-R3
Publish Date: 05 MAY 2020
Compliance Category - C
Timing Code - 6

TECHNICAL INFORMATION LETTER

LCI WATER–COOLED BUS LEAKS

APPLICATION

- Innovation Series static starters (ISLCI)
- LS2100 products, except 8.5 MVA LS2100
- LS2100e products without stainless steel flow restrictors, except 8.5 MVA and 11MVA LS2100e

PURPOSE

Leakage of the water-cooled bus has been detected in some static starters which have been in service for 10 or more years. Such leakage may result in loss of coolant and inability to start the gas turbine. Leakage may further result in failure of the static starter with an arcing fault within the enclosure.

REASON FOR REVISION

Recommendation is revised to replace water-cooled bus based on ultrasonic testing (UT) results (condition-based instead of interval-based).

COMPLIANCE CATEGORY

M - Maintenance	Identifies maintenance guidelines or best practices for reliable equipment operation.
C - Compliance Required	Identifies the need for action to correct a condition that, if left uncorrected, may result in reduced equipment reliability or efficiency. Compliance may be required within a specific operating time.
A - Alert	Failure to comply with the TIL could result in equipment damage or facility damage. Compliance is mandated within a specific operating time.
S - Safety	Failure to comply with this TIL could result in personal injury. Compliance is mandated within a specific operating time.

TIMING CODE

1	Prior to Unit Startup / Prior to Continued Operation (forced outage condition)
2	At First Opportunity (next shutdown)
3	Prior to Operation of Affected System
4	At First Exposure of Component
5	At Scheduled Component Part Repair or Replacement.
6	Next Scheduled Outage

BACKGROUND DISCUSSION

Static starters (LCIs) are used in gas turbine power plants to start a gas turbine generator set by adjusting its speed. By operating the generator as a synchronous motor, it accelerates the turbine to a specific speed profile and helps in starting the gas turbine. LCI hardware bridges comprising of SCRs (silicon controlled rectifiers) and bus bars are water-cooled and have a coolant circuit.

Leaks have been reported in water-cooled bus bars of some static starters after 10 or more years of service due to erosion of the copper tubing. All reported leaks have been observed at the ends or elbows of the copper tube, near the right-angle fittings (refer to Figures 1, 2, 3, and 4). This bus bar is used in both source and load bridges. A source bridge typically has 12 water-cooled bars and load bridge typically have 6 water-cooled bus bars.

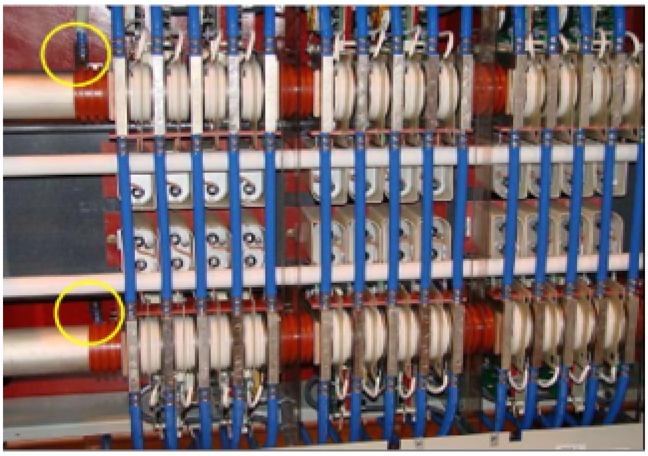


Figure 1: Load bridge water-cooled bus ends with SCRs and capacitor installed (2 out of 6 visible)

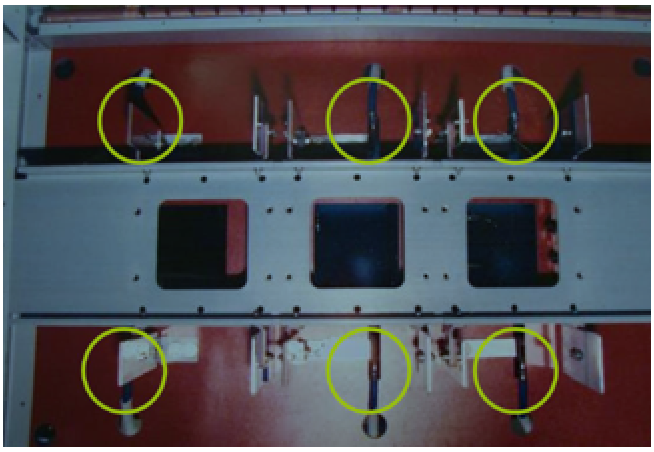


Figure 2 : Load bridge water-cooled bus ends (front side) without SCRs and capacitor installed

Figure 3: Water-cooled bus bar

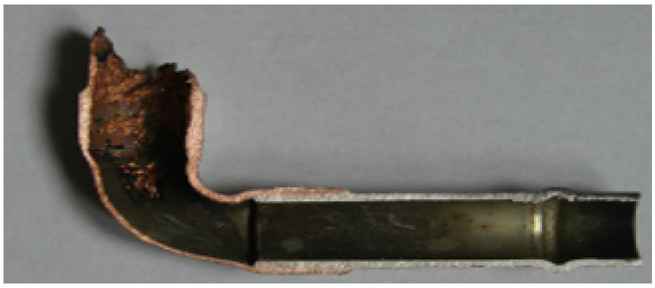


Figure 4: Cross section of eroded pipe removed from water-cooled bus bar

Electrochemical and mechanical erosion is the primary mechanism for these failures, caused by high flow velocities in the water-cooled bus bars. Units using demineralized water rather than a water-glycol mixture appear to be more susceptible to this erosion. Also, units that run at heavier loads and longer periods of time, such as industrial drives, have been observed to experience more erosion.

Recent LS2100e use stainless steel flow restrictors in the coolant circuit of source and load bridges. These flow restrictors reduce internal erosion of the water-cooled bus bars and aim at greatly extending their service life. Refer to Appendix A for flow restrictor pictures and installed locations.

Leaks in a water-cooled bus may result in loss of coolant and an unscheduled outage. An energized bus being exposed to this coolant may result in an arc flashover event and equipment failure.

RECOMMENDATIONS

TIL 1755 (superseded) recommended replacing the bus bar every 8 service years. Flow restrictor installation was not recommended.

TIL 1755-R1 (superseded) and TIL 1755-R2 (superseded) recommended installing flow restrictors. In addition, they recommended replacing the bus bar if it had been in service for more than 5 years.

The latest recommendations in this revision (TIL 1755-R3) have been updated to the following:

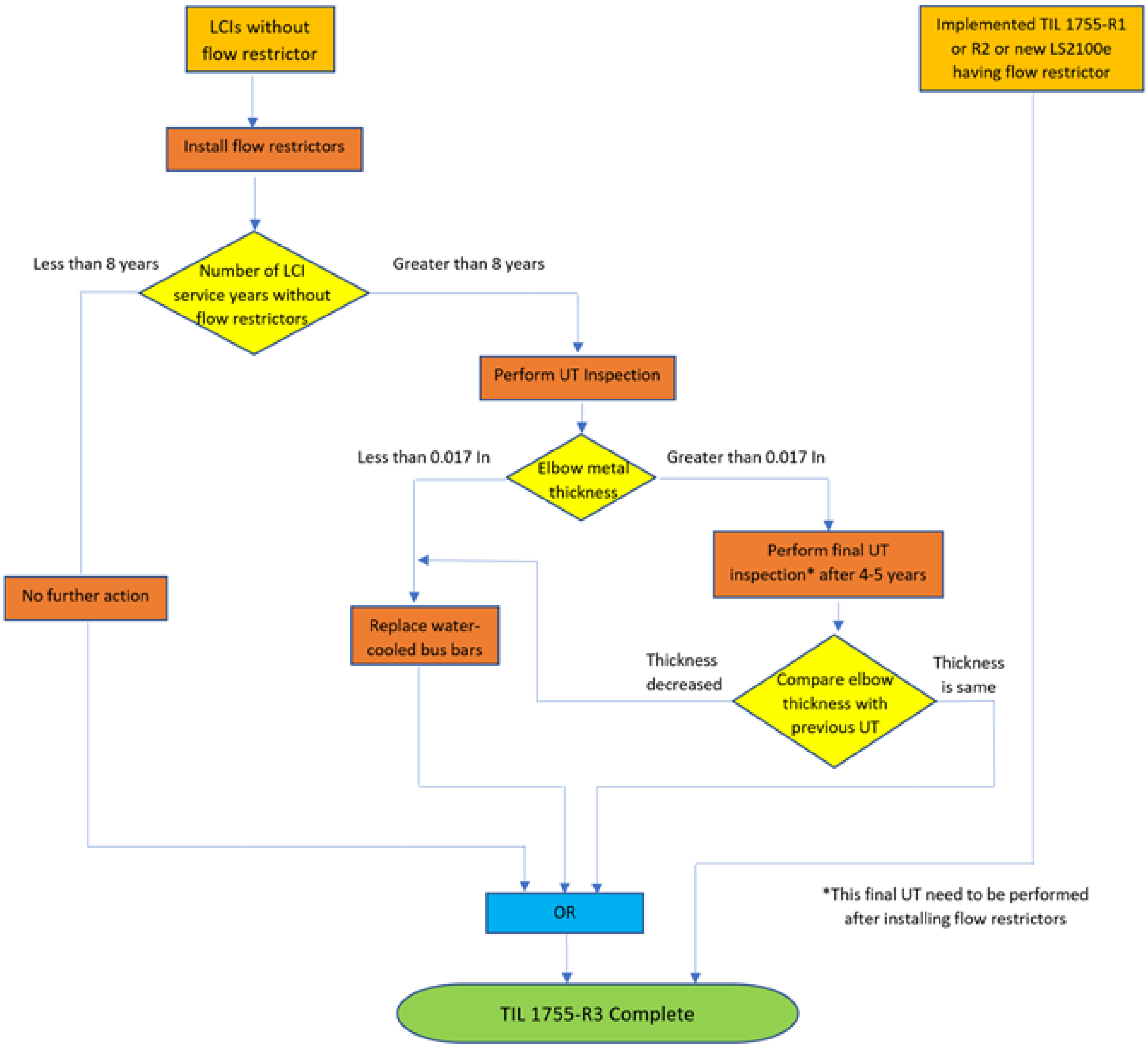


Figure 5: TIL 1755-R3 recommendation flow chart

1. Install flow restrictors on the LCI at the next scheduled outage. Reference Appendix A for location details to determine whether flow restrictors are already installed. If installed, recommendation 1 is complete. If not installed, then both below actions must be completed.

- Replace six nylon tee connectors with stainless steel flow restrictors in the source bridge.
- Add six stainless steel straight flow restrictors in the load bridge.

2. Assess, monitor, and/or replace LCI bus bars. To assess, determine the LCI service years operated without flow restrictors. For LCIs that have had the bus bar replaced, their service years are calculated from the installation date of the new bus bars.

a. For LCIs with <8 service years without flow restrictors, bus bar replacement is not required.
b. For LCIs with >8 service years without flow restrictors, perform an ultrasonic test (UT) on the accessible outer/rear side of the bus bar elbows through GE-LES services.
i. If elbow metal thicknesses are >0.017 inches, the bus bars are acceptable.

However, a final identical bus bar UT inspection should be added to your 4-5 year maintenance plan after implementing recommendation 1. If elbow metal thicknesses show any decrease, then the bus bars should be replaced after the final UT inspection. Please reach out to local GE representative if additional guidance is required.

ii. If elbow metal thicknesses are <0.017 inches, the bus bar needs to be replaced. Once replaced, no future UT inspections are required on that bus bar.

Note: To minimize future work, consider replacing all the bus bars in the source and load bridge if any have measured thicknesses <0.017 inches. If the water-cooled bus bars are replaced, perform all the commissioning tests as per applicable installation and startup manual before the static starter equipment is returned to service.

This TIL is considered complete when recommendations 1 and 2 are completed.

Following the recommendations of the TIL and routine inspection of the static starter or LCI bridge would prevent unscheduled outages and equipment failure due to coolant leak.

PLANNING INFORMATION

Compliance
- Compliance Category: **C**
- Timing Code: **6**

Manpower Skills
A GE Electrical Field Engineer and craft technician

UT inspection need to be performed through GE – LES services

Parts
1. Install flow restrictors:

GE Part # **151X1238WP99BK01**, which breaks down to below parts:

GE Part Number	Description	Quantity (Nos.)
151X1238WP01MG07	Flow Restricted splitter	6
277A9696P7S	Flow restrictor long orifice	6
305A6482P2	Hose crimper/Princer tool	1
305A6482P5	Hose clamp, 11/16-inch	100
278A2175PUP1	Blue hose, 5/8 OD, 3/8 ID	25 feet
342A4933CPP1	Temporary hose cut-off clamp tool	5

2. Replace Water-cooled bus bars :

Parts required for bus bar replacement are below:

Type of bridge	GE Part Number	Description	Quantity (Nos.)
Source bridge	246B9953BAG1	Water-cooled bus	2
	246B9953BAG2	Water-cooled bus	2
	246B9953BAG3	Water-cooled bus	8
Load bridge	246B9980ALG1	Water-cooled bus	1
	246B9980ALG2	Water-cooled bus	1
	246B9980AMG1	Water-cooled bus	2
	246B9980AMG2	Water-cooled bus	2

GE Part Number	Description	Quantity (Nos.)
305A6482P2	Hose crimper/Princer tool	1
305A6482P5	Hose Clamp, 11/16-inch	200
278A2175PUP1**	Blue Hose, 5/8 OD, 3/8 OD	150 feet
305A4108P1***	G-322L Versilube Silicone Grease 8 OZ tubes	1
342A4933CPP1	Temporary hose cut-off clamp tool	5
N722JP21016B6	SCREW, TAPTITE, 1/4 X 1.00	8
N657P25036B6	BOLT, CARRIAGE, 3/8 X 2.25	16
N657P25024B6	BOLT, CARRIAGE, 3/8 X 1.50	16
N657P29024B6	BOLT, CARRIAGE, 1/2 X 1.50	28
N657P29020B6	BOLT, CARRIAGE, 1/2 X 1.25	8
N657P25016B6	BOLT, CARRIAGE, 3/8 x 1.00	4
N22P25020B6	SCREW, HEX HEAD CAP, 3/8-16 X 1.25	18
N51P23020B6	FHMS, 5/16-18 X 1.25	16
N657P25020B6	BOLT, CARRIAGE, 3/8 X 1.25	18
N657P29036B6	BOLT, CARRIAGE, 1/2- 13 x 2.25	12
N269P29B6	NUT, KEPS, 1/2-13	44
N22HP25024B6	SCREW, HEX HEAD CAP, FULL THD, 3/8-16 X1.50	2
N26P21016B6	SCREW, SLOTTED HEX CAP, 1/4-20 X 1.00	2
N722JP23016B6	SCREW, TAPTITE, 5/16 X 1.00	16
N269P25B6	NUT, KEPS, 3/8-16	74
N269P21B6	1/4-20 KEPS NUT	2
N269P23B6	NUT, KEPS, 5/16-18	16
N402AP43B6	3/8 REGULAR, STEEL, PLAIN WASHER	36
N402AP42B6	5/16 REGULAR, STEEL, PLAIN WASHER	32
N402AP41B6	1/4 REGULAR, STEEL, PLAIN WASHER	10
N402AP72B6	5/16 WIDE, STEEL, PLAIN WASHER	8

**Necessary amount of blue hose may vary, please assess the required length before ordering.

*** Considering MSDS properties, part will not be shipped from GE Salem. User can procure it locally or can order over internet. Manufacture - Novagard Versilube, type G322L.

3. Perform UT inspection:

Below GE part will be replaced with new ones:

GE Part Number	Description	Quantity (Nos.)
N722JP21016B6	SCREW, TAPTITE, 1/4 X 1.00	8
N402AP41B6	1/4 REGULAR, STEEL, PLAIN WASHER	8

Special Tooling

- Chain fall or chain hoist for heavy lifting
- Standard ratchet and socket set
- Flathead screwdriver set
- Isopropyl alcohol
- Level indicator, Feeler gauge
- Torque wrenches (small enough to deliver 5-40 Nm force)
- Snap-on Stack Clamp Nut Wrench
- Heatsink Spreader Tool – 246B9953BPG1
- Wrench, Open End, 1 5/16” - PDMH1516WRENCHO
- Tubular Handle, 24” – PDMH1024TUBHNDL
- Clamp-on ammeter, Multimeter, Megger (1000 V)
- 2-channel oscilloscope (100 MHz minimum), Current probe (such as Tektronix ® model P6021)
- Masking tape, marker pens, zip-lock bags and medium cardboard boxes.

Reference Documents

GEH-6373: ISLCI User manual

GEH-6125: ISLCI Installation and startup manual

GEH-6680: LS2100 Static starter control Maintenance and Troubleshooting guide

GEH-6678: LS2100 Static starter control Installation and Startup guide

GEH-6799: LS2100e Static starter control Maintenance and Troubleshooting guide

GEH-6797: LS2100e Static starter control Installation and Startup guide

Scope of Work

Flow restrictor installation: GE Electrical Field Engineer and 1 craft technician for 2 shift

Water-cooled bus replacement: GE Electrical Field Engineer and 2 craft technicians for 8 shift

UT Inspection: GE-LES field engineer for 1 shift of 12 Hours

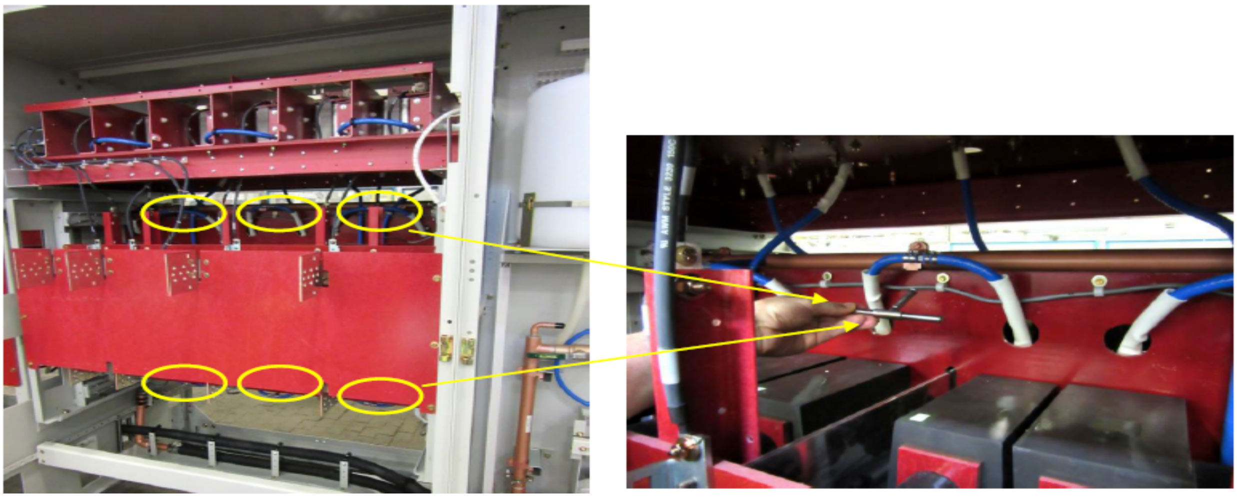
The above time estimation is only for TIL implementation. Preparation time for site activities (such as HV cable removal/connection, coolant flushing) are not included and should be accounted accordingly.

Appendix A

1. Source bridge rear view and locations of 6 stainless steel ‘Tee flow restrictors’

All Six locations

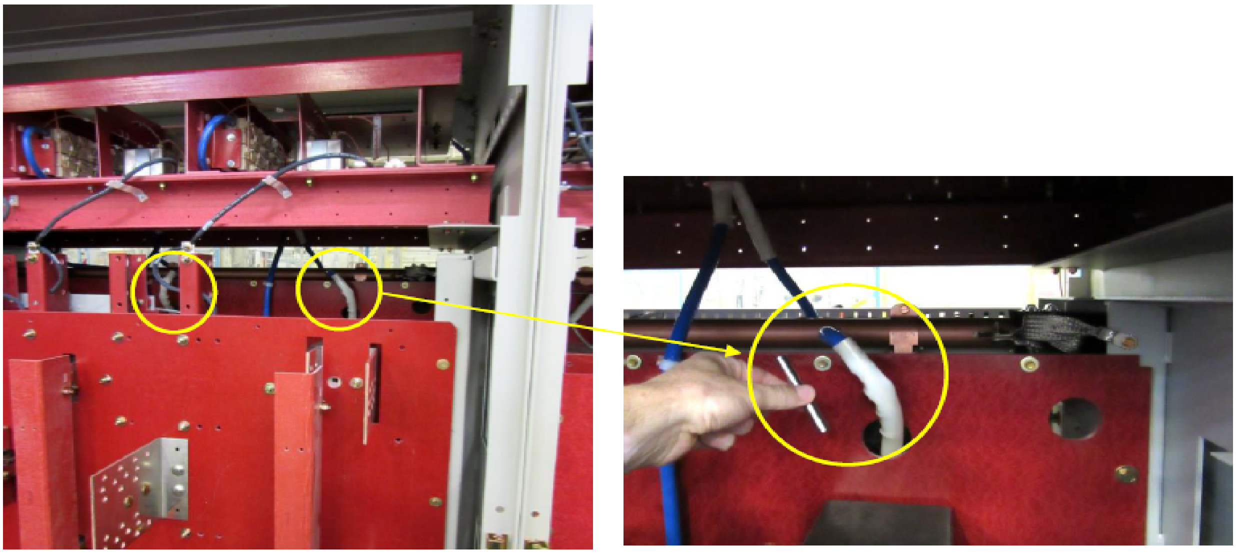
Stainless Steel Tee Flow restrictor GE #151X1238WP01MG07



2. Load bridge rear view and locations of 6 stainless steel ‘Straight flow restrictors’

Only two locations visible out of Six

Stainless Steel Straight Flow restrictor GE # 277A9696P7S



Date Printed: 05 MAY 2020

TIL DISPOSITION

Disposition of TILs should be entered in local records and also in GE Power ServiceNow. Follow the below instructions for entering the disposition record;

- Log into the Power ServiceNow at https://gepowerpac.service-now.com/til_new/ using your GE SSO number and password.
- Select "TIL Disposition".
- Click on the TIL for the serial number you want to update.
- Choose the most appropriate "Disposition Status" and enter "Disposition Notes".
- Click "Save".

Contact your local GE Services representative for assistance or for additional information

Gibbs Energy Pvt. Ltd.

Gibbs Energy Pvt. Ltd.®
PIONEERS IN ENERGY

Hydrogen Gas Plant, Refrigrated Type Hydrogen Dryer Air Dryer, Nitrogen plant, Chlorination Plant, Pressure Vessels, Heating Elements for all application etc.

UAN NO-DL08A0006623 PAN NO.: AAGCG6731M, GST NO.: 07AAGCG6731M1Z9

Work Report/ MOM

Basic work data:

Plant / Ship:	OTPC ONGC TRIPURA POWER COY. LTD.	Order / Job-No.:	WO 23-24Y-108 Dt. 15.09.2023
GEPL Visitor:	Subhash Singh Rawat	File No.:	OTPC/O&M/SERVICE/005
Service Carried out by	GIBBS ENERGY PVT LTD F-62/9, GROUND FLOOR, CHATTARPUR EXTENSION NEW DELHI 110074 INDIA	Phone No mail Id	9711608986 info@gibbsenergy.in

Hydrogen Plant Details:

H2 Plant Manufacturer, Detail- Capacity: 2x 5 Nm3/Hr.

	Type	Manifold Pressure Final	Cell Temperature Working	DC Current	DC Voltage	Cell Pressure
Eastern Electrolyser Ltd	Unipolar	145 Kg/cm2	55°C-60°C	2025 A	14.00 V	150MMWC

H2 Plant service by: (mark with ■)

☐	GEPL Service Station	■	GEPL Service Engineer	☐	Customer
☐	Third Party, Name of Third Party:				

Work in details:

General comment

E&C done by Eastern Electrolyser Ltd

Cell Sr. No.- 1411,1412,1413,1414,1415,1416,1417,1418,1419, 1420,1421,1422 & spare 1576

Sr. No. of Rectifier- 2012.A.00620/I/1/CKS & 2012.A.00620/I/2/CKS

Remarks

Problem raised by Customer

1. HGP inspection & problem rectification
2. Oxygen Impurity in both Stream

Observation During service

1. ***Lot of KOH Solution Deposit top of the Cell Skid. (Cell Top Cover)***
2. ***Found Leakage of KOH from Both Stream in Some Cells.***

Date: 10.10.2023 (Day 1st)

1. 9:30 A.M. Safety Induction. After that meet to HOD electrical & Operation
2. Reached Hydrogen Generation Plant and Check the Voltage of Both Stream A & B.

Skid A- 1600 Amp 13.5 volt DC

Cell No	Anode –Cathode VDC	Anode- Tank V	Cathode- Tank V	Temp °C
1	2.21	1.16	1.05	50
2	2.04	0.79	1.25	63
3	2.16	0.99	1.13	48
4	2.14	0.93	1.21	48

5	2.18	0.95	1.22	49
6	2.21	0.94	1.27	49

Skid B 1650 Amp 13.10 VDC

Cell No	Anode –Cathode	Anode- Tank	Cathode- Tank	Temp
1	2.04	0.83	1.21	45
2	2.16	0.81	1.35	55
3	2.22	0.78	1.43	51
4	2.05	1.05	1.00	57
5	2.16	0.77	1.35	48
6	2.13	1.01	1.11	45

Cell Voltage Discharging

Skid B 1500 Amp

Cell No	1	2	3	4	5	6
Purity	99.40	98.40	98.70	99.50	99.80	99.60

Skid A 1500 Amp

Cell No	1	2	3	4	5	6
Purity	99.60	99.00	99.80	99.90	99.30	99.80

Specific Gravity Checking

Specific Gravity checked of both Skid found as below

A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6
1220	1200	1265	1280	1240	1280	1260	1170	1150	1260	1200	1270
35⁰C	35⁰C	36⁰C	35⁰C	34⁰C	35⁰C	35⁰C	38⁰C	35⁰C	35⁰C	35⁰C	38⁰C

11:10 A. M. - Cell Bank B Discharging started and it was completed at 11:45 A.M.
12:00 Onwards dismantling started of Cell B2 & B3 (From Cell Bank B). Like Bus Bar, Feed Water Bowl, KOH Level Switch, Vent Tube for Oxygen & Hydrogen, RTD, Cooling water Line, DM water line.
5:30 P.M. KOH Mixing started

11.10.2023 (2nd Day)

9:30 KOH draining started from B2 (1418) & B3.(1411)
10:30 Cell B3 (1411) removed from Bank to outside for checking purpose.
11:30 KOH Complete drain out
12:00 Top cover open and washed out of Anode/Cathode/Grid Bag Assembly by DM Water.
12: 30 During the checking of Grid bag Assembly/Skirt/Anode/Cathode found some bolt loose between Grid Bag Assembly and Skirt. Tighten the same and change the Top Cover Gasket.
14:30 During the checking of cell B3 (1411) found under cut in welding (Due to doubt in under cut in welding DP test done for the same and found it is ok)
15:30 Check the KOH Solution Specific Gravity which is mixed for filling the Electrolyte Cell found as below
Drum 1 1320 Drum 2 1320 Drum 3 1320 Drum 4 1320 @ Ambient Temp
16:30 Open the Top Cover of Cell B2 (1418)
17:30 After complete cleaning/washed out of Anode/Cathode/Grid Bag Assembly by DM Water. During the checking of Grid bag Assembly/Skirt/Anode/Cathode found some bolt loose between Grid Bag Assembly and Skirt. Tighten the same and change the Top Cover Gasket.
18:30 Preparation of leak test for cell B2 &B3
20:00 Leak test Start and found no leakage in both cell (B2 &B3)
20:45 Left the HGP

KOH Solution Mixing

Gibbs Energy Pvt. Ltd.

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PIONEERS IN ENERGY

Hydrogen Gas Plant, Refrigrated Type Hydrogen Dryer Air Dryer, Nitrogen plant, Chlorination Plant, Pressure Vessels, Heating Elements for all application etc.

UAN NO-DL08A0006623 PAN NO.: AAGCG6731M, GST NO.: 07AAGCG6731M1Z9

Work Report/ MOM

12/10/2023 (3rd Day)

10:00 Cell Skid A Discharge
10:30 Work Started in Cell Skid A, Cooling water header removed, DM water Header Removed, Feed Water Bowl removed, KOH Level Switch removed, RTD removed, Inter Cell Bus Bar removed, Base Insulator removed. Parallel work is going on in Cell Skid B i.e. Fixed the Cooling water Header, DM water Header, KOH Collection Header, Inter Cell Bus Bar, Temperature Gauge removed in Cell Skid A.
14:30 KOH drain out in cell A2 (1412) & A5
15:30 Cell removed from Skid to outside for checking purpose.
16:00 Cell A2 (1412) Open from top cover and washed out for checking.
17:00 During the checking found a pin hole in skirt. Rectify the same (by welding) in workshop
19:00 Welding Complete at workshop and return to HGP
20:30 Start box up after that place same in position

13/10/2023 (4th Day)

10:00 Cell A5 (1414) removing start from Cell Bank A
10:30 Cell A5 dismantling started. In Cell Bank B KOH level switch, Feed water Bowl and other Accessories assembled/fixed.
11:00 Inter Cell Bus bar fixed.
11:30 Check the Cell A5 Some bolt found loose. After tightness box up start. Cell B RTD Connection made and check the value in SCADA.
12: 30 KOH Filling Start in Cell B2 (1418).
15:30 Leak Test Completed for A 5 (1414)
16:00 Place the position of Cell A5 and all accessories mounted.
17:00 KOH filling Start in B3 (1411), after that Top Up Completed in B1(1417), B4 (1420), B5 (1421) & B6 (1422).
Skid B Mist Eliminator of Hydrogen open and check the filter element found damage, Replaced with new filter element.
Skid B Oxygen Mist Eliminator open and check the filter element found in good condition.
19:00 Skid A, Oxygen Mist Eliminator open and check the filter element, found in good condition.
19:30 KOH Drain from A1 (1576), & A3 (1413) due to low specific Gravity observed during the Checking

14/10/2023 (5th Day)

10:00 KOH Level switches mounting complete. Feed Water Bowl Installed.
11:00 KOH Filling Started in A2 (1412)
12:00 KOH Filling Started in A5 (1414). After that KOH Top Up in Cell A1, A3, A4 & A6
12:45 Specific Gravity test in Skid B after completion of Top up & KOH Filling and found that 1260 in Cell A1.
14:15 Removed Feed Water bowl & Start draining of KOH from A1 Cell.
14:30 Made strong concentration for top up of Cell A1.
15:30 Start Skid B take in service for testing purpose @ 500 Amp. Check the visually observed everything is running smoothly.
16:15 Rectifier B is running 1000 Amp Voltage 12:13VDC
16:00 Cell A1 KOH Top Up and check the specific Gravity again now it is 1280
16:20 Rectifier A Start, continue running in 500 Amp. Voltage- 11:18VDC

Skid B 1000 Amp

Cell No	1	2	3	4	5	6
Purity	99.50	99.60	99.70	98.60	99.60	99.50

17:15 Rectifier A tripped due to KOH Level (Cell No A6) low while in field it is not low. Switch Malfunction

Cell Leak Testing

Cell Leak Test

Instrument Calibration

Pin Hole

DP Test

Skid A 500 Amp

Cell No	1	2	3	4	5	6
Purity	99.80	99.70	99.70	98.80	99.80	99.80

15.10.2023 (6th Day)

Stream A 1000 Amp

Cell No	1	2	3	4	5	6
Purity	99.90	99.80	99.99	99.99	99.90	99.99

Stream B 1000 Amp

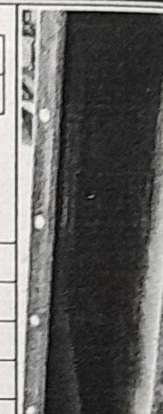
Cell No	1	2	3	4	5	6
Purity	99.50	99.60	99.70	99.60	99.60	99.50

Stream A 1500 Amp

Cell No	1	2	3	4	5	6
Purity	99.90	99.90	99.99	99.99	99.90	99.99

Stream B 1500 Amp

Cell No	1	2	3	4	5	6
Purity	99.60	99.70	99.90	99.70	99.90	99.60



Corrosion in Tank

Final output purity in ppm analyser- 99.99 %

Over all Purity check by manual Analyser of Stream A- 99.90 %

Overall Purity of Stream B Checked by manual Analyser- 99.80 %

Stream A O2 Header Temp- 35Deg C — H2 Header Temp- 35 Deg C

Stream B O2 Header Temp.- 35 Deg C — O2 Header Temp- 35 Deg C

Cell A Pressure- 170MMWC — Gas Holder Pressure- 150MMWC

Differential Pressure- 20 MMWC — Oxygen Pressure- 170MMWC

Cell b Pressure- 170MMWC — Gas Holder Pressure- 150MMWC

Differential Pressure- 20 MMWC — Oxygen Pressure- 170MMWC

Catalytic Purifier Inlet Temp- 30 Deg C — Outlet Temperature- 35 Deg C

Dryer Tower A pressure- 80 Kg/Cm2, — Dryer Tower B Pressure -0 Kg/Cm2.

Purification Skid Inlet Pressure- 80 Kg/Cm2

Tower A Temp- 29.4 Deg C, — Tower B Temp 29.9 Deg C

Rectifier B trip due to SCR Fuse Fail. Main control card need to be replace.

Compressor A Running

Inlet Pr.	Crankcase Pr.	Oil Pr.	1st Stage Pr.	2nd Stage pr.	3rd Stage Pr.	4th Stage Pr.	Delivery Pr.
100MMWC	00 Kg/cm2	4.5 Kg/Cm2	2.8 Kg/Cm2	14.5 Kg/Cm2	50 Kg/Cm2	135K	80 Kg/Cm2

Skid A- 1735 Amp 12.95 volt DC

Cell No	Anode –Cathode	Anode- Tank V	Cathode- Tank V	G Temp	RTD
1	2.18	1.33	0.85	38	40.3
2	2.07	0.83	1.23	39	41.92
3	2.12	1.08	1.04	35	42.84
4	2.13	0.89	1.23	42	42.43
5	2.12	0.88	1.24	41	42.53
6	2.23	0.90	1.32	40	40.42

Skid B 1612 Amp 12.96 VDC

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Hydrogen Gas Plant, Refrigrated Type Hydrogen Dryer Air Dryer, Nitrogen plant, Chlorination Plant, Pressure Vessels, Heating Elements for all application etc.

UAN NO-DL08A0006623 PAN NO.: AAGCG6731M, GST NO.: 07AAGCG6731M1Z9

Work Report/ MOM

Cell No	Anode –Cathode	Anode- Tank	Cathode- Tank	G- Temp	RTD
1	2.05	0.81	1.24	37	41.82
2	2.09	0.71	1.37	41	47.59
3	2.10	0.82	1.28	39	43.12
4	2.09	1.09	0.99	41	42.84
5	2.12.	0.68	1.44	39	42.33
6	2.10	1.04	1.05	38	41.52

Conductivity of DM Water 0.68μS

Dew Point -42 Deg C

Instrumentation general / safety devices / panel / pressure gauges *Calibration of Temperature Gauge/ Pressure Gauge/ Pressure Switch done by C & I Department of OMS.* *Compressor A Inlet Pressure Gauge replaced.*	These activity carried out during the service/overhauling
Piping /Cooler/Filters Mist Eliminator Filter replace for Cell Skid B. Tapping point for H2 Gas line for hydrogen sample line for percent oxygen sensor panel has been changed. Earlier it was taken from inlet of mist eliminator now taken outlet of mist eliminator(as per site KOH is carrying in that line and due to KOH Sensor damaged, to protect the sensor from KOH it has been taken after mist eliminate or (outlet)	These Activity carried out during the overhauling

Remarks by Customer:

Recommendations

Teflon Ferrule for Vent Tube to be procured.

1" BSP Threaded SS 304 Unions are recommended for All cells, as lot of union joint (presently used material investment casting and groove type) found leakage

As per my observation both Cell Banks need to be replace because self-life of electrolytic cell is approximately 10 Years. Some deterioration like corrosion and pin holes etc. started in Tanks. Plant is running more than10 years.

Check the chloride contents in Electrolyte (KOH Solution) it should be less than 500PPM. If it is >500PPM replace the electrolyte immediately

KOH Solution Specific Gravity must be checked once in a month in each cell. For easy checking of the specific gravity quick connector required which is not available in the specific gravity tester.

Gibbs Energy Private Limited

Santosh
16/10/2023

O &M SOLUTION Pvt. Ltd.

G. T. Rao
16/10/2023

Srinivasu
KADIYAM SRINIVASU
16/10/2023.

Narrendra Kumar Gupta

From:	JKS <jk_soni@hitachi-hirel.com>
Sent:	03 September 2024 09:54
To:	Narendra Kumar Gupta
Cc:	Prabhat Chandra; Subhajit Ganguly; Mitangshu Saha; Sourav Das; 'Bhavesh Panchal'; krishnendu_guchait@hitachi-hirel.com; csdu2spare_east@hitachi-hirel.com; jk_soni@hitachi-hirel.com
Subject:	RE: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir,

Good Morning,

Reference to your mail, please find our response as under,

1. We recommend the upgradation as the controller in the Card HRD 253/255 are obsoleted and we are not getting any support from the manufacturer.
2. We have two options to support the UPS till upgradation.
   a. Faulty cards have been despatched from your end. Once we receive the same, we will try to get it repaired. Once it is done we will send back these cards to you and will remain as a ready spare with you for the support.
   b. In case your returned cards are not repairable, we keep two set of cards ready with us and can be sent to you any time.

Hope this arrangement is acceptable to you.

Sorry for the delay in response from our side.

Assuring our best services all the time,

Regards,

JK Soni (he/him) | Vice President – Customer Support
Hitachi Hi-Rel Power Electronics Private Limited
B-14/1 & 171, GIDC Electronics Zone, Sector – 25, Gandhinagar 382 044| Gujarat - India
Phone: +91 79 6170 0500 | **Mobile:** +91 97250 10860

From: Narendra Kumar Gupta <nk.gupta@otpcindia.in>
Sent: 14 August 2024 11:44
To: jk_soni@hitachi-hirel.com
Cc: Prabhat Chandra <prabhat.chandra@otpcindia.in>; Subhajit Ganguly <subhajit.ganguly@otpcindia.in>; Mitangshu Saha <mitangshu.saha@otpcindia.in>; Sourav Das <sourav.das@otpcindia.in>; 'Bhavesh Panchal' <bhavesh_panchal@hitachi-hirel.com>; krishnendu_guchait@hitachi-hirel.com; csdu2spare_east@hitachi-hirel.com

Subject: FW: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.
Importance: High

"*** CAUTION : This email is originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe. ***"

Dear Sir,
With reference to subject line and had discussion with you, please accept our sincere gratitude for extending support during U-2 Both UPS failure.

As you aware that during trouble shooting of U-2 UPS-1 & 2, it was communicated by service engineers that both UPS needs Upgradation with latest version of cards. However it was not mentioned in any of service report done by service engineer under AMC.

We have asked quotation for spare cards and upgradation, however sales team didn't given offer for HRD 255 & HRD 253 Series 17, it is worthwhile to mention here that U-1 UPS have Series-7 cards and U-2 UPS have series -17 cards.

In the view of above we need following support ....

1. Written recommendation of UPS upgradation with proper reason like obsolescence, modification, no support of spare etc (please revisit the upgradation offer as discussed).
2. We need spare support for our both unit UPS i.e. 04 nos of 150KVA UPS installed at our site till upgradation done.

We need important cards as spare at site.

Your kind support required in this matter, kindly look into to provide spare support for U-1 & U-2 UPS till upgradation.

Early response will be highly solicited.

With best regards,

Narendra Kr Gupta | Head (Plant Electrical Maintenance) | ONGC Tripura Power Company Limited
Palatana, Gomati, Tripura -799105, India | Call: +91 381 236 3806 | +91 97742 33426
www.otpcindia.in

From: Buddhadev Bhakat [mailto:csdu2spare_east@hitachi-hirel.com]
Sent: 07 August 2024 17:24
To: Subhajit Ganguly <subhajit.ganguly@otpcindia.in>
Cc: Narendra Kumar Gupta <nk.gupta@otpcindia.in>; 'JK Soni' <jk_soni@hitachi-hirel.com>; 'Bhavesh Panchal' <bhavesh_panchal@hitachi-hirel.com>; 'Krishnendu Guchait' <krishnendu_guchait@hitachi-hirel.com>
Subject: RE: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir,

Please find the techno-commercial offers for spare and modification kit for the subject enquiry.
We are sorry as we can not quote for the below materials, as these Cards are obsolete:

1. HRD 255 (Display UI Card)
   Quantity: 02
2. HRD 253 Series 17
   Quantity: 01

(Note: Modification Offer is attached against the same)

This is for your needful and kind consideration.

Thanks & Regards
Buddhadev Bhakat
Assistant Manager – Customer Support

Hitachi Hi-Rel Power Electronics Private Limited.
902, Shaila Tower, J 1/16 EP Block, Salt Lake,
Sector – V, Kolkata – 700091, West Bengal
Phone : +91 33-4033 3920
Mob: +91 7069058868
Email : csdu2spare_east@hitachi-hirel.com
Website: www.hitachi-hirel.com

From: Subhajit Ganguly <subhajit.ganguly@otpcindia.in>
Sent: 06 August 2024 10:10
To: Alok Kr. Srivastava <alok_srivastava@hitachi-hirel.com>; Csdu2spare_East <csdu2spare_east@hitachi-hirel.com>
Cc: Narendra Kumar Gupta <nk.gupta@otpcindia.in>; 'JK Soni' <jk_soni@hitachi-hirel.com>; Bhavesh Panchal <bhavesh_panchal@hitachi-hirel.com>; Nimesh Patel <nimesh_patel@hitachi-hirel.com>; Krishnendu Guchait <krishnendu_guchait@hitachi-hirel.com>
Subject: RE: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir

Payment for the cards sent on loan basis is processed on the very day you shared the invoice with us.
Payment shall be disbursed shortly.
Request you to send offer for the items mentioned in trail mail.

Regards
Subhajit Ganguly

From: Alok Kr. Srivastava [mailto:alok_srivastava@hitachi-hirel.com]
Sent: 01 August 2024 11:05
To: Subhajit Ganguly; Csdu2spare_East
Cc: Narendra Kumar Gupta; 'JK Soni'; Bhavesh Panchal; Nimesh Patel; Krishnendu Guchait
Subject: Re: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir,

Please process for payment of attached offer which already been supplied during breakdown of Unit-2 UPS system on 26th & 27th Jul instant. Refer the attached report.

Offer for other spares & modification kit will furnish shortly by our concern team. Till then please bear with us.

Thanks,
With regards
Alok Kr. Srivastava
Dy. GM - Customer Support
Mobile : +917069058862 | Mail : alok_srivastava@hitachi-hirel.com |

Hitachi Hi-Rel Power Electronics Pvt. Limited
Website : www.hitachi-hirel.com

From: Subhajit Ganguly
Sent: Thursday, August 1, 2024 10:33 AM
To: Csdu2spare_East
Cc: 'bhavesh panchal' ; Narendra Kumar Gupta ; 'JK Soni' ; 'Nimesh_Patel' ; 'krishnendu guchait' ; Alok Kr Srivastava
Subject: RE: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

REMINDER-1

Dear Sir

Awaiting for the offer. Treat it as urgent.

Regards
Subhajit Ganguly

From: Subhajit Ganguly
Sent: 30 July 2024 16:49
To: 'Csdu2spare_East'
Cc: 'bhavesh panchal'; Narendra Kumar Gupta; 'JK Soni'; 'Nimesh_Patel'; 'krishnendu guchait'; Alok Kr Srivastava
Subject: RE: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir

Kindly share offer for other items too mentioned in enquiry mail.

Regards

Subhajit Ganguly

From: Csdu2spare_East [mailto:csdu2spare_east@hitachi-hirel.com]
Sent: 30 July 2024 15:55
To: Subhajit Ganguly
Cc: 'bhavesh panchal'; Narendra Kumar Gupta; 'JK Soni'; 'Nimesh_Patel'; 'krishnendu guchait'; Alok Kr Srivastava
Subject: RE: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir,

Please find the attached Spare Offer for supplied items on your emergency requirement. Please arrange to place the order at the earliest.
Offer for modification of your UPS system will be sent as soon as possible.

Thanks & Regards
Buddhadev Bhakat
Assistant Manager – Customer Support

Hitachi Hi-Rel Power Electronics Private Limited.
902, Shaila Tower, J 1/16 EP Block, Salt Lake,
Sector – V, Kolkata – 700091, West Bengal
Phone : +91 33-4033 3920
Mob: +91 7069058868
Email : csdu2spare_east@hitachi-hirel.com
Website: www.hitachi-hirel.com

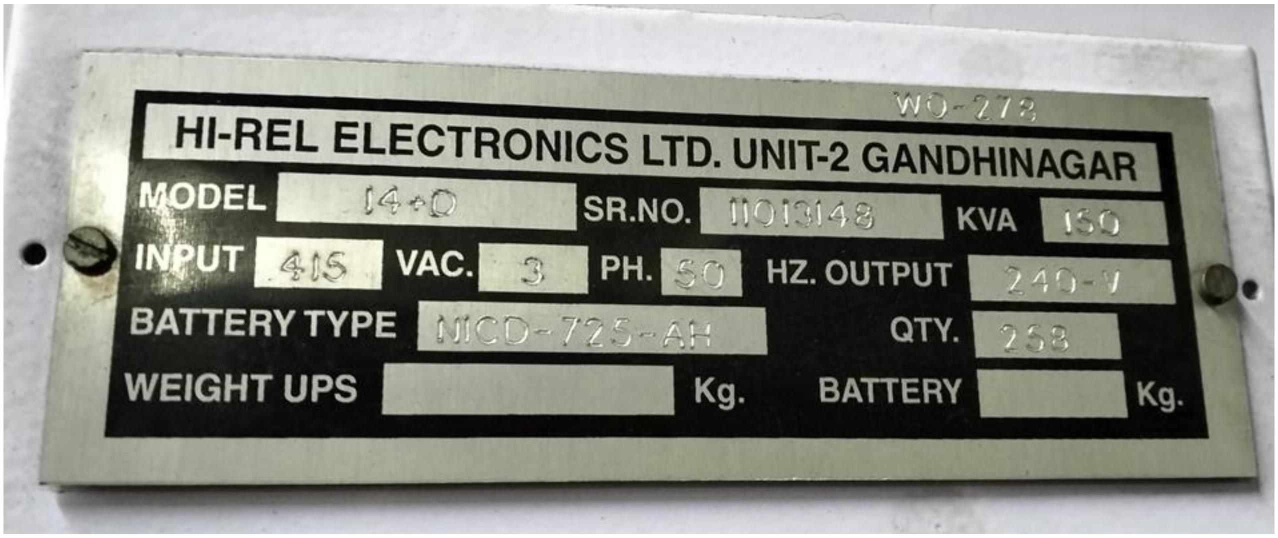
From: Subhajit Ganguly <subhajit.ganguly@otpcindia.in>
Sent: 30 July 2024 12:49
To: 'Nimesh Patel' <nimesh_patel@hitachi-hirel.com>
Cc: Narendra Kumar Gupta <nk.gupta@otpcindia.in>
Subject: Budgetary price offer for spares of 150KVA UPS at OTPC Plant of M/s Hitachi Hi-Rel make.

Dear Sir

Kindly send budgetary price offer for following spares of 150KVA UPS

1. HRD 238 (SMPS for Control Card)
   Quantity: 02
2. HRD 326 (Display Mimic Card)
   Quantity: 02
3. HRD 255 (Display UI Card)
   Quantity: 02
4. HRD 334 (Static Switch Card)
   Quantity: 02
5. HRD 253 Series 17 (Charger Control Card) ***INVERTER CONTROL CARD***
   Quantity: 01

UPS Details provided below:



With best regards,

Subhajit Ganguly
Assistant Manager-Electrical Maintenance | ONG
Palatana, Gomati Tripura, Pin-799105|Mobile:+

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and delays. Anyone communicating with OTPC (ONGC Tripura Power Company Ltd) by email accepts the risks involved and their consequences".

OTPC
ONGC-Tripura Power Company (P) Ltd.

ONGC TRIPURA POWER COMPANY LIMITED

Palatana, Tripura

RCA# 113
Station Transformer-2 LV breaker tripped on under voltage on 21.10.2021 resulting in Unit-1&2 trip

O&M By:

OMS

O&M Solutions Private Limited

						13/12/2021
00	30.10.2021	IFI	Issued for Implementation	G. Tejeswar Rao HOD Operation OMS	Mohinder Singh Patel Plant Manager OMS	Prabhat Chandra DGM(O&M) OTPC
REV	DATE	STATUS	REVISION LIST	PREPARED BY	REVIEWED & APPROVED BY	VERIFIED BY

~~IR/21-22/21.10.2021/113~~

RCA COMMITTEE MEMBERS/CONCERNED DEPARTMENTS

OTPC			OMS		
DEPTT.	NAME	SIGNATURE	DEPTT.	NAME	SIGNATURE
OPERATION	J. Chakraborty	13/12/2021	OPERATION	G. T. Rao	
MECHANICAL	Bhaskar Sen Choudhury	10.12.2021	MECHANICAL	R. Bhadra	
ELECTRICAL	Alokesh Hazarika	11/12/21	ELECTRICAL	Ashok Kumar	
C & I	MD MUSA	11/12/21	C & I	D. DEBBARMA	
TECH. CELL	J. Chakraborty	13/12/2021	TECH. CELL		

INCIDENT NO	IR/21-22/21-10-2021/113
DATE OF INCIDENT	21-10-2021

INCIDENT:
At **11:15 hrs,** station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection & station 6.6KV section-B (OCA) bus got dead, resulting in tripping of Unit-1&2.

TIME OF OCCURRENCE	**11:15 hrs**
TIME OF RESTORATION	**GTG-1 sync at 18:01 hrs, STG-1 sync 20:03 hrs and GTG-2 sync at 21:16 hrs, STG-2 sync at 03:20 hrs (22.10.2021)**
GENERATION LOSS	**6.7093 MU**
GT COASTING DOWN TIME	GT-1 36 min and GT-2 29 min.
ST COASTING DOWN TIME	STG-1 49 min and STG-2 53 min.

Status of Unit-1&2 before Incident :
Station Load -655 MW, Total Gas Flow-128000 SM3/hr
Unit-1 Load –GT-1- 210 MW, STG-1- 114, Total- 324 MW
Unit-2 Load –GT-2- 215 MW, STG-2- 116 MW, Total- 331 MW
GBC-2 & 3 were in service
400KV lines-1&2, ICT-1&2, 132 KV lines-1&2 were in service and station transformer-1&2 in service.

DESCRIPTION OF INCIDENT:
At **11:15 hrs,** station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection & station 6.6KV section-B (OCA) bus got dead, resulting in tripping of 415V PMCC section-B of GBC switchgear, station switchgear, admin bldg switchgear, raw water switchgear, river water intake switchgear etc.

GBC-3 tripped due to loss of power and GBC-2 tripped due to both lube oil pumps power supply failure resulting in low lube oil header pressure. Due to low fuel gas pressure, both GT-1 and GT-2 run back started. During runback, at **11:16 hrs,** GT-1 tripped on purge valve fault protection and GT-2 tripped due to loss of flame protection. And both STG tripped due to GT trip.

After the tripping of both GTG, Unit 6.6 KV bus-B got dead as station 6.6KV bus was not available and resulted in tripping of auxiliaries drives like CW pumps, HPBFPs, DMCW pumps and IAC-B etc., those are connected with BUS-B.

EDG-1 and EDG-2 start in auto and emergency lube oil pumps came in service, both STG and GTG turning gear came into service. Later after getting EMD clearance, station 6.6 KV BUS-B charged at 11:37 hrs with bus coupler and normalized all above said 415V switchgear section-B and unit 6.6 KV switchgear section-B one by one.

SEQUENCE OF INCIDENT: As tabulated & attached

RELAY/ALARM EVENTS:

Max DNA HMI:

11:15:45 hrs: station transformer#2 tripped.
11:15:47 hrs: GBC-3 tripped.
11:15:51 hrs: GBC-2 tripped.
11:16:24 hrs: GT-1 tripped
11:16:24 hrs: ST-1 tripped due to GT-1 trip.
11:16:28 hrs: GT-2 tripped.
11:16:28 hrs: ST-2 tripped due to GT-2 trip

IMMEDIATE ACTION TAKEN:

- Ensure the auto cut-in of DC lube oil pumps and DC jacking oil pump of both GTG and STG.
- Ensure auto start of EDG-1 and EDG-2 and charging of both units 415V GTPMCC and STGPMCC emergency section.
- Informed to NERLDC for DC revision.
- Monitor the coasting down rate of STG-1 and STG-2.
- Charged Station 6.6 KV section-B switchgear from bus-coupler.
- Charged all 415V section-B switchgear with incomer-2, as bus-coupler not came in auto.
- Charged 6.6 KV section-B unit switchgear and started cooling water pumps, CEPs and HPBFPs etc.
- Bring Hot well level, deaerator level and drum level in normal working level for start-up.

ROOT CAUSE ANALYSIS :

RCA OF INCIDENT: Why –Why Analysis

1. Why Unit-1 & 2 tripped?
- During run back, GT-1 tripped on purge valve fault during PM to PPM mode change over & GT-2 tripped on loss of flame due to no gas supply.
2. Why GT-1&2 run back happened?
- Station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection. Station Bus-B became dead. All the down stream PMCC section -2 became dead. Hence, GBC-3 which was in Station Bus-B tripped. Gas fuel pressure dropped immediately & on fuel gas pressure low protection, both GT-1&2 run back started.
- Within 6 secs, GBC-2 also tripped on lube oil header pressure low protection as running lube oil pump was from Gas fuel sec-B. Standby lube oil pump started in auto, but by that time GT-1 tripped on gas purge fault.
- Control supply of GBC PMCC was supplied from GT PMCC-1 Section-B. As there is no supply to GT PMCC Sec-B , fuel gas PMCC control supply also got out resulting in no control power supply to any of the GBC. Both STG-1&2 tripped as GTs tripped.

3. Why Station transformer#2 LV side breaker tripped?

- Station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection.

4. Why Under voltage acted in ST-2 Transformer breaker?

- ST-2 MW transducer was found faulty.
- Probable cause of failure of MW transducer are:

a) Although Work permit (LWC) on ECP for MW transducer checking was issued to EMD, it's out put is short circuit proof & output could not impact on entire transducer failure as it is in milliamps. Hence it is reasonably concluded that the LWC issued to check 4-20 mA output of MW transducer at ECP may not be the reason for the above disturbance.

b) Intermittent spike of power supply i.e 220V DC: Inbuilt surge protector with a range 2KV (peak) installed in the transducer. Since other breakers & instruments power feed through same 220V DC, the impact could have experienced. Hence this is ruled out.

c) Ageing of Transducer circuit: Since the transducer is manufactured in 2010: Internal circuit of ST-2 MW transducer was short circuited which grounded the R phase VT input in the transducer itself. This caused the blowing of R phase fuse. Hence the R-Phase voltage transformer input to relay was reduced to zero causing under voltage operation from relay.

- **In view of above, it is reasonably concluded that due to aging, the insulation of ST-2 MW transducer became weak resulting in internally developed fault & got short.**

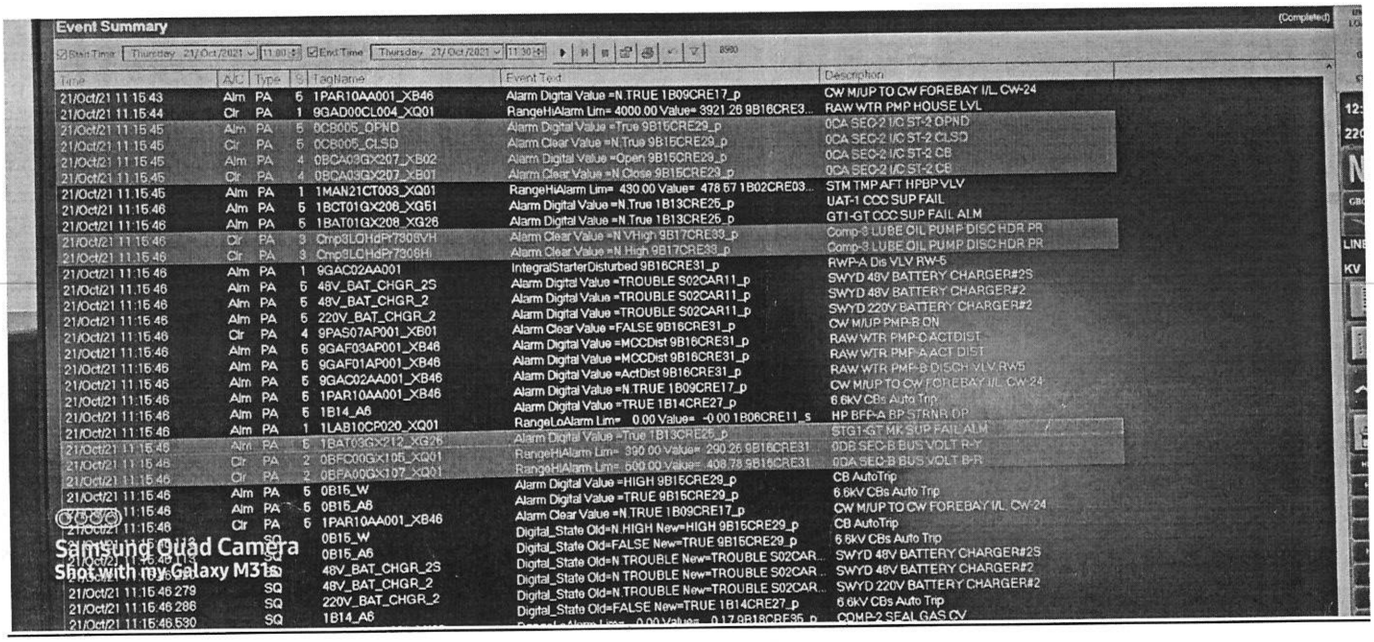
RCA RECOMMENDATIONS :

S.No	Recommendations	Responsibility	Target date
1	MW Transducer to be replaced.	OMS- EMD	Done immediately
2	Control supply of fuel PMCC to be changed over from GT-1 PMCC to Unit-2 UPS supply. As mentioned in RCA-104.	OMS-EMD	Done immediately
3	Fast bus transfer scheme to be implemented to 6.6KV station switchgears	OTPC- EMD	
4	Digital ~~Analog type~~ Transducer to be replaced with Digital type programmable Transducer in entire plant circuits.	OTPC- EMD	During Planned/opportunity shutdown
5	VT fuse fail blocking protection to be incorporated.	OTPC- EMD	May-2022

Reference to Incident & repetition if any	Nil

Annexure	DR of ST

MAX DNA SOE



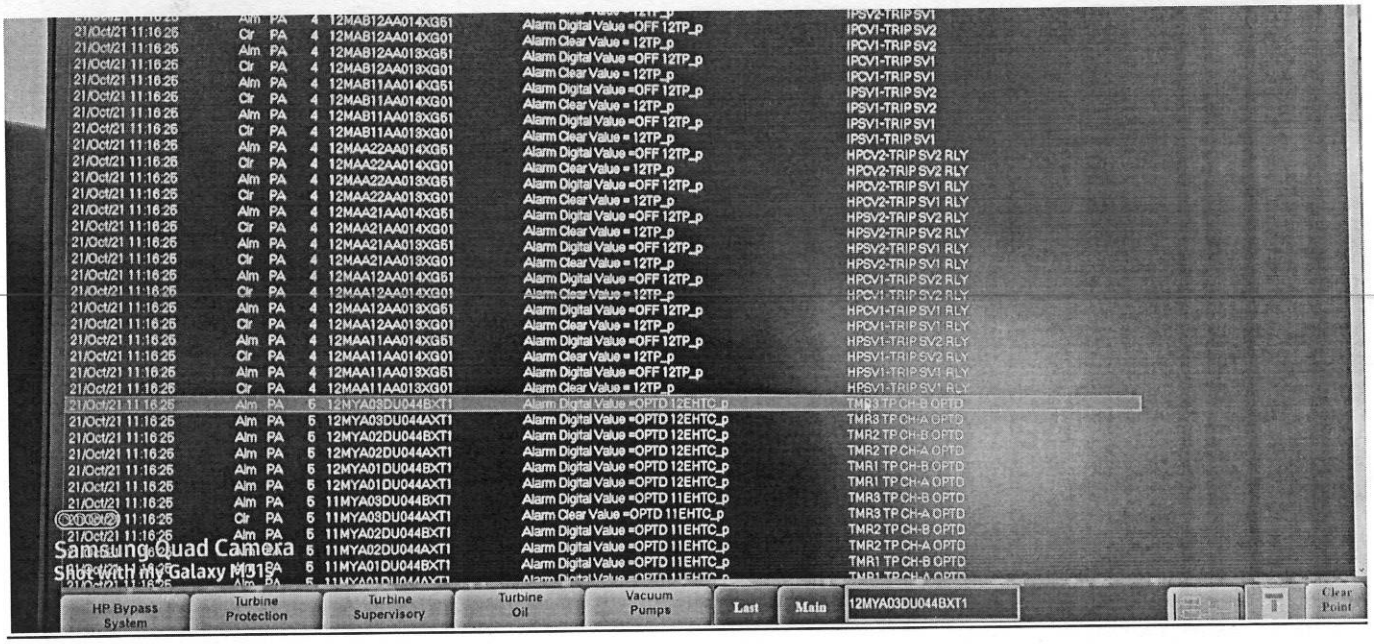
Event Summary (Completed)

Start Time Thursday 21/Oct/2021 11:00 End Time Thursday 21/Oct/2021 11:30 8980

Time	A/C	Type	S	TagName	Event Text	Description
21/Oct/21 11:15:43	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:44	Clr	PA	1	9GAD00CL004_XQ01	RangeHiAlarm Lim= 4000.00 Value= 3921.26 9B16CRE3...	RAW WTR PMP HOUSE LVL
21/Oct/21 11:15:45	Alm	PA	5	0CB005_OPND	Alarm Digital Value =True 9B15CRE29_p	0CA SEC-2 I/C ST-2 OPND
21/Oct/21 11:15:45	Clr	PA	5	0CB005_CLSD	Alarm Clear Value =N.True 9B15CRE29_p	0CA SEC-2 I/C ST-2 CLSD
21/Oct/21 11:15:45	Alm	PA	4	0BCA03GX207_XB02	Alarm Digital Value =Open 9B15CRE29_p	0CA SEC-2 I/C ST-2 CB
21/Oct/21 11:15:45	Clr	PA	4	0BCA03GX207_XB01	Alarm Clear Value =N.Close 9B15CRE29_p	0CA SEC-2 I/C ST-2 CB
21/Oct/21 11:15:45	Alm	PA	1	1MAN21CT003_XQ01	RangeHiAlarm Lim= 430.00 Value= 478.57 1B02CRE03...	STM TMP AFT HPBP VLV
21/Oct/21 11:15:46	Alm	PA	5	1BCT01GX206_XG51	Alarm Digital Value =N.True 1B13CRE25_p	UAT-1 CCC SUP FAIL
21/Oct/21 11:15:46	Alm	PA	5	1BAT01GX208_XG26	Alarm Digital Value =N.True 1B13CRE25_p	GT1-GT CCC SUP FAIL ALM
21/Oct/21 11:15:46	Clr	PA	3	Cmp3LOHdPr7306VH	Alarm Clear Value =N.VHigh 9B17CRE33_p	Comp-3 LUBE OIL PUMP DISC HDR PR
21/Oct/21 11:15:46	Clr	PA	3	Cmp3LOHdPr7306Hi	Alarm Clear Value =N.High 9B17CRE33_p	Comp-3 LUBE OIL PUMP DISC HDR PR
21/Oct/21 11:15:46	Alm	PA	1	9GAC02AA001	IntegralStarterDisturbed 9B16CRE31_p	RWP-A Dis VLV RW-5
21/Oct/21 11:15:46	Alm	PA	5	48V_BAT_CHGR_2S	Alarm Digital Value =TROUBLE S02CAR11_p	SWYD 48V BATTERY CHARGER#2S
21/Oct/21 11:15:46	Alm	PA	5	48V_BAT_CHGR_2	Alarm Digital Value =TROUBLE S02CAR11_p	SWYD 48V BATTERY CHARGER#2
21/Oct/21 11:15:46	Alm	PA	5	220V_BAT_CHGR_2	Alarm Digital Value =TROUBLE S02CAR11_p	SWYD 220V BATTERY CHARGER#2
21/Oct/21 11:15:46	Clr	PA	4	9PAS07AP001_XB01	Alarm Clear Value =FALSE 9B16CRE31_p	CW M/UP PMP-B ON
21/Oct/21 11:15:46	Alm	PA	5	9GAF03AP001_XB46	Alarm Digital Value =MCCDist 9B16CRE31_p	RAW WTR PMP-C ACTDIST
21/Oct/21 11:15:46	Alm	PA	5	9GAF01AP001_XB46	Alarm Digital Value =MCCDist 9B16CRE31_p	RAW WTR PMP-A ACT DIST
21/Oct/21 11:15:46	Alm	PA	5	9GAC02AA001_XB46	Alarm Digital Value =ActDist 9B16CRE31_p	RAW WTR PMP-B DISCH VLV RW5
21/Oct/21 11:15:46	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:46	Alm	PA	5	1B14_A6	Alarm Digital Value =TRUE 1B14CRE27_p	6.6kV CBs Auto Trip
21/Oct/21 11:15:46	Alm	PA	1	1LAB10CP020_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.00 1B06CRE11_s	HP BFP-A BP STRNR DP
21/Oct/21 11:15:46	Alm	PA	5	1BAT03GX212_XG26	Alarm Digital Value =True 1B13CRE25_p	STG1-GT MK SUP FAIL ALM
21/Oct/21 11:15:46	Clr	PA	2	0BFC00GX105_XQ01	RangeHiAlarm Lim= 390.00 Value= 290.26 9B16CRE31	0DB SEC-B BUS VOLT R-Y
21/Oct/21 11:15:46	Clr	PA	2	0BFA00GX107_XQ01	RangeHiAlarm Lim= 500.00 Value= 408.78 9B16CRE31	0DA SEC-B BUS VOLT B-R
21/Oct/21 11:15:46	Alm	PA	5	0B15_W	Alarm Digital Value =HIGH 9B15CRE29_p	CB AutoTrip
[illegible] 11:15:46	Alm	PA	5	0B15_A6	Alarm Digital Value =TRUE 9B15CRE29_p	6.6kV CBs Auto Trip
[illegible] 11:15:46	Clr	PA	5	1PAR10AA001_XB46	Alarm Clear Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
[illegible]		SQ		0B15_W	Digital_State Old=N.HIGH New=HIGH 9B15CRE29_p	CB AutoTrip
[illegible]		SQ		0B15_A6	Digital_State Old=FALSE New=TRUE 9B15CRE29_p	6.6kV CBs Auto Trip
[illegible]		SQ		48V_BAT_CHGR_2S	Digital_State Old=N.TROUBLE New=TROUBLE S02CAR...	SWYD 48V BATTERY CHARGER#2S
21/Oct/21 11:15:46.279		SQ		48V_BAT_CHGR_2	Digital_State Old=N.TROUBLE New=TROUBLE S02CAR...	SWYD 48V BATTERY CHARGER#2
21/Oct/21 11:15:46.286		SQ		220V_BAT_CHGR_2	Digital_State Old=N.TROUBLE New=TROUBLE S02CAR...	SWYD 220V BATTERY CHARGER#2
21/Oct/21 11:15:46.530		SQ		1B14_A6	Digital_State Old=FALSE New=TRUE 1B14CRE27_p	6.6kV CBs Auto Trip
					RangeLoAlarm Lim= 0.00 Value= 0.17 9B18CRE35_p	COMP-2 SEAL GAS CV

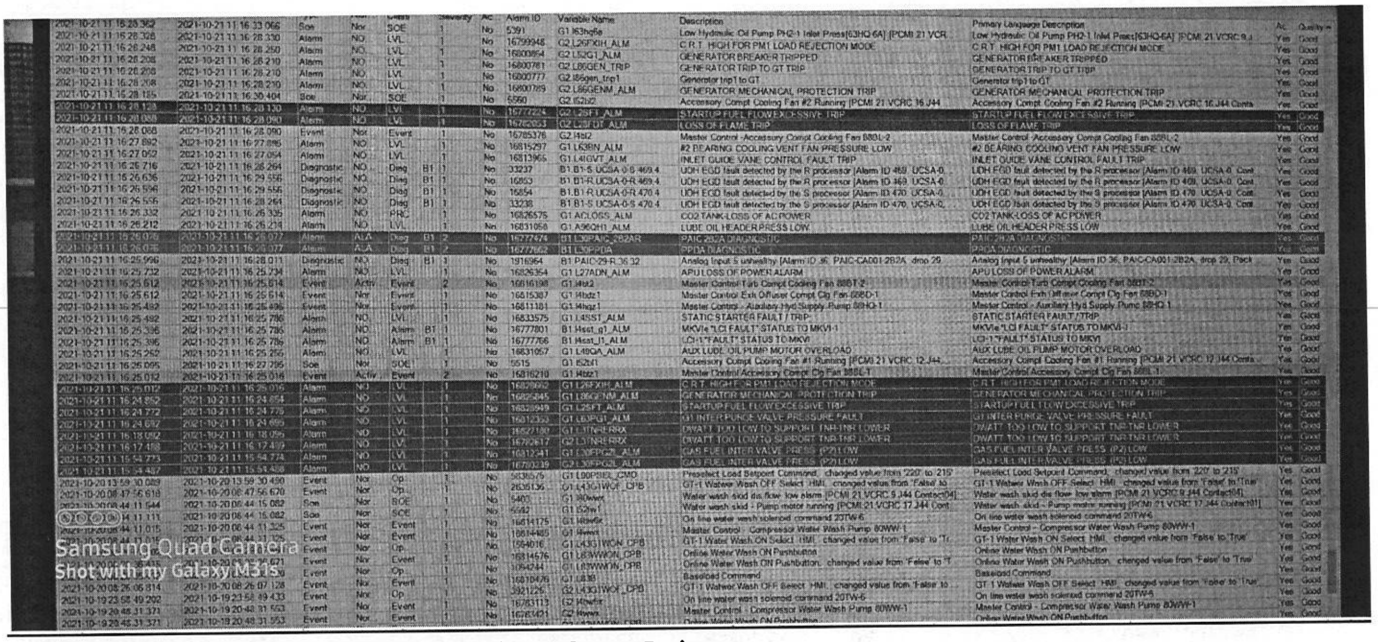
21/Oct/21 11:15:49	Clr	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= 195.94 9B17CRE33_p	CMP3 SUC FLTR DP2
21/Oct/21 11:15:49	Clr	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= 364.42 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:49	Alm	PA	2	0BFC00GX105_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.02 9B16CRE31_p	0DB SEC-B BUS VOLT R-Y
21/Oct/21 11:15:49	Alm	PA	2	0BFA03GX103_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.08 9B16CRE31_p	0DA I/C-0DAT02 CUR B PH
21/Oct/21 11:15:49	Alm	PA	1	2MMV42CP302_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B18CRE35_p	CMP2 LO DIFF PR PDT-7310
21/Oct/21 11:15:49	Alm	PA	5	1B14_A7	Alarm Digital Value =TRUE 1B14CRE27_p	415 V CBs Auto Trip
21/Oct/21 11:15:49.271		SQ		3QJN30AA_AUTO	Digital_State Old=AUTO New=MANUAL 9B17CRE33_p	GBC-3 ANTI SURGE VLV
21/Oct/21 11:15:49.853		SQ		3MMV21AP021_XB02	Digital_State Old=FdbkOff New=FALSE 9B17CRE33_p	GBC-3 LOP MAIN OFF
21/Oct/21 11:15:49.855		SQ		3MMV21AP021_XB01	Digital_State Old=FALSE New=FdbkOn 9B17CRE33_p	GBC-3 LOP MAIN ON
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOHdrPrVLo	Alarm Digital Value =High 9B17CRE33_p	Cmp-3 LO Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	2	0BFA00GX107_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.64 9B16CRE31_p	0DA SEC-B BUS VOLT B-R
21/Oct/21 11:15:50	Clr	PA	1	1LAB10CP020_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 1B06CRE11_s	HP BFP-A BP STRNR DP
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOPr7312CVLo	Alarm Digital Value =V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOPr7312BVLo	Alarm Digital Value =V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOPr7312AVLo	Alarm Digital Value =V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOHdrPrLow	Alarm Digital Value =High 9B17CRE33_p	Cmp-3 LO Hdr Pr Low
21/Oct/21 11:15:50	Clr	PA	5	3MMV21AP021_XB02	Alarm Clear Value =FALSE 9B17CRE33_p	GBC-3 LOP MAIN OFF
21/Oct/21 11:15:50	Alm	PA	5	3MMV21AP021_XB01	Alarm Digital Value =FdbkOn 9B17CRE33_p	GBC-3 LOP MAIN ON
21/Oct/21 11:15:50	Alm	PA	1	3MMV42CP310AXQ01	LowAlarm Limit = 1.00 Value = 0.92 9B17CRE33_p	CMP3 LO UPSTR PR PT-7312A
21/Oct/21 11:15:50	Alm	PA	2	0BFA03GX102_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.96 9B16CRE31_p	0DA I/C 0DAT02 CUR Y PH
21/Oct/21 11:15:50	Alm	PA	2	0BFA03GX101_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B16CRE31_p	0DA I/C-0DAT02 CUR R PH
21/Oct/21 11:15:50	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:50.311		SQ		Cmp3LOPr7312CVLo	Digital_State Old=N.VLow New=V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:51	Clr	PA	2	1LT4510	RangeLoAlarm Lim= 0.00 Value= 0.06 1B01CRE01_p	GT1 FSS FLT2 LVL1
21/Oct/21 11:15:51	Alm	PA	2	3QJN00CE001_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B17CRE33_p	COMP-3 MOTOR CURRENT
21/Oct/21 11:15:51	Alm	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= -38.46 9B17CRE33_p	CMP3 SUC FLTR DP2
21/Oct/21 11:15:51	Alm	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= -30.22 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:51	Clr	PA	3	Cmp2LOHdrPrLow	Alarm Clear Value =N.LOW 9B18CRE35_p	Cmp-2 LO Hdr Pr Low
21/Oct/21 11:15:51	Alm	PA	5	Cmp2LOPr7312CVLo	Alarm Digital Value =V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
[illegible]	Clr	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= 8.24 9B17CRE33_p	CMP3 SUC FLTR DP2
[illegible]	Clr	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= 111.25 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:51	Alm	PA	2	0BFA00GX105_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.11 9B16CRE31_p	0DA SEC-B BUS VOLT R-Y
21/Oct/21 11:15:51.681		SQ		Cmp2LOPr7312CVLo	Digital_State Old=N.VLow New=V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52	Clr	PA	5	3QJN30CP201B	[illegible]	[illegible]

21/Oct/21 11:15:51 Clr PA 3 Cmp2LOHdrPrLow Alarm Clear Value =N.LOW 9B18CRE35_p Cmp-2 LO Hdr Pr Low
21/Oct/21 11:15:51 Alm PA 5 Cmp2LOPr7312CVLo Alarm Digital Value =V.Low 9B18CRE35_p Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:51 Clr PA 5 3QJN30CP201B RangeLoAlarm Lim= 0.00 Value= 8.24 9B17CRE33_p CMP3 SUC FLTR DP2
21/Oct/21 11:15:51 Clr PA 5 3QJN30CP201A RangeLoAlarm Lim= 0.00 Value= 111.25 9B17CRE33_p CMP3 SUC FLTR DP
21/Oct/21 11:15:51 Alm PA 2 0BFA00GX105_XQ01 RangeLoAlarm Lim= 0.00 Value= -0.11 9B16CRE31_p 0DA SEC-B BUS VOLT R-Y
21/Oct/21 11:15:51.681 SQ Cmp2LOPr7312CVLo Digital_State Old=N.VLow New=V.Low 9B18CRE35_p Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52 Clr PA 5 3QJN30CP201B RangeLoAlarm Lim= 0.00 Value= 14.19 9B17CRE33_p CMP3 SUC FLTR DP2
21/Oct/21 11:15:52 Clr PA 5 3QJN30CP201A RangeLoAlarm Lim= 0.00 Value= 298.95 9B17CRE33_p CMP3 SUC FLTR DP
21/Oct/21 11:15:52 Alm PA 2 0BCB00GX103_XQ01 RangeLoAlarm Lim= 0.00 Value= 0.00 9B16CRE31_p 0CA BUS SEC-2 OLT B-R PH
21/Oct/21 11:15:52 Clr PA 5 2QJN00AN001_XB11 Alarm Clear Value = 9B18CRE35_p COMP-2 MOTOR
21/Oct/21 11:15:52 Alm PA 5 1LAB82AA001_XB46 Alarm Digital Value =ActDist 1B04CRE07_p LP FCS LO CAP CV-16 ISO, BFD-28
21/Oct/21 11:15:52 Alm PA 3 Cmp2LOHdrPrVLo Alarm Digital Value =V.LOW 9B18CRE35_p Cmp-2 LO Hdr Pr V.Low
21/Oct/21 11:15:52 Alm PA 5 Cmp2LOPr7312BVLo Alarm Digital Value =V.Low 9B18CRE35_p Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52 Alm PA 5 Cmp2LOPr7312AVLo Alarm Digital Value =V.Low 9B18CRE35_p Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52 Alm PA 3 Cmp2LOHdPr7308VL Alarm Digital Value =V.Low 9B18CRE35_p Comp-2 LUBE OIL PUMP DISC HDR PR
21/Oct/21 11:15:52 Clr PA 1 1MAN21CT003_XQ01 RangeHiAlarm Lim= 430.00 Value= 288.81 1B02CRE03 STM TMP AFT HPBP VLV
21/Oct/21 11:15:52.181 SQ Cmp2LOPr7312BVLo Digital_State Old=N.VLow New=V.Low 9B18CRE35_p Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52.181 SQ Cmp2LOPr7312AVLo Digital_State Old=N.VLow New=V.Low 9B18CRE35_p Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52.192 SQ Cmp2LOHdrPrVLo Digital_State Old=OK New=V.LOW 9B18CRE35_p Cmp-2 LO Hdr Pr V.Low
21/Oct/21 11:15:52.202 SQ 2QJN00AN001_XB92 Digital_State Old= 0.00 New=CmdStop 9B18CRE35_p COMP-2 MOTOR
21/Oct/21 11:15:52.285 SQ 2QJN00AN001_XB11 Digital_State Old=FdbkOn New= 0.00 9B18CRE35_p COMP-2 MOTOR
21/Oct/21 11:15:52.287 SQ 2QJN00AN001_XB12 Digital_State Old= 0.00 New=FdbkOff 9B18CRE35_p COMP-2 MOTOR
21/Oct/21 11:15:52.569 SQ 1MAL11AA011XB94 Digital_State Old= 0.00 New= 1.00 1ATRS1_p DRN BEF HP CTRL VLV-1
21/Oct/21 11:15:53 Clr PA 3 Cmp3LOPr7312CVLo Alarm Clear Value =N.VLow 9B17CRE33_p Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:53 Clr PA 3 Cmp3LOPr7312BVLo Alarm Clear Value =N.VLow 9B17CRE33_p Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:53 Clr PA 3 Cmp3LOPr7312AVLo Alarm Clear Value =N.VLow 9B17CRE33_p Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:53 Clr PA 1 3MMV42CP310AXQ01 LowAlarm Limit = 1.00 Value = 1.06 9B17CRE33_p CMP3 LO UPSTR PR PT-7312A
21/Oct/21 11:15:53 Alm PA 5 1PAR10AA001_XB46 Alarm Digital Value =N.TRUE 1B09CRE17_p CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:53 Clr PA 5 1LAB82AA001_XB46 Alarm Clear Value =FALSE 1B04CRE07_p LP FCS LO CAP CV-16 ISO. BFD-28
21/Oct/21 11:15:53 Alm PA 5 3QJN30CP201B RangeLoAlarm Lim= 0.00 Value= -41.20 9B17CRE33_p CMP3 SUC FLTR DP2
PA 5 2QJN00AN001Trip Alarm Digital Value =Tripped 9B18CRE35_p Comp-2 MOTOR
Clr PA 5 1PAR10AA001_XB46 Alarm Clear Value =N.TRUE 1B09CRE17_p CW M/UP TO CW FOREBAY I/L CW-24
SQ 2QJN30AA203_AO Digital_State Old= 0.00 New= 1.00 9B18CRE35_p
SQ 2QJN00AN001Trip Digital_State Old=N.TRUE New=Tripped 9B18CRE35_p Comp-2 MOTOR
21/Oct/21 11:15:53.201 SQ 2QJN00AN001_XB92 Digital_State Old=CmdStop New= 0.00 9B18CRE35_p COMP-2 MOTOR
Samsung Quad Camera
Shot with my Galaxy M31s

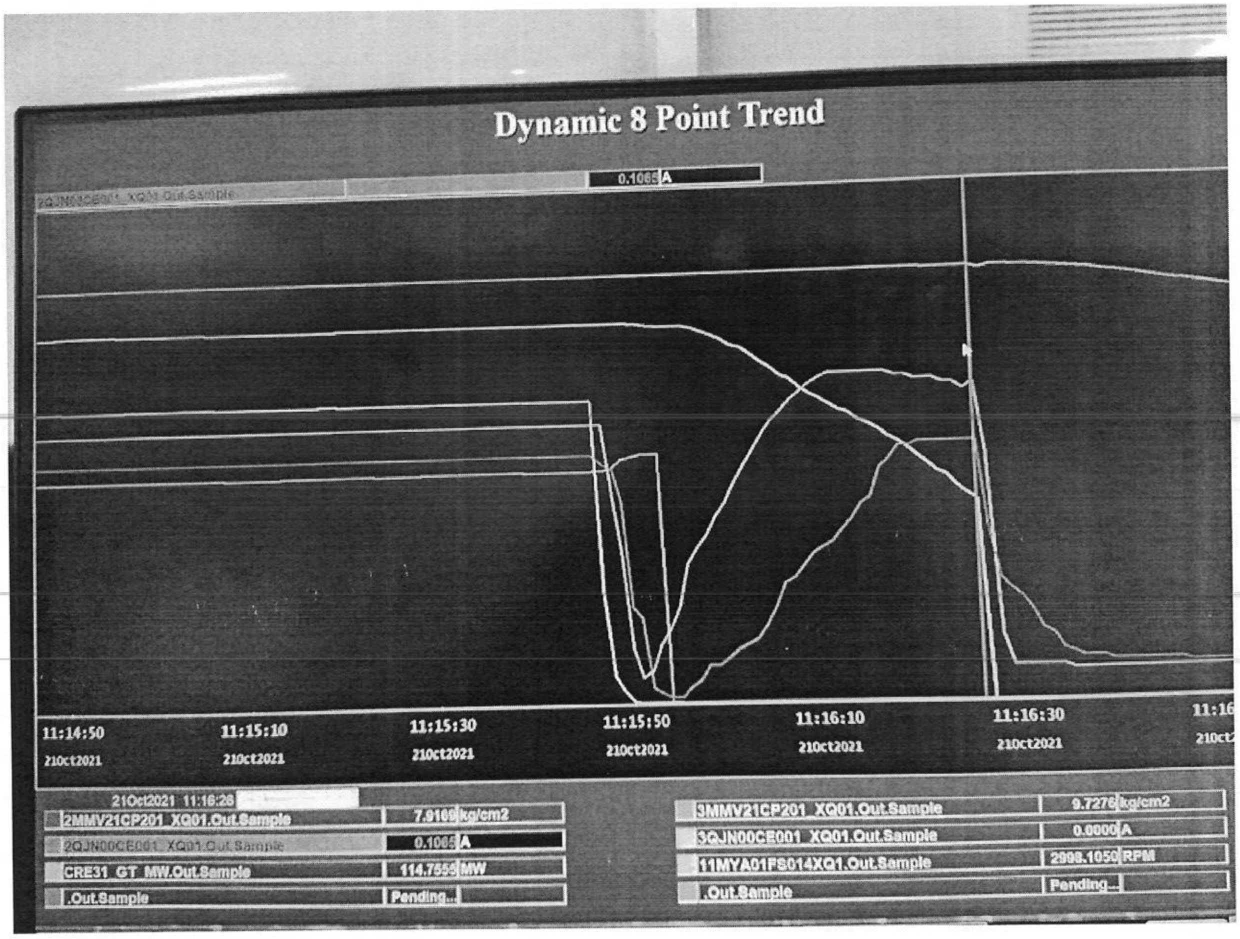


21/Oct/21 11:16:25 Clr PA 4 12MAB12AA014XG01 Alarm Digital Value =OFF 12TP_p IPCV1-TRIP SV2
21/Oct/21 11:16:25 Alm PA 4 12MAB12AA013XG51 Alarm Clear Value = 12TP_p IPCV1-TRIP SV2
21/Oct/21 11:16:25 Clr PA 4 12MAB12AA013XG01 Alarm Digital Value =OFF 12TP_p IPCV1-TRIP SV1
21/Oct/21 11:16:25 Alm PA 4 12MAB11AA014XG51 Alarm Clear Value = 12TP_p IPCV1-TRIP SV1
21/Oct/21 11:16:25 Clr PA 4 12MAB11AA014XG01 Alarm Digital Value =OFF 12TP_p IPSV1-TRIP SV2
21/Oct/21 11:16:25 Alm PA 4 12MAB11AA013XG51 Alarm Clear Value = 12TP_p IPSV1-TRIP SV2
21/Oct/21 11:16:25 Clr PA 4 12MAB11AA013XG01 Alarm Digital Value =OFF 12TP_p IPSV1-TRIP SV1
21/Oct/21 11:16:25 Alm PA 4 12MAA22AA014XG51 Alarm Clear Value = 12TP_p IPSV1-TRIP SV1
21/Oct/21 11:16:25 Clr PA 4 12MAA22AA014XG01 Alarm Digital Value =OFF 12TP_p HPCV2-TRIP SV2 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA22AA013XG51 Alarm Clear Value = 12TP_p HPCV2-TRIP SV2 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA22AA013XG01 Alarm Digital Value =OFF 12TP_p HPCV2-TRIP SV1 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA21AA014XG51 Alarm Clear Value = 12TP_p HPCV2-TRIP SV1 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA21AA014XG01 Alarm Digital Value =OFF 12TP_p HPSV2-TRIP SV2 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA21AA013XG51 Alarm Clear Value = 12TP_p HPSV2-TRIP SV2 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA21AA013XG01 Alarm Digital Value =OFF 12TP_p HPSV2-TRIP SV1 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA12AA014XG51 Alarm Clear Value = 12TP_p HPSV2-TRIP SV1 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA12AA014XG01 Alarm Digital Value =OFF 12TP_p HPCV1-TRIP SV2 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA12AA013XG51 Alarm Clear Value = 12TP_p HPCV1-TRIP SV2 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA12AA013XG01 Alarm Digital Value =OFF 12TP_p HPCV1-TRIP SV1 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA11AA014XG51 Alarm Clear Value = 12TP_p HPCV1-TRIP SV1 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA11AA014XG01 Alarm Digital Value =OFF 12TP_p HPSV1-TRIP SV2 RLY
21/Oct/21 11:16:25 Alm PA 4 12MAA11AA013XG51 Alarm Clear Value = 12TP_p HPSV1-TRIP SV2 RLY
21/Oct/21 11:16:25 Clr PA 4 12MAA11AA013XG01 Alarm Digital Value =OFF 12TP_p HPSV1-TRIP SV1 RLY
Alarm Clear Value = 12TP_p HPSV1-TRIP SV1 RLY
21/Oct/21 11:16:25 Alm PA 5 12MYA03DU044BXT1 Alarm Digital Value =OPTD 12EHTC_p TMR3 TP CH-B OPTD
21/Oct/21 11:16:25 Alm PA 5 12MYA03DU044AXT1 Alarm Digital Value =OPTD 12EHTC_p TMR3 TP CH-A OPTD
21/Oct/21 11:16:25 Alm PA 5 12MYA02DU044BXT1 Alarm Digital Value =OPTD 12EHTC_p TMR2 TP CH-B OPTD
21/Oct/21 11:16:25 Alm PA 5 12MYA02DU044AXT1 Alarm Digital Value =OPTD 12EHTC_p TMR2 TP CH-A OPTD
21/Oct/21 11:16:25 Alm PA 5 12MYA01DU044BXT1 Alarm Digital Value =OPTD 12EHTC_p TMR1 TP CH-B OPTD
21/Oct/21 11:16:25 Alm PA 5 12MYA01DU044AXT1 Alarm Digital Value =OPTD 12EHTC_p TMR1 TP CH-A OPTD
21/Oct/21 11:16:25 Alm PA 5 11MYA03DU044BXT1 Alarm Digital Value =OPTD 11EHTC_p TMR3 TP CH-B OPTD
11:16:25 Clr PA 5 11MYA03DU044AXT1 Alarm Clear Value =OPTD 11EHTC_p TMR3 TP CH-A OPTD
21/Oct/21 11:16:25 Alm PA 5 11MYA02DU044BXT1 Alarm Digital Value =OPTD 11EHTC_p TMR2 TP CH-B OPTD
5 11MYA02DU044AXT1 Alarm Digital Value =OPTD 11EHTC_p TMR2 TP CH-A OPTD
5 11MYA01DU044BXT1 Alarm Digital Value =OPTD 11EHTC_p TMR1 TP CH-B OPTD
HP Bypass System
Turbine Protection
Turbine Supervisory
Turbine Oil
Vacuum Pumps
Last
Main
12MYA03DU044BXT1
Clear Point
Samsung Quad Camera
Shot with my Galaxy M31s

MARK VIe SOE:



Trend showing GT-1 trip, GBC lube oil pr. shoot & drop


Dynamic 8 Point Trend
0.1065 A
11:14:50 21Oct2021
11:15:10 21Oct2021
11:15:30 21Oct2021
11:15:50 21Oct2021
11:16:10 21Oct2021
11:16:30 21Oct2021
21Oct2021 11:16:28
2MMV21CP201_XQ01.Out.Sample 7.9169 kg/cm2
2QJN00CE001_XQ01.Out.Sample 0.1065 A
CRE31_GT_MW.Out.Sample 114.7555 MW
.Out.Sample Pending...
3MMV21CP201_XQ01.Out.Sample 9.7276 kg/cm2
3QJN00CE001_XQ01.Out.Sample 0.0000 A
11MYA01FS014XQ1.Out.Sample 2998.1050 RPM
.Out.Sample Pending...

SL. NO.	SALIENT OBSERVATIONS	CORRECTIVE ACTIONS/ RECOMMENDATIONS
GENERAL		
01	During dismantling, LP-GEN axial and radial misalignment found.	Alignment corrections done during assembly. Ref. Protocol.
02	During dismantling, LP-GEN CRO found on higher side	Assembled with improved CRO.
STATOR		
01	Oil ingress found in generator stator chamber and coolers.	Cleaning of stator outer chamber done. Oil fume ingress from generator bearings are the probable cause. Bearing drain line vacuum found insufficient. Recommended for vacuum correction of drain lines.
02	All air sealings found intact except few small gaps and bulging.	After minor rectification, Joint inspection of Stator core outer air sealing done and cleared for cooler box-up.
03	All electrical test found satisfactory.	Refer Test Report
ROTOR		
01	All electrical test found satisfactory.	Refer Test Report
AIR COOLERS		
01	All Coolers were found in good condition. All the gasket of the coolers was changed with new one.	Cleaning done properly and hydro test passed successfully.
02	After removal of coolers, air sealing gaskets found damaged.	All cooler air sealing gaskets were replaced and cooler box-up done.
OIL CATCHERS		
01	The oil catchers' clearances were checked and found that the clearances were more than the nominal value in both bearing pedestal. Ref. Protocol.	As fins of all oil catchers cannot be replaced, it is recommended to replace the same to maintain clearance as per drawing. Presently Site is not having new oil catchers.
BEARINGS AND PEDESTALS		

			NAME	SIGNETURE	DOC.NO. QPE-TG-088
PROJECT	OTPC/STG	BHEL	AMIT KARMAKAR		REV.NO. R00
UNIT NO.	01	OTPC/EMD	MITANGSHU SAHA		LOG SHEET NO. L-
RATING	131 MW				SHEET 1/1 SHEETS

01	Bearing No-4, 5 found in good condition.	All dimension found ok. DP/UT test found ok.
02	Saddle insulation of Pedestal no-04 found in deteriorated condition.	It is recommended to replace the insulation sheet of the pedestal. As spare pedestal is not available at site box-up done with old pedestal with minor correction. Ref. Email Dated 10.07.2024 from BHEL Hyderabad.
MAIN EXCITER STATOR AND ROTOR		
01	Main exciter Stator and Rotor are free from any abnormalities like overheating, rubbing marks.	Properly heated and cleaned. During Assembly Air gap maintained as per drawing. Ref. Protocol.
02	All electrical test found satisfactory.	Refer Test Report
PMG		
01	The PMG was found in healthy condition. No rubbing marks, overheating marks found.	Properly heated and cleaned. Air gap maintained as per drawing. Ref. Protocol.
02	All electrical test found satisfactory.	Refer Test Report
DIODE WHEEL		
01	Diode wheel found healthy.	Properly heated and cleaned. Air gap maintained as per drawing.
02	All electrical test found satisfactory.	Refer Test Report

			NAME	SIGNETURE	DOC.NO. QPE-TG-088
PROJECT	OTPC/STG	BHEL	AMIT KARMAKAR		REV.NO. R00
UNIT NO.	01	OTPC/EMD	MITANGSHU SAHA		LOG SHEET NO. L-
RATING	131 MW				SHEET 1/1 SHEETS

Dinesh Laha

From: Amit Karmakar(Engineer/C&ISASKOL/PS-ER) <amit83@bhel.in>
Sent: 10 July 2024 11:44
To: Mitangshu Saha
Cc: Narendra Kumar Gupta; Shakeel Ahmed(Sr Manager/GENSSASKOL/PS-ER)
Subject: Insulation sheet of Brearing Pledestal no-04 found damaged at STG U#1 OTPC Palatana, Tripura.
Attachments: IMG-20240706-WA0011.jpg

Dear Sir,
Please refer to the subject matter as informed you earlier, please go through the trailing mail from BHEL Hyderabad regarding damaged insulation of pedestal #4 bottom. It is recommended to replace the pedestal.
As discussed with you that spare pedestal is not available at site , we are proceeding for box-up with old pedestal only.

Regards,
Amit Karmakar
BHEL-PSER
SAS/KOL

From: DALINAIDU <dalinaidu@bhel.in>
To: 'Amit <amit83@bhel.in>
Cc: 'Krushna <kcpanda@bhel.in>; 'Shakeel <shakeel@bhel.in>; 'Mohammad <asim@bhel.in>
Date: Tuesday, 9 July 2024 2:34 PM IST
Subject: RE: Insulation sheet of Brearing Pledestal no-04 found damaged at STG U#1 OTPC Palatana, Tripura.

Dear Amit,

With reference to the trailing mail and discussions with you over phone, it is understood that insulation sheet between bearing pedestal and bearing shell on Turbine Side is damaged and Exciter Side found healthy.

Hence, it is recommended to replace the insulation sheet on Turbine Side.

सादर/Regards,

पी दाली नायुडू P Dali Naidu

वरि. प्रबंधक, ईएम अभियांत्रिकी/Sr. Manager, EM Engineering,

बीएचईएल आरसी पुरम/BHEL RC puram

फोन/Ph: +914023182997

मोबाइल/Mobile: 9490473788

From: Amit Karmakar(Engineer/C&ISASKOL/PS-ER) <amit83@bhel.in>
Sent: Sunday, July 07, 2024 5:14 PM
To: Dalinaidu Pagoti(Sr Manager/Design/EM/425_EMENGG/HPEP) <dalinaidu@bhel.in>
Cc: Krushna Chandra Panda(Sr Dy GM/HRTRNSFR1013/HPEP) <kcpanda@bhel.in>; Shakeel Ahmed(Sr Manager/GENSSASKOL/PS-ER) <shakeel@bhel.in>
Subject: Insulation sheet of Brearing Pledestal no-04 found damaged at STG U#1 OTPC Palatana, Tripura.
Importance: High

Dear Sir,

STG U#1, OTPC ,Palatana is under shutdown for intermediate and medium inspection. After dismantling of Bearing -4 bottom half , pedestal saddle insulation found damaged. Photo attached for reference.

Kindly suggest corrective action and usability of the Bearing pedestal No-4.

Matter is most urgent.

Follow us on :

चेतावनी: यद्यपि कंपनी ने यह सुनिश्चित करने के लिए कि इस ई-मेल में कोई वायरस मौजूद नहीं हो, काफी सावधानी बरती है, फिर भी प्राप्तकर्ता यह जाँच कर लें कि इस ई-मेल और इसके अटैचमेंट्स में वायरस न हों। इस ई-मेल द्वारा संक्रामित किसी वायरस के कारण होने वाली किसी क्षति के लिए ई-मेल का प्रेषक या बीएचईएल जिम्मेदार नहीं हैं।

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Annexure 2b

GT 2 Hot Gas Path Inspection Aug 2019

Hot Gas Path inspection

ONGC TRIPURA POWER COMPANY LIMITED
Equipment Serial #: 298872
Job Start Date: 08/18/2018
Approved Date: 09/18/2019
Oracle Project ID: A-1414834 | FSP-233260 | C-10313916

Prepared By

Sinoj Nair/Karthikeyan.P
Field Engineer

Approved By

Parag Lamba
Outage Manager

3.34 CRANE SHARING WITH ST MINOR

Part Condition: Fair

Part Condition Description

Crane was shared with ST minor work during this outage.

Recommendation

Crane sharing needs to be captured in the schedule.There was delay in critical path activities of 15 hours which is excludes disassembly and lunch break time use.
Since most of the lifting in GT are smaller weights ,It is recommended to have additional 25 ton crane in the same railing towards GT2 side subject the design and structural limitations to avoid outage delay.

3.35 QUALITY

Part Condition: Good

Part Condition Description

Strict Quality control plan was implemented right through the outage to maintain Quality standards. Site specific FME plan was implemented during this outage.

Annexure 2a

MINUTES OF MEETING HELD BETWEEN M/S OTPC, M/S SESI AND M/S BHEL

Date: 30/08/2019
Place: PALATANA

Members Present:

M/S OTPC	M/S BHEL	M/S SESI
1) Mr Bibek Roy	1) Mr Goutham Reddy	1) Mr T P Pandey
2) Mr Bhaskar Sen Choudhury	2) Mr Prasahant K Singh	2) Mr OP Sharma
3) Mr Biswajit Sarkar	3) Mr Lakavath Shekar	3) Mr Siddhartha Nath
		4) Mr Ramashish Bhadra
		5) Mr DB Panchal

- Mr Goutham Reddy from M/S BHEL Hyderabad has travelled to OTPC Tripura on 20/08/2019 and attended site from 21/08/2019 for supervision of minor inspection of 130.91 MW Block 2 Steam Turbine (Model: K 30-16 + N30-2X5.0; Machine no: T-0846) as per Work order OTPC/WO/PLT/ 19-20/BHELHYD/002, dated 19/08/2019.
- The running hours of Block 2 Steam Turbine is 30789 hours.
- Steam Turbine 2 shutdown was taken on 16/08/2019 @ 00:00 hours.
- Activities scheduled for 1st minor inspection of Steam Turbine as per OEM (BHEL Hyderabad) is attached as Annexure I.
- After joint discussion amongst BHEL service engineer, OTPC and STEAG it was understood that it would take at least 15 days to complete all the said activities. The said 15 days start after stopping of barring gear, i.e. when HP shaft temperature drops to below 80 °C. This would altogether require a shutdown of Steam Turbine for 22 days.
- OTPC had an approved shutdown of 15 days only in total for Block 2 on account of Hot Gas Path Inspection (HGPI) of Block 2 Gas Turbine. Accordingly, OTPC has communicated to OEM, BHEL Hyderabad regarding time constraint for the said inspection and sought for the list of activities that could be carried out during the said period. BHEL had responded to our requirement. The relevant communication and response from BHEL is attached as Annexure II.
- Barring gear of Steam Turbine 2 was stopped on 23/08/2019 @ 08:55 hours. HP shaft temperature was 92 °C after getting clearance from OEM, BHEL.
- Minor inspection was started from 23/08/2019. Tick marked activities in Annexure-I along with bearing inspection completed on 30/08/2019.
- Next inspection is due for medium inspection and will cover remaining points of minor inspection.
- Only single EOT crane is available in entire Turbine Hall which is continuously engaged for HGPI job. In view of this combined time and resource crisis, we could not inspect the lower half of BrG#2 of Steam Turbine 2. However, complete inspection followed by Dye penetrant test has been carried out for Brg#1 and Brg#3, both top and bottom half and Brg#2 top half. DP test and thickness test has been done for all the active and inactive thrust pads.
- Run-out check has been carried out.
- Total rotor float was checked and found 0.48 mm, which has been adjusted to 0.28 mm using shims, as per advice of OEM, BHEL.

(O.P. Sharma) 30/8/19 30/8/19 30/08/2019 30.08.2019 B Sarkar 30/08 (T. Pandey)

- Jacking oil circuit has been inspected. Air has been blown through the oil ports in the bearings.
- Jacking oil hose (long size) of Brg#2 was found punctured and the same has been replaced.
- Leakage test has been carried out for atmospheric relief diaphragms in LP turbine and found satisfactory.
- HP/IP turbine casing insulation, piping insulation, etc has been inspected visually and found satisfactory.
- Left and right side cross around piping has been inspected by opening the manholes and found satisfactory.
- The activities that are done as per scheduled checklist of BHEL has been marked and available as Annexure I.
- After putting back the bearings in positions, readings of oil clearances have been noted. Oil catchers/guards have been inspected and clearances are maintained.
- Lock nut for two nos. of foundation bolts for HP/IP front bearing pedestal are not found in position. The same have to be assembled in position.
- Rotor lift readings have been noted at the bearings. Rotor was found free with hand barring.
- The turbine has been put on barring gear on 30/08/2019 @ 20:55 hrs. Barring speed is 90 rpm at Jacking Oil header pressure of 152 ksc.
- Recommendations:
    - BHEL has advised OTPC to adhere to carry out the inspections (minor, medium, major, etc) as per schedule (running hours) and as per OEM checklist.
    - Inspection of Brg#4 and Brg#5 (Generator Front and Rear Journal bearing) due to less lift.
    - Inspection of Brg#2 lower half which could not be carried out this time.
    - BHEL has also advised to ensure availability of EOT crane on continuous basis to carry out scheduled inspections successfully in future.
- BHEL has been requested to share the list of tools and tackles, fixtures required to carry out recommended inspections.
- OTPC has requested BHEL to provide the standard list of spares against each type of inspections.
- BHEL will send the detailed protocols after reaching Hyderabad office.
- BHEL service engineer is being released on 30/08/2019 and shall leave site on 31/08/2019.

30/8/19 30/08/2019 30/8/19 30.08.2019

BHEL STEAG OTPC

(D. Panchal) B Samar 30/08/2019

FINAL REPORT

PLANT TECHNICAL SYSTEM AUDIT CYCLE 2

For 2 x 363.3 MW Combined Cycle Power Plant, India

BV PROJECT NO. 410764

PREPARED FOR

ONGC Tripura Power Company Limited (OTPC)

02 AUG 2023

- As per site visit and above RCA observations, Black & Veatch understands that OTPC and primarily unit 1 has some ongoing HVAC issues which result in some inadvertent trips due to high temperatures with high humidity inside the control cubicle. Also witnessed during the site visit. Black & Veatch would suggest rectifying the existing HVAC issues prevailing in the plant and to strengthen periodic maintenance of the HVAC system.
- Black & Veatch noted some exposed live conductors and open cabinets for some HT/LT switchgear panels and recommends MV/LV panels & DBs to be secured & locked to avoid access to live parts. Proper insulating covers to be provided over live terminals to avoid accidental access and moisture ingress.
- Black & Veatch opines to commission switchgear room air pressurized system (in 4.5 meters) to overcome dust deposition on switchgear panels–By MMD (OTPC) as per RCA 25 and site visit observations.
- Black & Veatch opines to install a Dehumidifier in switchgear/equipment rooms to mitigate issues like moisture etc. UPS system to be made available with redundancy in battery banks as per industrial standard (only one battery bank for dc system).
- In accordance with RCA 16 guidelines, Black & Veatch opines to conduct a relay coordination study and to check the incomer relay setting for PMCC-LT (415V) Incomer PMCC HT (6,6KV Side) and Emergency DG PCC incomer to avoid earth fault-related trips and fault propagation to LT level in future.
- Black & Veatch recommends periodic inspection of cable termination, motor terminal box and block, earthing, and terminal box tightness for the equipment. Proper PM checklist, schedule, and effectiveness need to be strengthened

9.2.2 Tripping due to Instrumentation Issues

Black & Veatch has noted some major frequently recurrent issues causing I&C forced outage are as follows:

Mark VIe Card issues

As per RCA-82 and based on on-site visit observation, Black & Veatch understands that when Mark VI is connected to 125 V AC UPS (as per design), it is tripping showing incoming voltage unbalance.

Recommendations

- Black & Veatch as per the site visit observation understands that the present dc applied voltage to Mark Card (125 V) has been tapped from 230 V AC UPS and utilized for Mark card. This is almost exceeding the limits the specified limit by 7% of specified voltage (maintaining around 130 to 145V DC) . Black & Veatch recommends consulting OEM as this could lead to card unbalance, overload, and damage in the longer run. After implementation of corrective action for the specified output voltage of 125V DC, the same needs to supply the Mark VIe system as per the original design.
- It was also noted that the 125V DC UPS system is with a single battery bank without any redundancy. Black & Veatch recommends periodic charging-discharging tests on battery banks that cannot be done. It is recommended to have redundancy for the 125V DC UPS battery bank for better reliability and required periodic maintenance.
- 2X 125 Float cum booster charger needs to be inspected periodically as there is an ongoing issue of voltage unbalance & greater O/P DC voltage.

OPERATIONAL RISK SURVEY REPORT

ONGC TRIPURA POWER COMPANY, UDAIPUR, TRIPURA, INDIA

APRIL 2019

Prepared by: Sundeep Pugliya BE(Mechanical), CPM
Sundeep.pugliya@marsh.com
Global Energy Risk Engineering - India

Following: A survey visit to the OTPC, Udaipur, Tripura, India Power Plant on 5th and 6th April 2019 and discussions with the site personnel

REV. OTPC.U.UW.1.0

SOLUTIONS...DEFINED, DESIGNED, AND DELIVERED.

MARSH & McLENNAN COMPANIES

Recommendations Overview

15 new Risk Improvement Recommendations and eight observations were raised following the survey, which were well received by the site management and are as mentioned below:

2019.04.01	Annual Steam Turbine and Gas Turbine functional overspeed test
2019.04.02	Monthly DC lube oil pump run test on cut in pressure set point
2019.04.03	Monthly Steam Turbine Stop and control Valve exercising
2019.04.04	Annual Emergency shut off valve exercising test
2019.04.05	Implementation of GE upgrade Packages for Gas Turbines
2019.04.06	Gas Turbine door fan test
2019.04.07	Emergency Diesel Generator annual load test
2019.04.08	Fire water testing as per NFPA 25
2019.04.09	Fire detection identification below false flooring in control room
2019.04.10	Fixed fire protection system for Steam Turbine Generator bearings as per NFPA 850
2019.04.11	Gas Turbine seal oil system fixed fire protection system
2019.04.12	Annual foam solution test
2019.04.13	Critical Piping inspection
2019.04.14	Gas detection and interlocking of the gas leak signal with the emergency shut of valve
2019.04.15	STG AC and DC Lube Oil Pump Power Cables

Following Observations also made during the survey

- During the discussions with the site team, it could not be established that the positive fire zoning/isolation in the control and DCS rooms above false sealing has been envisaged effectively.
- Fire signal to respective area equipment trip interlocking is not envisaged.
- Unit 1 steam turbine got jammed during the Turbine costing down after the trip because of station black out scenario.
- Presently, Ware house fire detection system is limited to some of the air conditioned areas only whereas, it needs to be extended to cover the whole covered area as a lot of expensive spare parts are stored.
- Uncontrolled growth of vegetation near critical area like transformer and switchyard area need to be controlled.
- Fault signals were persisting on main and repeater fire alarm panels since last three months, which need to be attended on priority.
- An audit to verify Plant illumination level is required as in some critical area like fire water pump house the illumination level was observed low.
- Standard and Emergency Operating Procedures were last updated in 2015. These should be updated at least once in two years.

Insured Values and Estimates

Following values are considered based on John Foord Paper.

Main Equipment Value	Million US $
Gas Turbine + Generator	81
Transformers	27
Steam Turbine + Generator	40
HRSGs	40
Balance of Plant	80

The loss scenarios have included additional clean-up costs and work on the assumption that equipment will be replaced at the same contract value.

MARSH RISK CONSULTING

RISK. DISPUTES. STRATEGY.

INSURANCE MARKETING REPORT

OTPC, TRIPURA

ONGC TRIPURA POWER COMPANY LTD.

KAKRABAN ROAD, PO- KAKRABAN, GOMATI DISTRICT

TRIPURA-799116

PREPARED BY: SHUBHAM GUPTA

DATE: 18TH NOVEMBER 2015

MARSH

2015 - 007	Protection		Hydrogen generation plant
Status	Open	Status Date	17-Nov-15
Priority	Immediate Action	Type	Minor Capital
Related RTM ID	RTM-2015-002 RTM-2015-003 RTM-2015-004		
Recommendation	▪ Ensure all the filled and empty cylinders are chained properly. ▪ Provide automatic fire detection and protection systems in hydrogen generation plant as per FMDS 7-91 section 2.4.3. ▪ Route the signal from hydrogen analyzer installed in the hydrogen generation plant to the unit control room.		
Client Response	Plant management has understood the intent behind the recommendation and will implement the same.		

2015 - 008	Protection		Hydrogen Manifold Room
Status	Open	Status Date	17-Nov-15
Priority	Immediate Action	Type	Minor Capital
Recommendation	▪ Seal the opening between the hydrogen manifold room and the gas turbine hall on the ground floor. ▪ Provide ventilation in the room at ceiling level at a minimum of ten air changes per hour. The ventilation rate should increase to 25 air changes per hour upon operation of the hydrogen gas analyzer at not more than a 2% level (50% of LEL). ▪ Provide approved hydrogen gas analysers to sound an alarm and increase ventilation at a 2% hydrogen concentration in room. At present hand held hydrogen detector is used to monitor the hydrogen concentration. ▪ Chain all the filled and empty hydrogen cylinders. ▪ Avoid any loose connections/tapings on the electrical wires		
Client Response	Plant management has understood the intent behind the recommendation and will implement the same.		

2015 - 009	Protection		Lube Oil system for Gas booster Compressor and BFP room.
Status	Open	Status Date	17-Nov-15
Priority	Complete within 3 months	Type	Moderate Procedural
Related RTM ID	RTM-2015-001 RTM-2015-002		
Recommendation	▪ Provide adequate containment and drainage for the maintenance oil tank located in BFP (Boiler Feed Pump) room. Containment was provided for maintenance oil tank in the BFP room but it was open from one end. ▪ Provide adequate containment for the lube oil tank of Gas booster compressors. ▪ Install Automatic fire detection and protection system on the lube oil		

2015 - 009	Protection		Lube Oil system for Gas booster Compressor and BFP room.
	tank area of the Gas booster compressor area at ground floor. ▪ Provide automatic shutdown of oil pumps of Lube oil tanks of GBC(Gas Booster Compressor) actuated by heat detectors located at ceiling level or by activation of sprinklers.		
Client Response	Plant management has understood the intent behind the recommendation and will implement the same.		

2015 - 010	Protection		Battery Room
Status	Open	Status Date	17-Nov-15
Priority	Complete within 3 months	Type	Moderate Capital
Related RTM ID	RTM-2015-001 RTM-2015-002 RTM-2015-003		
Recommendation	▪ Provide Continuous ventilation that is provided at a rate of not less than 1 ft3/min/ft2 (5.1 L/sec/m2) of floor area of the room or cabinet as per NFPA 70E. ▪ Provide Hydrogen detector in the battery bank room with alarm in control room. ▪ Smoke detector in battery charging rom was observed to be capped. ▪ Install argonite system considering the openings in the false ceiling, main access door etc. ▪ Provide design calculation of argonite flooding system. ▪ Conduct enclosure integrity test for battery rooms and battery charging area after installing argonite system.		
Client Response	Plant Management understood the hazard behind the recommendation and will try to implement the same after evaluation.		

2015 - 011	Protection		Cooling Towers
Status	Open	Status Date	17-Nov-15
Priority	Complete within 3 months	Type	Moderate Capital
Related RTM ID	RTM-2015-001 RTM-2015-002		
Recommendation	Provide sprinkler protection for the inside of the cooling towers as per the guidelines available in FM Global datasheet 1-6.		
Client Response	Plant Management understood the hazard behind the recommendation and will try to implement the same after evaluation.		

05/11/2019

VOLTAS

Work Description (ADM BUILDING)

- Checked and cleaned the all allied Equipment's of Chiller units
- Checked leak on all chiller's found is ok.
- Checked the all starter's contacts and found Chiller # 3, Circuit # 3 replaced one MCB- C40 and Compressor Contactor 3TF46 from Security building, check the cable tightness, now all 3 No's chiller working with all compressor.
- Checked the heater and liquid line sight glass and verifying the all safety device and set point.
- Checked ate all controls and electrical starter contacts and bus bar and cable for loose termination and compressor for overheating.
- Checked the flow switch and electrical switch board for sign of carbon deposits, pitting of contacts.
- Checked the suction and discharge refrigerant pressure.
- Checkedand cleaned all condenser motors, cable tighten and overheating.
- Checked and cleaned the all Chilled water pumps and motor's bearing lubrication, and found Pump # 2 cooling blade broken so need to replace cooling blade.
- Cleaned the pump's Strainer and drain line.
- Checked the pump's vibration, abnormal sound and overheating.
- Checked the pump's water leakage and tighten of pump's gland.
- Checked the all A.H.U and found first floor AHU # 2 replaced defective blower bearing # UK-201 2 No's check the vibration, abnormal noise and body bolts tighten.
- Checked the V-Belt condition, tightensalignment and recondition.
- Checked and Cleaned all air filters of A.H.U,
- Checked the motor and blower bearing lubrication
- Checked the drain line, Drain tray and cleaned of A.H.U.
- Cleaned the Evaporator of A.H.U by blower and cleaned the body.

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05/11/2019

Problems found in system

- Chiller 2:-one MPD is not working.
- Chilled water Pump # B:- Motor cooling blade is not available (Damaged)

REQUIRED METERIALS

	Meterials	Specification	Quantity
1	MPD	Model:- M3PD, Dr. Number:- 198/2k11 – 42, Range :- 5-30 Amps, Aux supply :- 15VAC, Special:- 5 Sec	01 No
2	Cooling Blade (Motor)	Y - 100	01 No
3	Chilled water sensor	Unit Model #ACDS04DPMN 2x2	01 No

Note:-ADM Building roof side light is not available, need to arrange light is very urgent.

- Need to arrange Emergency push button of all units and pump's,

05/11/2019

VOLTAS

Work Description (MEDICAL CENTER)

- Checked and cleaned the all allied Equipment's of Chiller units,
- Checked leak on all chiller's found is ok.
- Checked the all starter's contacts and found defective in unit # 1, 2, 3 compressor breaker, and replaced compressor breaker C40, 3Ph 440 Volt in unit # 1, 2 2No's from security building and unit # 1 need one breaker C40, so this compressor is off by breaker and check the cable tightness, now all unit is working normally.
- Checked and all controlsfound and by pass unit # 3 defective MVPD and checked electrical starter contacts and bus bar and cable for loose termination and compressor for overheating.
- Checked the heater and liquid line sight glass and verifying the all safety device and set point.
- Checked the flow switch and electrical switch board for sign of carbon deposits, pitting of contacts.
- Checked the suction and discharge refrigerant pressure is ok.
- Checked and cleaned the all condenser motors and found unit # 2 condenser fan contactor defective, so replaced contactor 3TF31 from security building, and motor cable tighten for overheating.
- Checked and clean all Chilled water pumps, and motor's bearing lubrication.
- Cleaned the pump's Strainer and drain line.
- Checked the pump's vibration, abnormal sound and overheating.
- Checked the pump's water leakage and tighten of pump's gland.
- Checkedthe A.H.U vibration, abnormal noise, lubrication and body bolts tighten.
- Checked the V-Belt condition, tightens alignment and recondition.
- Checked and Cleaned air inlet filters of A.H.U
- Checked the motor and blower bearing lubrication
- Checked the drain line, Drain tray and cleaned of A.H.U.
- Cleaned the Evaporator of A.H.U by blower and cleaned the body.

REQUIRED METERIALS

	Meterials	Specification	Quantity
1	MPD	Model:- M3PD, Dr. Number:- 198/2k11 – 42, Range :- 5-30 Amps, Aux supply :- 15VAC, Special:- 5 Sec	01 No
2	Chilled water sensor	Unit Model #ACDS022DPMN 2x1	01 No

Note:- ADM Building roof side light is not available, need to arrange light is very urgent.

- Need to arrange Emergency push button of all units and pump's,

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05/11/2019

VOLTAS

Work Description (TRANING HOSTEL)

- Checked and cleaned the all allied Equipment's of Chiller units,
- Checked leak on all chiller's found is ok.
- Checked the all starter's contacts and found defective in unit # 2, 3 compressor breaker, and replaced compressor breaker C40, 3Ph 440 Volt in unit # 2Ckt # 1, 4, and unit # 3 Ckt # 3,total 3No's of breaker from security building and check the cable tightness, now all unit is working normally.
- Checked and all controls found and by pass unit # 3 defective MVPD and checked electrical starter contacts and bus bar and cable for loose termination and compressor for overheating.
- Checked the heater and liquid line sight glass and verifying the all safety device and set point.
- Checked and all controls and electrical starter contacts and bus bar and cable for loose termination and compressor for overheating.
- Checked the flowswitch and found and by pass defective flow switch in unit # 2, 3, and electrical switch board for sign of carbon deposits, pitting of contacts.
- Checked the suction and discharge refrigerant pressure is ok,
- Checked and cleaned the all condenser motors cable tighten for overheating,
- Checked and clean all Chilled water pumps, and motor's bearing lubrication.
- Cleaned the pump's Strainer and drain line.
- Checked the pump's vibration, abnormal sound and overheating.
- Checked the pump's water leakage and tighten of pump's gland.
- Checked the F.C.U vibration, and repair water leaking where ever found and replaced defective motorized valve in room # 119,
- Checked and Cleaned air filters of F.C.U,and found Reception area 2No's FCU air filter not access for remove and clean due chilled water line,
- Checked the drain line, Drain tray and cleaned of F.C.U.

* REQUIRED METERIALS

	Meterials	Specification	Quantity
1	MPD	~~Unit is # 2 of due to material not available~~ Model:- M3PD, Dr. Number:- 198/2k11 – 42, Range :- 5-30 Amps, Aux supply :- 15VAC, Special:- 5 Sec	01 No
2	Chilled water sensor	Unit Model #ACDS034DPMN 3x1	01 No
3	Safety valve	Pressure Release valve	03 No's

Note:- ADM Building roof side light is not available, need to arrange light is very urgent.

- Need to arrange Emergency push button of all units and pump's,

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VOLTAS

Work Description (MAIN PLANT)

- Checked and cleaned the all allied Equipment's of Chiller units,
- Checked the all starter's contacts and check the cable tightness,
- Checked the heater and liquid line sight glass and verifying the all safety device and set point.
- Checked ate all controls and electrical starter contacts and bus bar and cable for loose termination and compressor for overheating.
- Checked the flow switch and electrical switch board for sign of carbon deposits, pitting of contacts,
- Checked the suction and discharge refrigerant pressure, found unit # 1 is not going to 100% full load due to high condenseson for defective cooling tower, need to repair cooling tower descaling the condenser and cooler and all A.H.U's coil's.
- Checked the butterfly valve of 2 No's of chiller condenser inlet line,
- Checked and clean condenser Pump motor's lubrication bearing, cable tighten and overheating ,
- Checked and clean Chilled water Pump motor's lubrication bearing, cable tighten and overheating and need to urgent replaced chilled water pump motor urgent,
- Cleaned the pump's Strainer and drain line and checked the gland 's water leakage and tighten the gland,
- Checked the chiller and condenser water pump's suction and discharge pressure and rotation speed as visual.
- Checked and fill lubrication oil in bearing housing,checked V-Belt tension, cleanedcooling tower's fills, sump and basin,
- Need to repair cooling tower body of roof top due to water leakage and repair Nozzle guider, replace service valve, need to shutdown unit,
- Checked the all 8 No's A.H.U's motor and blower abnormal sound and vibration
- Changed the 4.5 miter (1st Floor) Blower bearing, UK-210, Replaced V-Belt A-52 in 4.5 miter and 17.5 miter 2No's did alignment and run the unit.
- Cleaned all A.H.U's filters, cooling coil, and Drain tray and drain line.
- Checked the air inlet and outlet temperature and actuators and repair balancing valve in 0 miter, 4, 5 miter and 17.5 and checked and found is working normally.

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✻ REQUIRED METERIALS

	Materials	Specification	Quantity
1	Refrigerant	Refrigerant 134a	200 Kg
2	Compressor oil	BSE 170	40 Liter
3	HCL	Hydro cloric acid for descaling	50 Liter
4	Angle Valve	1/2 inch	06 No's
5	Syphon	1/2 Inch	06 No's
6	Water pressure gauge	Range 0 to 6 Kg	10 No's
7	Temperature Gauge	Range 0 to 80^{0}C	10 No's
8	Chilled water motor	Kirloskar, Frame 1132M, V-415, KW/HP- 9.3/12.5, RPM-1440, IEC6003	2 No's

Note:-Provide the light in all A.H.U's inside for confined space,

- ✻ Cooling tower's body damage need to repair or change,
- ✻ 17.5 mtr phase # 2 A.H.U # 1 is not running.
- ✻ All E.P.B switch are not working.

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VOLTAS

Work Description (SWITCH YARD)

- Checked and cleaned the all allied Equipment's of Package units,
- Checked the all starter's contacts and check the cable tightness,
- Checked and verifying the all safety device and set point,
- Checked and all controls and electrical starter contacts and bus bar and cable for loose termination and compressor for overheating and found unit # 1 and unit # 4 defective relay board need to replace unit off by breaker.
- Checked electrical switch board for sign of carbon deposits, pitting of contacts.
- Checked the suction refrigerant pressure is ok in unit # 2, 3, 5 and need gas R-22 in unit # 1
- Package Unit # 2,3,4 Replaced V-Belt and unit #2 replaced Compressor contactor and repair burn out main wire,
- Checked and cleaned the all condenser coil and cooling coil through water.,
- Checked the condenser motors lubrication, cable tighten and overheating,
- Checked the Pipes insulation and drain line,

REQUIRED METERIALS

	Materials	Specification	Quantity
1	Relay Board	Board # SOL, SMD-RLY1 Relay # OMRON,G4A-1A-E, 12 VDC, 20 A, 250 V AC	02 No

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VOLTAS

05/11/2019

Work Description (Unit # 1 and 2 bettery charger room)

Make: - **Blue Star**

Model: - DSA1021R2-0A

- Check and cleaned the all allied Equipment's of DuctableSplite units,
- Check the all starters contacts and check the cable tightness,
- Check the refrigerant pressure is found ok Phase -1 & 2
- Cleaned the condenser fins cooling coil fins,
- Cleaned the air intake filter,
- Clean the body of unit
- Check the abnormal sound and condenser motor and blower (OK)

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ENERGY AUDIT REPORT

2 X 363.3 MW (CCPP)

ONGC Tripura Power Company Limited

Palatana, Udaipur, Tripura

(An ISO 9001:2008 certified Company)

STEAG Energy Services India Pvt. Ltd.

(Formerly Evonik Energy Services (India) Pvt. Ltd.)

(A wholly owned subsidiary of STEAG Energy Services GmbH, Germany)

A-29, Sector-16, NOIDA-201301, India

September - 2017

ACKNOWLEDGMENT

Steag Energy Services India Private Limited, SESI expresses their sincere gratitude to the management of ONGC Tripura Power Company , Palatana, Udaipur, Tripura for their cooperation in carrying out the energy audit of Combined Cycle Power Plant at Palatana, Udaipur, Tripura.

We would like to express our deep sense of gratitude to the all departments who helped us with infrastructure / arrangements and encouragement in our endeavor. The valuable information / input furnished by the Plant Manager & Technical Cell personnel of the plant during site activity are also highly appreciable.

We do hope you will find our recommendations useful in saving energy and recover your investment in the periods estimated. While we have made every attempt to adhere to high quality standards in both data collection and analysis as well as in presentation through the report; we welcome your suggestions towards improvement of the report.

Finally, we thank all those who helped us directly or indirectly to execute this Energy Audit project.

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The working details of Energy Audit Project are as follows:

Project	Energy Audit
Client	ONGC Tripura Power Company Limited
Site	ONGC Tripura Power Company Limited, Palatana, Udaipur, Gomati district, Tripura.
Consultant	Steag Energy Services India Pvt Ltd., Noida, UP, India -201301
Project Scope	Energy audit of the 2X363.3 MW Combined Cycle Gas Turbine (CCGT) power plant and process to assess the loss in the system/subsystems and identify energy efficiency measures to be taken.
Note	*The recommendations in this report are based on the present operating conditions of equipments/systems.*

Index (Revision)	Date	Description	Prepared By	Reviewed By	Approved By
R0	21/07/2017	Energy Audit Report	Mr. K G Sudhan Ramkumar, Mr. Mayakant Shukla, Mr. Vineet Ku Jha Mr. Manish Sharma	Mr. Lalatendu Pattanayak	Mr. Rakesh Mishra

SUMMARY

ONGC Tripura Power Company Limited (OTPC), is operating two units of 2 x 363.3 MW (726.6 MW) Combined Cycle Gas Power Plant for providing power to the state electricity distribution companies. Each unit (Unit 1 & 2) has a configuration of 1GTG+1HRSG+1STG. Each Gas Turbine (GT) with rated capacity of 232.39 MW and each Steam Turbine (ST) 130.91 MW are installed for providing the power. Each Heat Recovery steam generator (HRSG) with rated capacity of 289 T/H is installed for recovering the heat from the exhaust by generating steam at different temperature and three pressure levels.

The combined cycle gas power station is equipped with two HRSG, two STG and two GTG along with Balance of plant is selected for conducting Energy Audit. Steps were taken to identify energy efficiency improvement areas measures and quantifiable energy saving on account of implementation of selected recommendations.

- Gap identification and analysis based on:
  - Assessment of HRSG, Gas turbine, Steam turbine & balance of plant based on data/documents collected from the plant, hot walk down survey as per the running condition of the systems.
  - Assessment of the impact of individual equipment performance's variation on overall plant working/performance.
  - Thermodynamic analysis of the unit with the help of Ebsilon® Professional
- Identification of potential areas of improvement and detailing out recommended measures for energy efficiency improvement.

Major Observations / Identified Gaps

At the time of audit unit – 1 was running in part load and unit – 2 was in base load. The focus of activities was therefore to assess the plant system and subsystem based on individual operating status. Based on audit results and gaps identified, recommendations made under short term (0 – 6 months), medium term (6 months to 2 years) and long term (> 2 years), measures. Gaps were also identified in O&M practices and recommendations in this regard were made as short term measures for improvement in energy efficiency.

Overall Performance of the Station

Description	Unit	Design	Test	
			Unit 1	Unit 2
Ambient Temperature	°C	27	33.83	30.54
Ambient Pressure	kg/cm^2 (a)	1.02	1.0044	1.0069
Relative humidity	%	77	87.8	87.8
Gross load	kW	363300	249170	343010
LHV	kJ/kg	49328	49058.3863	49058.3863
GT exhaust flow	kg/h	2217600	1716480	2189880
Fuel flow	kg/h	48270.24	35160	46070
Gross Heat rate(NCV Basis)	kJ/kWh	6299.85	6922.6	6589.1
	kcal/kWh	1505.7*	1653.4	1573.8
Gross Efficiency	%	54.94	52.01	54.65
Specific Fuel consumption	SCM/kWh	0.187	0.198	0.190

** Guaranteed Gross Heat Rate – 1565.40 kcal/kWh.*

Summary of Recommendations

Various recommendations made in this energy audit report are summarized below.

Sr. No.	Recommendations	Annual Saving (Rs. Cr)	Investment (Rs Cr)	Payback (Month)
1	Optimize the pressure drop across HP FCS	0.16	NIL	Immediate
2	Unit - 1 HP BFP recirculation arresting	0.093	0.1	13
3	Unit - 1 CEP Optimization (By reducing head loss & internal maintenance)	0.09	NIL	Immediate
3.1	Installation of VFD for Unit - 1 CEP	0.13	0.3	27
4	Unit - 2 CEP Optimization By reducing head loss & internal maintenance)	0.08	NIL	Immediate
4.1	Installation of VFD for Unit - 2 CEP	0.14	0.3	25
5	Installation of temperature control VFD in CT fan	0.18	0.14	9
6	Replacing GRP blades with FRP blades in CT Fan	0.17	0.16	11
7	Drain flow optimization of both unit	0.102	0.05	11
8	Installation of VFD for Unit – 1 LPBFP	0.015	0.045	35
8.1	Installation of VFD for Unit – 2 LPBFP	0.016	0.045	33

9	Lighting optimization (reduction of energy consumption by operation optimization of existing lighting)	0.02	Nil	Immediate
10	Maintenance of HVAC Cooling tower(to reduce running of one CT)	0.01	0.005	12
11	Installation of VFD for AHUs to optimize the energy consumption	0.007	0.015	26
12	Instrument Air Compressor optimization	0.04	Nil	Immediate
Total		**1.253**	**1.16**	**11.11**

CHAPTER- 1

INTRODUCTION

OTPC is sponsored by Oil and Natural Gas Corporation (ONGC), Infrastructure Leasing and Financial Services Limited (IL&FS) and Government of Tripura (GoT) have implemented Combined Cycle Gas Turbine (CCGT) power plant with total installed capacity of 726.6 MW (2 X 363.3 MW) at Palatana, Tripura. The plant has 2 units each of 363.3 MW (GT+ST) Capacity. Each unit consists of 1 GTG, 1 HRSG and 1 STG along with associated plant auxiliaries. Plant also includes, river water intake system, fuel supply system, plant water system, air supply system, hydrogen plant, nitrogen plant, 400 KV & 132 KV Switch Yard, Various Laboratories, etc. Each unit is equipped with 232.39 MW GE 9351FA Heavy duty Gas turbines, three pressure level HRSG and STG with capacity of 130.9 MW. The Heat Recovery Steam generator supplies HP steam, IP steam and LP steam with different pressure and temperature to Steam turbine for generating the power and utilizes the flue gas exhaust energy.

The power plant site is located at Palatana in district Udaipur in the state of Tripura. The plant is located about 12 kms from the sub-district head quarters of Udaipur and is an about 60 Kms from the capital city of Agartala. The plant is located adjacent to the existing state highway connecting to Udaipur, with onward connectivity to Agartala by NH-44. A perennial river, namely Gumti flows near the site and it is the main water source for the power plant.

The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January, 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015. The commissioning details of the station are shown below.

Unit No.	Capacity [MW]	Date of commissioning	Date of commercial operation
1	363.3	January 2013[1]	04-01-2014
2	363.3	November 2014[2]	24-03-2015

[1] ONGC Tripura Power Plant". Power Technology. 2011-06-15. Retrieved 2015-02-27

[2] BHEL commissions second gas-based power plant in Tripura - Economic Times". Articles.economictimes.indiatimes.com. Retrieved 2015-02-27

Gas Turbine & its Control System were manufactured by GE/BHEL. Other Major Equipments like generators, Steam Turbines, HRSG, Transformers, DCS, Major pumps, HT Motors, HT Switchgears etc. were manufactured by BHEL.

Steag Energy Services India Pvt. Ltd. (STEAG), has performed the Energy Audit in 2X363.3 MW CCGT plant of ONGC Tripura Power Corporation Limited. A field visit was carried out between 08th August 2017 to 12th August 2017 and detailed audit was carried out using the audit instruments.

1.1 Plant Performance

The performance guarantees at base reference condition as per EPC contractor is shown in Table 1.1.The past plant performance of Unit No.1 & Unit No.2 was reviewed for last 4 years for which detailed energy audit was conducted. During year 2016-17 OTPC has generated 4170.28 MU with 64.81% Plant Load factor (Table 1.2). The total generation, APC and Heat rate for the last four financial years are shown in Figure 1.1, Figure 1.2 and Figure 1.3 respectively.

Table 1.1: Performance guarantee at base reference condition

Parameters	**Unit**	**Value**
Block -1 Gross power output	MW	363.3
Block -2 Gross power output	MW	363.3
Block -1 weighted average gross Heat rate	kcal/kWh	1505.7
Block -2 weighted average gross Heat rate	kcal/kWh	1505.7
Auxillary Power Consumption for entire plant	MW	24.8
NOx for each Block	ppm	50
Reference Condition		
Ambient Pressure	Bar (a)	1.0
Dry bulb Temperature	^oC	27
Relative Humidity	%	77
LHV	kJ/kg	49328
CW inlet temperature	^oC	32

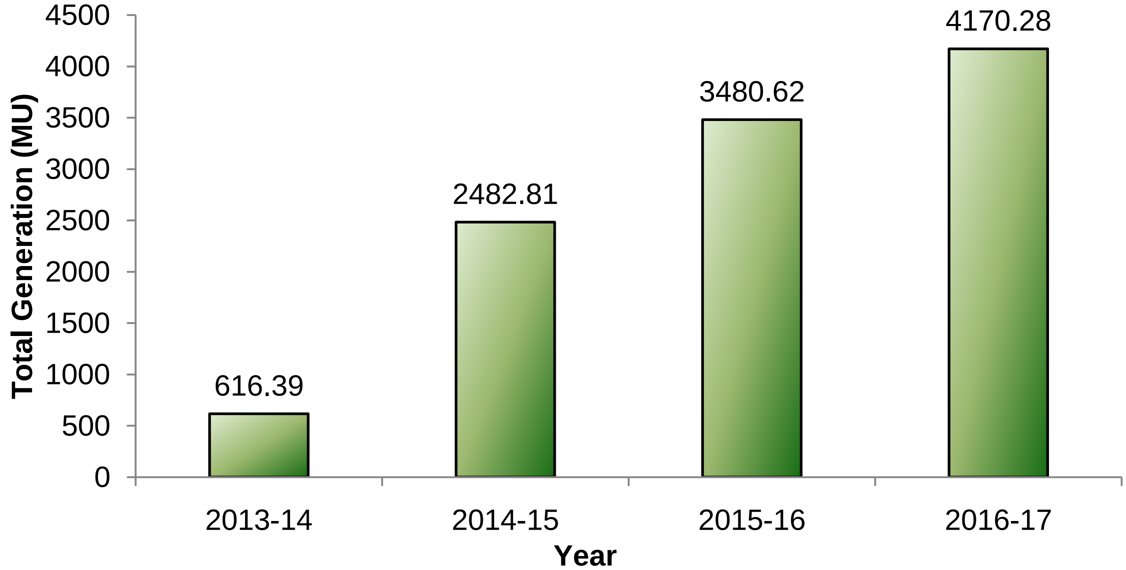


Figure 1.1: Total Station Generation

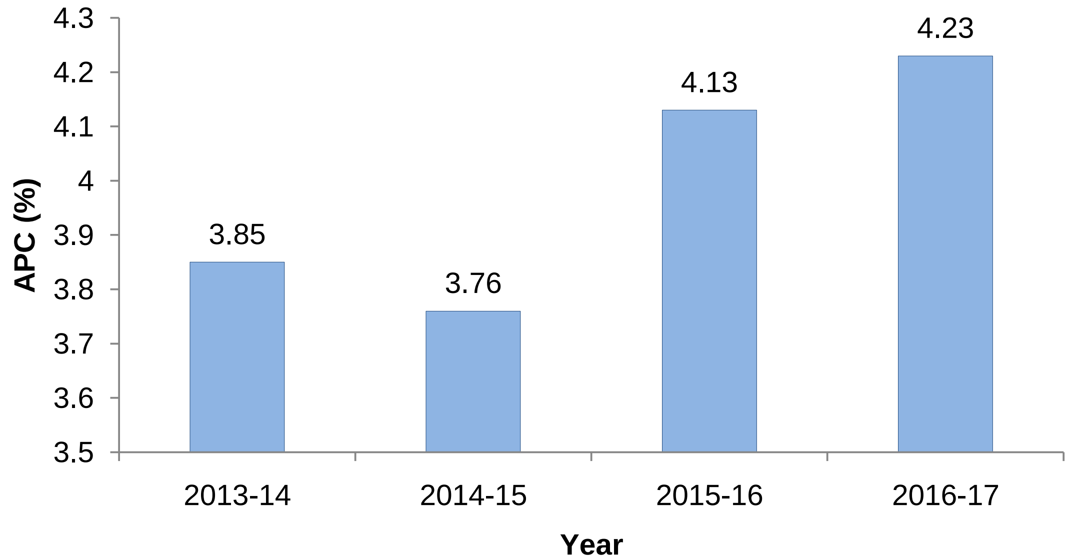


Figure1.2: Total station APC

Based on the above data, it can be seen that the APC of the plant increases from 3.76 % to 4.23 % from year 2014-15 to 2016-2017. However, the Heat rate on GCV basis has improved from1833 kcal/kWh to 1805 kcal/kWh. The overall station generation was highest in year 2016-2017 i.e. 4170.28 MU compared to last three financial years. As there is no data available for individual unit generation hence unit wise comparison is not possible.

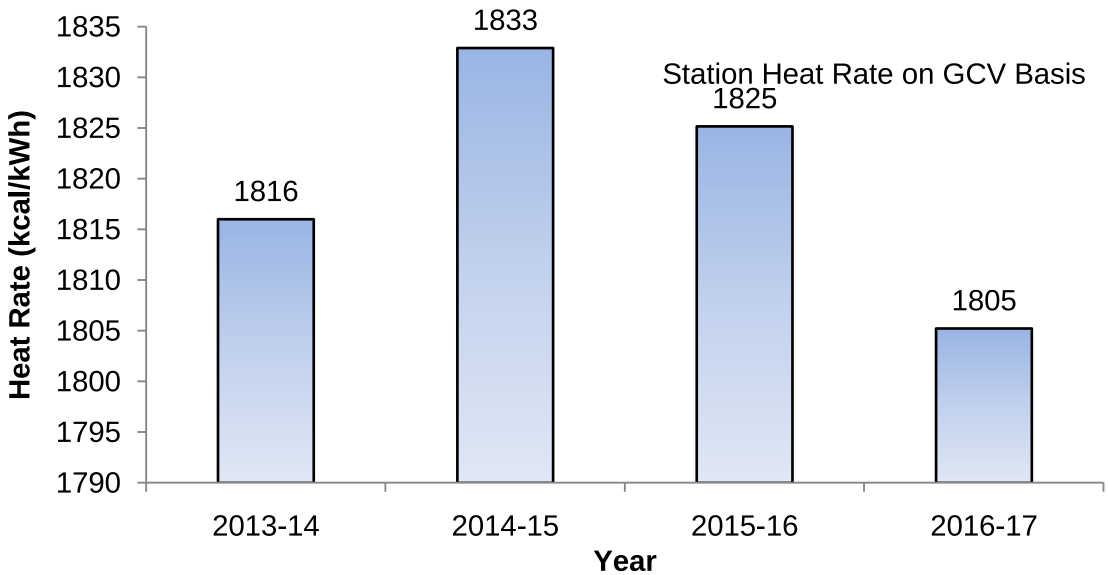


Figure 1.3: Plant Heat Rate

Table 1.2: Station performance scenario for year 2013 to 2017

Parameter	UOM	2013-14	2014-15	2015-16	2016-17
Generation	MU	616.39	2482.81	3480.62	4170.28
APC	%	3.85	3.76	4.13	4.23
PAF	%	84.96	77.29	55.74	66.39
PLF	%	81.26	79.52	54.3	64.81
MAF	%	93.24	88.30	70.63	87.40
HR on GCV	kcal/kWh	1816	1833	1825	1805

1.2 Process Description

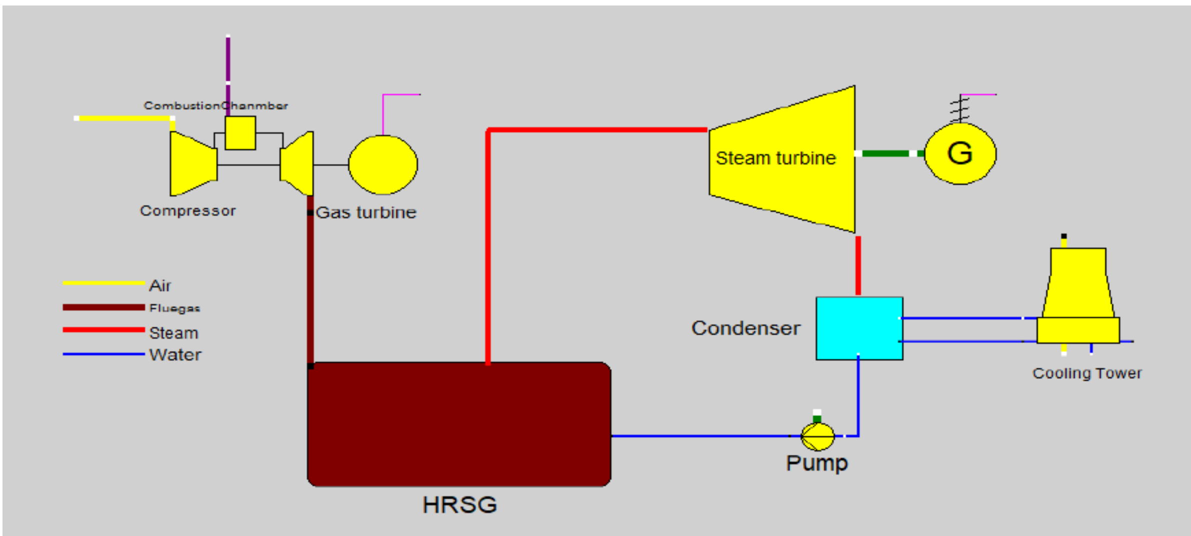
Gross output of each GT is 232.390 MW and gross output of each STG is 130.910 MW. Plant is designed to operate only in combined cycle mode with no provision for bypass stack. HRSG is horizontal gas path type triple pressure design. STG is double casing unit with single flow high pressure/Intermediate pressure module (HP/IP Module) and double flow low pressure module (LP Module). GT generator is hydrogen cooled while ST generator is water cooled. ONGC's Fuel metering station is located within the plant boundary. Fuel Supply system consists of 3 nos. of Gas Booster compressors at site, Gas Conditioning System and fuel supply pipeline. River Water Intake system includes river water intake pump house on the Gomati river bank. A 1.8 Km long carbon steel pipeline is laid up to plant boundary and 1.5 Km long glass fiber reinforced plastic (GRP) inside the plant boundary up to raw water reservoir.

Each unit power generation cycle consists of GT compressor having 18 stage, Gas Turbine of 3 stage, 3 no's of Steam Turbine (HPT 23 stages, IPT 21 stages and LPT with 18 stages) a constant pressure De-aerator and a water cooled Surface Condenser. There are 2 nos. of Condensate Extraction Pumps (CEP), one running and one standby provided to pump condensate to De-aerator. For one unit there are 4 nos. of feed pumps consisting of two LPBFPs (1 running & 1 standby) and two HPBFPs (1 running & 1 standby).

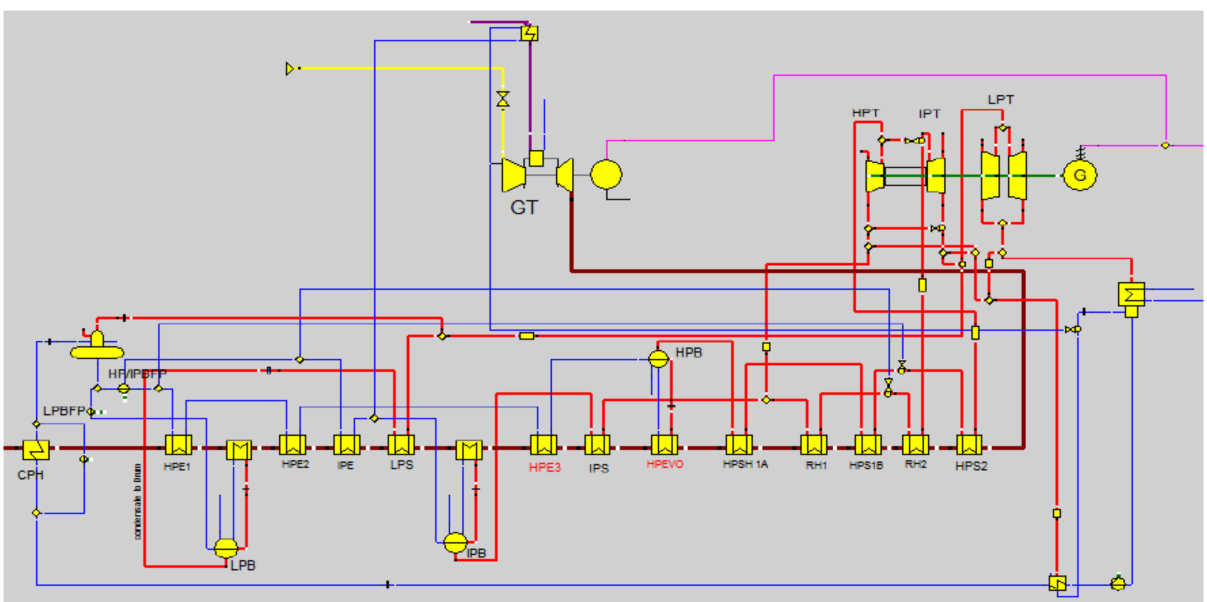
The compressed air exits through the compressor discharge casing to the combustion chambers. Combustion chamber includes the fuel nozzles, a spark plug ignition system, flame detectors. Exhaust gas from Combustor enters the three-stage turbine section and converts heat to mechanical energy. The exhaust of Gas turbine enters into HRSG section at 615°C and exits at design temperature of 103°C after giving its heat to HRSG for conversion of water to steam at different pressure levels.

The condensate from CEP discharges flows to the condensate pre-heater at the temperature of 60°C for heating the condensate water before de-aerator. The design CPH inlet pressure, temperature, and flow is 25 kg/cm^2, 60°C, 444.8 TPH respectively. The same is heated in the condensate pre-heater and design outlet pressure, temperature, and flow is 25 kg/cm^2, 141.5 °C, 444.8 TPH respectively. The LP Feed water takes suction from the De-aerator Storage Tank by LP BFP. The LP BFP discharges the feed water at pressure of 10.4 kg/cm^2 and enters the LP drum. The IP feed water is extracted from intermediate stage of HP/IP Boiler feed pump and passed to the IP economizer then enters the IP Steam Drum through the feed water inlet nozzle. Natural circulation is maintained in the IP Evaporator by means of down comers. From the IP steam drum the saturated steam passes to the IP super heater. The IP main steam from the IP super heater combines with CRH from HP turbine and passes to the Re heater for further heating. HP feed water is supplied to the HP pressure section via the HP stage of the feed water pump, which extracts feed water from the De-aerator Storage Tank.

The steam after expanding through HP turbine is reheated in the re-heater at HRSG and returned to the IP turbine. Before returning to the IP turbine as HRH, addition IP steam is mixed with the CRH and heated in re heater then passes to the IP turbine. Then the reheated steam after expanding through IP and double flow stages of LP turbine is exhausted to the condensers at the exhaust part of the LPT. LP steam is also mixed with the IP exhaust and passed to the LP turbine.



(a)



(b)

Figure 1.4: (a) Block diagram, (b) Overall Process Flow Diagram

During field testing for energy audit the performance /efficiency test was carried out for GT, STG, HRSG and their auxiliaries at part load operation for Unit 1 and at full load operation for Unit 2. Flow, temperature, flue gas parameters and electrical parameters of motors were measured using digital instruments available with STEAG. Readings were also taken from OTPC instruments from panel & UCB as per the requirement. The behaviour of plant at different load conditions was studied. Name plate/design data were taken from respective sections and the performance of equipment is compared with actual operating data.

The thrust areas studied during detailed Energy Audit includes:

- Gas turbine and Compressor
- HRSG
- Steam Turbine
- Electrical System
- Pumps
- Insulation study

All these areas are critically analyzed to recommend suitable energy saving measures and are discussed in the report.

CHAPTER- 2

ENERGY AUDIT METHODOLOGY

An energy audit comprehensively will identify the degraded area in the plant system and subsystems and their respective contribution to overall thermal efficiency. Therefore these will be valuable inputs into the next inspection maintenance scope to implement the necessary corrective actions. Having established the baseline performance the energy audit can easily be extended to studying the feasibility of potential improvements to the plant. Energy Audit is a systematic search of energy conservation opportunities as well as systematic approach to measure energy consumption levels of the equipment/plant in a limited time frame by a team of energy experts.

2.1 Objective

Objective of work

- To evaluate the current level of performance of the station as well as individual Units.
- Comparing the actual performance with the reference/guaranteed performance.
  - Assessment of plant equipment/system based on data/document and field measurements, hot walk down survey and comparing different conditions of units.
  - Thermodynamic analysis of the equipment/system.
- To identify the degraded plant components and their respective contribution to overall energy efficiency loss and therefore will be valuable input into the next inspection maintenance scope to implement the necessary corrective action.
- Identification of potential areas of improvement and detailing out recommended measures for energy efficiency improvement to the level of design with application of current technologies and cost effectiveness methods.

The major objectives of conducting Energy Audit in OTPC, Tripura for GTG, STG and HRSG are to:

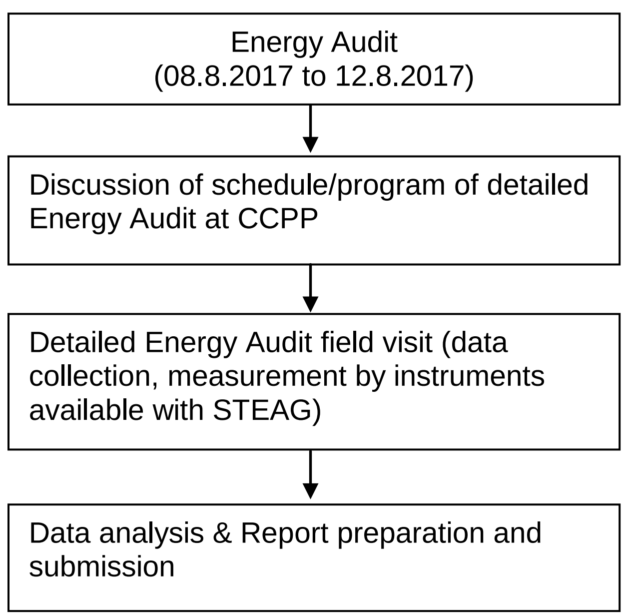
1. Study the HRSG and its Auxiliaries.
2. Study the Gas turbine and its Auxiliaries
3. Study the Steam turbine and its Auxiliaries.

4. Study the Electrical systems
5. Reduce Auxiliary power consumption
6. Improve Overall performance of power plant.
7. Reduce Specific fuel & Electrical energy consumption
8. To measure power consumption for the following major systems

   ⇒ HP/LP Feed Pumps
   ⇒ Condensate Extraction Pumps
   ⇒ CW pumps
   ⇒ Air Compressors
   ⇒ Air Conditioning System
   ⇒ Lighting System
   ⇒ CPH Pumps

2.2 Methodology

The methodology of conducting Energy Audit & Energy Conservation study at CCPP OTPC, Tripura. is given in the form of flow chart below.



The audit adopts the method of measuring field data using calibrated instruments and thermodynamic simulation based analysis to evaluate the performance of individual major components in the plant and also to assess the overall plant efficiency. The performance assessment typically applied to:

- Comparing actual performance to Design performance
- Comparing different conditions of the systems and subsystems
- Analyzing the impact of individual equipment performance's variation on Overall plant efficiency
- Assessing different retrofit or energy efficiency measures implementation options

The field measurements were carried out with calibrated instruments as per the availability of approaches at CCPP of OTPC, Tripura plant. For analysis of the collected data the standard formulas as per ASME Standards and BEE Guidelines were used.

Improvement in energy efficiency of units through EE Measures/improved O&M practices, to be made by undertaking the following steps:

- Assessment of unit based on data/documents collected from the plant
- Walk down survey
- Thermodynamic performance analysis (comparing operating parameters with design) to evaluate the current status of the plant including heat rate and other efficiency parameters of the concerned unit
- Subsequent discussions with plant personnel
- Gap identification and analysis
- Identification of potential areas of improvement
- Detailing out action plan for introduction of identified energy efficiency measures including improved O&M practices

2.3 Instruments Used

Following instruments were used for measurement during field studies of Energy audit,

1. Testo flue gas analyzer : For temperature, CO (ppm) & O_2 % of Flue Gas, excess air
2. Digital temperature indicator : For measuring the temperature at HRSG, Turbine & Condenser, Flue gas temperature. etc.

3. Hygrometer : For measuring Temperature, Humidity during the study of AHU' and Cooling tower.
4. Power analyzer - KRYKARD ALM-36 : For complete electrical Energy management (V, I, kW, kVA, KVAR, P.F., etc.) during the study of transformer, electrical motors, distribution system.
5. Portable clamp on multimeter : For measurement of V, I, kW, kVA, P.F. etc.
6. Lux meter : For measuring the illumination level.
7. Ultrasonic Flow meter : For measuring flow of water for study of Feed pump, Main condensate pump, DMCW & D.M. water pump etc.
8. Non contact infrared digital thermometer : For measuring surface temperature during insulation audit.

2.4 Data Analysis and Report Preparation

Data analysis done after the field visit includes:

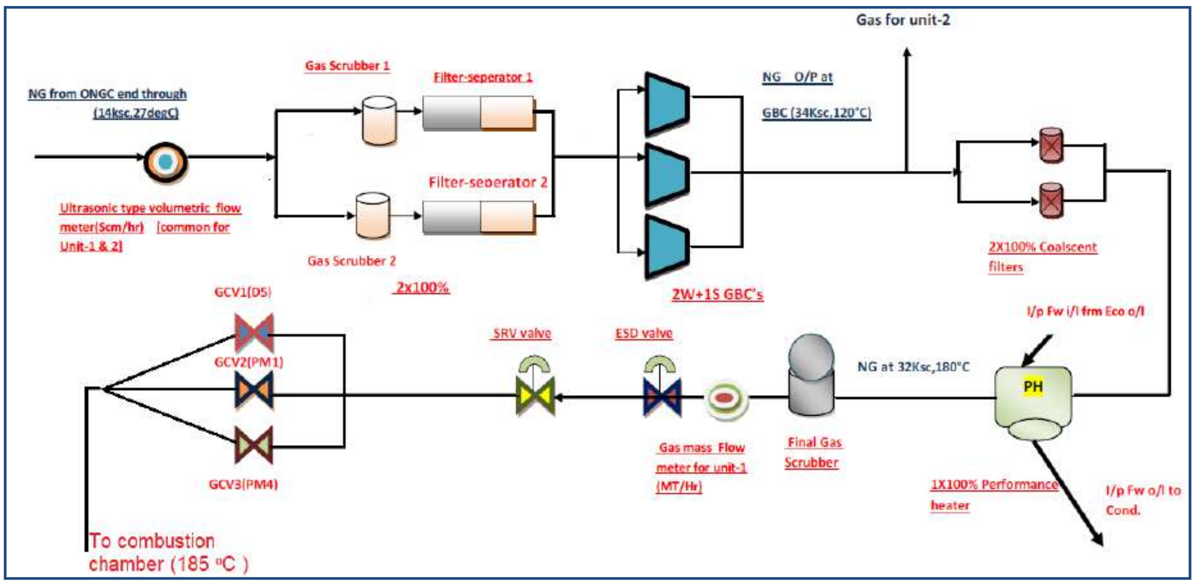
- Brain storming and search of energy saving options by Energy Audit team.
- Analysis of the measured and UCB data collected during field visit from individual equipments like HRSG, Turbines etc.
- Quantification of efficiency & associated losses in the equipment.
- Techno-Economic benefits calculations for the cost effective recommendations.

Based on the data (both designed & measured) collected from site, has been used for subsequent analysis by experts. Report has been prepared to submit to OTPC which contains measured & designed data of electrical and thermal equipment along with Recommendations & Analysis. The report also contains observations & analysis; Recommendations in thrust areas of energy conservation like HRSG, Turbine & auxiliaries, electrical system and station auxiliaries. Energy Management and Implementation plan is also provided in this report to assist OTPC, Tripura for effective energy management & smoother implementation of recommendations provided in the report.

CHAPTER- 3

NATURAL GAS SOURCE & QUALITY

ONGC supplies Natural Gas to the OTPC through a dedicated gas pipeline from the natural gas reserves located in Tripura. ONGC's Fuel metering station is located within the plant boundary. Fuel Supply system consists of 3 nos of Gas Booster compressors at site, Gas Conditioning System and fuel supply pipeline. The supplied Natural gas is properly treated in the fuel feeding system for removing sludge, liquid and other impurities before feeding into the combustion chamber. Natural Gas sample is analyzed online by chromatograph on daily basis. Below diagram shows the NG flow process from source to combustion chamber.



3.1 Design Gas Analysis

Table 3.1 depicts the gas composition at rated reference condition.

Table 3.1: Natural Gas analysis (reference condition)

Natural Gas Analysis Design (Volume)		
Description	**Unit**	**Design**
CH_4	%	96.956
C_2H_6	%	1.87
C_3H_8	%	0.409
C_4H_{10}	%	0.209
C_5H_{12}	%	0.064
C_6H_{14+}	%	0.14
N_2	%	0.216
CO_2	%	0.276

Total	%	100.14
LHV	kJ/kg	49328
H/C	ratio	3.93

3.2 NG Gas Analysis during Energy Audit

Based on Online Gas Chromatograph Report

Natural gas samples online chromatograph analysis provided by OTPC, Tripura is depicted in Table 3.2.

Table 3.2: Natural Gas analysis report (Test condition)

Description	Un Norm (%)	Norm (%)	Ideal (kcal/m^3)
Propane	0.3785	0.3775	84.783
Hidrogen Sulfide	0.0000	0.0000	0.000
IsoButane	0.1141	0.1138	33.032
Butane	0.0604	0.0602	17.539
NeoPentane	0.0000	0.0000	0.000
IsoPentane	0.0283	0.0282	10.061
Pentane	0.0000	0.0000	0.000
Hexane+	0.1424	0.1420	0.000
Nitrogen	0.3333	0.3324	0.000
Methane	96.8817	96.6124	8710.072
CarbonDioxide	0.3698	0.3688	0.000
Ethane	1.9702	1.9648	310.362
Hexane	0.0000	0.1420	60.279
Heptane+	0.0000	0.0000	0.000
Heptane	0.0000	0.0000	0.000
Octane	0.0000	0.0000	0.000
Nonane+	0.0000	0.0000	0.000
Nonane	0.0000	0.0000	0.000
Decane	0.0000	0.0000	0.000
Undecane	0.0000	0.0000	0.000
Dodecane	0.0000	0.0000	0.000
Ethane-	0.0000	0.0000	0.000
Pentane-	0.0000	0.0000	0.000
Oxygen	0.0000	0.0000	0.000
Water	0.0000	1.7407	0.000
Total	100.2787	100	9226.128

Table 3.3: Natural Gas Analysis Comparison (Design vs Test condition)

Description	Unit	Design	Actual (norm)	Deviation
CH_4	%	96.956	96.6124	0.4
C_2H_6	%	1.87	1.9648	-5.1
C_3H_8	%	0.409	0.3775	7.7
C_4H_{10}	%	0.209	0.174	16.7
C_5H_{12}	%	0.064	0.0282	55.9
C_6H_{14+}	%	0.14	0.142	-1.4
N_2	%	0.216	0.3324	-53.9
CO_2	%	0.276	0.3688	-33.6
Total	%	100.14	100.0001	

Observations and Recommendations

- ISO-6976-1995 methods have been followed for the calculation of superior calorific value and the inferior calorific value, density, relative density and Wobbe index of dry natural gas and other combustible gaseous fuels. However, ISO-6976-1995 is withdrawn by International Organization for standards and revised by ISO-6976-2016.
- The density of Natural gas is found to be 0.0444 lbm/ft^3. The same is converted into kcal/kg and found to be 0.7112 kg/m^3.
- Based on the sample report collected form plant site, it is found that inferior CV and superior CV of natural gas is 8333.6357 kcal/m^3 and 9246.2363 kcal/m^3 respectively. Based on the natural gas density the operating inferior CV and superior CV is found to be 11717.3847 kcal/kg (49058.39 kJ/kg) and 13000.5332 kcal/kg (54430.63 kJ/kg). Present report considered the inferior CV as supplied by plant for further calculation.
- The chemical components of natural gas is analyzed during energy audit and design chemical components are almost similar and the same is depicted in the Table 3.3.

CHAPTER- 4

GAS TURBINE MODULE

Each unit of OTPC, Tripura has one GTG; each capacity at base load is 232.39 MW at 27^{o}C ambient condition and 77 % relative humidity. In normal condition, the air is compressed by a compressor and passed to the combustor, there fuel is supplied from fuel feeding system and burnt in the combustion chamber. The burned high temperature fuel – air mixture passes through the turbine. A part of the work developed by the gases passing through the turbine is used to run the compressor and generate the electrical energy through the generator coupled on the same shaft of the gas turbine. Air is admitted to the Gas Turbine compressor via an inlet filter house, ducting/silencing section and air inlet valve. The heat exhaust from the GT is used in HRSG to generate steam. Steam is passed to the STG for each unit to produce Electrical Power.

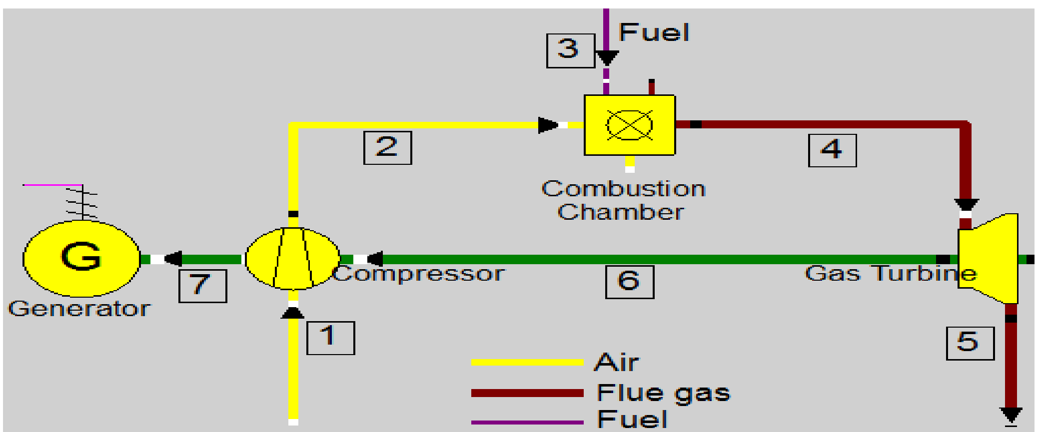


Figure 4.1: Schematic diagram of Gas turbine cycle

Figure 4.1 shows a schematic diagram of GT 9351FA machine with 100% output (232.39 MW site condition, 235.40 kW at ISO condition) at ambient temperature of 27^{o}C and air pressure at compressor inlet 1.02 at. The conversion of heat released by burning fuel into mechanical energy in a gas turbine is achieved by first compressing air in an air compressor, then injecting and burning fuel at (ideally) constant pressure, and then expanding the hot gas in the Gas turbine. The waste heat in flue gas exits from GT at temperature of 616.1^{o}C. The turbine provides the necessary power to operate the compressor. Whatever power is left is used as the mechanical output of the engine. This thermodynamic cycle is called as Brayton cycle. To represent the physical parameters of working fluid at different state is marked as 1, 2, 3…7 as shown in Figure 4.1.

4.1 Design Specification

The design specifications of the Gas turbine are shown in Table 4.1

Table 4.1: Design Specification of Gas Turbine

Make	General Electric
Type	9351FA
Machine No.	298967,298872
Inlet Air Temperature	27°C
Inlet Air Humidity	77%
Altitude	114.9 m
Fuel	Natural Gas
ISO output with natural Gas	256900 kW
ISO heat rate with natural gas	9745 kJ/KWh
ISO exhaust flow	663 kg/s
ISO exhaust temperature	602.2 °C

Main design parameters of GT at different load are given below in Table 4.2:

Table 4.2: Comparison of Gas Turbine parameters

Description	Unit	Design				
Loading	%	100	90	80	70	60
Gas Turbine output	MW	232.99	205.3	174.9	147.9	120.6
GT exhaust flow	t/h	2217.6	1986.2	1811	1675.8	1539.8
GT Exhaust flue gas temperature	^oC	616.1	633.1	648.9	648.9	648.9
HRSG exhaust flue gas temperature	^oC	103	101	90	98	97

4.2 Gas Turbine Module Performance Evaluation

In this section, following system and subsystems have been analyzed to assess their operating condition performance, power consumption pattern and compare with reference condition. The one hour average values for calculating the performance assessment of gas turbine and compressor was taken from the DCS. During Audit the GT1 was running at part load and GT2 was running at base load. During audit equipment changeover was not performed and makeup & de-superheating was in controlled mode.

The systems includes,

- GT compressor efficiency
- GT Module efficiency & Heat rate
- Station efficiency & Heat rate
- Gas performance heater analysis
- Flue gas analysis

4.2.1 GT compressor Efficiency

The OTPC, Tripura has axial flow compressor with 18 numbers of stages. The design compression ratio is 1:16.5 and further details is provided in table 4.3

Table 4.3: Compressor Design details

Compressor Type	**Axial flow**
Number of Compressor Stages	18
Compressor Blade Attachment	Dovetail
Direction of rotation	CCW viewing towards air flow direction from compressor end
Compression ratio	1:16.5
Compressor rated speed	3000rpm
Extractions	9^{th} and 13^{th} stages,18^{th} stage for IBH

The GT compressor was tested for both the unit at operating load of 149.24 MW (unit #1) and 220.55 MW (Unit #2). The compressor adiabatic efficiency was derived based on the data collected during field study and the results are shown in Table 4.4.

Table 4.4: GT Compressor efficiency

Description	**Unit**	**Design**	**Test**	
GT Compressor (Test on 09.08.2017)			Unit 1	Unit 2
GT Load	MW	232.39	149.24	220.55
Air inlet Pressure	bar (a)	1.0003	1.0044	1.0069
Air outlet Pressure	bar (a)	16.5	11.53	14.99
Air inlet temperature	°C	27	33.83	30.54
Air outlet temperature	°C	410*	378.88	415.13
DP air filter	inH2O		1.17	1.19
Pressure Ratio (P2/P1)	-	16.5	11.48	14.89
(k-1)/k	-	0.286	0.286	0.286
Efficiency	%	92.41	89.71	91.85
Air flow	kg/s	602.59	467.03	595.50

Expected Compressor Work	kW	235408.4	164372.8	233604.9
Expected Gas turbine work output	kW	496816.32	327858.17	481472.49
Percentage work required by compressor	%	47.38	50.14	48.52

**value assumed as design information is not available*

Observation and Analysis

- GT compressor efficiency as per test data is found to be 89.71% and 91.85% for unit #1 and 2 respectively. During test, unit#1 and unit #2 was operating at 149.24 MW and 220.55 MW respectively against the design load of 232.39 MW.
- The pressure ratio during test condition is calculated to be 11.48 and 14.89 respectively against design of 16.5 bar. The air flow through compressor was calculated based on the flow of GT exhaust and natural gas, for unit #1 and unit # 2 found to be 467.034kg/s and 595.50 kg/s respectively against design of 602.59 kg/s. The expected power consumption of compressor is around 45 % for unit #1 and 48 % in unit#2. This may be due to higher air temperature as compared to the design of 27^oC.
- As the air temperature is higher about 3 to 5^oC as compared to design, warm air needs more energy to compress, hence removing more work from the compressor, increasing internal losses. The work required by the compressor is increased by 2.75 % in unit 1 and 1.14% in unit 2 of the total turbine power.
- During field test compressor Inlet guide vane for unit – 1 and unit – 2 is at 60.34 DGA and 88 DGA respectively for controlling the GT power output.
- Overall performance of the compressor is found to be satisfactory.

Recommendation

- It is suggested to maintain the compressor clean by maintain GT intake air filter DP as per requirement by periodic pulsation cleaning.
- Recommended to follow the PM schedules & steps for sustaining the efficiency.

4.2.2 GT Module efficiency and Heat rate

Each Gas turbine is of 3 stages with rated shaft speed at 3000rpm. Open cycle heat rate has been calculated based on the natural gas flow and power output. Details of natural gas flow, NCV, heat rate and efficiency are shown in Table 4.5.

Table 4.5: GT heat rate

Description	Unit	Design	Test	
GT (Test on 09.08.2017)			Unit 1	Unit 2
GT Gross Load at generator terminal	kW	232390	149240	220550
Fuel flow	kg/s	13.41	9.77	12.80
LHV	kJ/kg	49328	49058.39	49058.39
GT Efficiency	%	35.14	31.15	35.13
GT Heat rate (gross)	kcal/kWh	2447.66	2761.04	2448.05
Expected Gas turbine work output	kW	496816.32	364428.73	486217.23

Observations and Analysis

- The Gas turbine module heat rate for unit #1 & 2 has calculated based on the data collected during the field visit and found to be 2761.04kcal/kWh and 2448.05kcal/kWh against design of 2447.66 kcal at ambient temperature of 27^{o}C. The GT efficiency of unit 1 &2 is found to be 31.15 % and 35.13 % against design of 35.14% respectively.
- Based on the efficiency test the unit 2 GT operates better than the unit1 GT. The poor performance of unit 1 GT is due to part load operation. The specific fuel consumption is found to be 0.33 SCM/kWh and 0.29 SCM/kWh (open cycle) for Gas Turbine 1 and Gas Turbine 2 respectively as compared with the design value of 0.29 SCM/kWh.
- The GT exhaust temperature of unit #1 and 2 is recorded as 649^{o}C and 645.36^{o}C respectively. The exhaust temperature of GT 1 is close to the expected value of 647.4^{o}C (based on thermodynamic balance), where as exhaust temperature of GT2 is expected to be 620.84^{o}C. The higher recorded value of GT2 may due to measurement uncertainty.
- Overall performance of GT is found to be satisfactory.

4.2.3 Station Efficiency & Heat rate

The combined cycle efficiency and heat rate has been calculated based on the data collected during field test. The results are depicted in Table 4.6.

Table 4.6: Overall station performance

Description	Unit	Design	Test	
			Unit 1	Unit 2
Ambient Temperature	°C	27	33.83	30.54

Ambient Pressure	kg/cm^2 (a)	1.02	1.0044	1.0069
Relative humidity	%	77	87.8	87.8
Gross load	kW	363300	249170	343010
LHV	kJ/kg	49328	49058.3863	49058.3863
GT exhaust flow	kg/h	2217600	1716480	2189880
Fuel flow	kg/h	48270.24	35160	46070
Gross Heat rate	kJ/kWh	6299.85	6922.6	6589.1
	kcal/kWh	1505.7	1653.4	1573.8
Gross Efficiency	%	54.94	52.01	54.65
Specific Fuel consumption	SCM/kWh	0.187	0.198	0.190

Observation and Analysis

- Overall combined cycle efficiency of unit 1 is calculated to be 52.01 % and unit 2 is found to be 54.65 % against design value of 54.94%. Corresponding gross heat rate based on LHV is calculated as 1653.4 kcal/kWh and 1573.8 kcal/kWh for unit #1 & 2 (against the design value of 1505.7 kcal/kWh).
- Based on the correction curve the corrected heat rate is calculated as 1617.96 kcal/kWh and 1541.36 kcal/kWh for unit 1 & 2. The operating heat rate is affected by higher ambient temperature, Relative humidity and CW temperature. Deteriorated heat rate in unit 1 is due to part load operation.
- The specific fuel consumption for unit 1 and unit 2 is calculated and found to be 0.198 SCM/kWh and 0.190 SCM/kWh against the design value of 0.187 SCM/kWh.

4.3 Flue gas analysis

Flue gas composition is measured using the Testo flue analyzer at the HRSG exhaust and the findings are depicted in Table 4.7 and Table 4.8 for both the units

Table 4.7: Measured Flue gas parameter at HRSG outlet (unit #1)

Parameter	Unit	2nd Port		3rd Port		4th port		Average
		2m	1m	2m	1m	2m	1m	
O_2	%	13.6	13.56	13.52	13.49	13.5	13.59	13.54
CO_2	%	4.19	4.23	4.2	4.24	4.2	4.2	4.21
CO	PPM	1	1	1	1	1	1	1.00
NOx	PPM	9	8	8	7	7	6	7.50
Temp	˚C	95.1	95	94.9	94.8	90.5	90.5	93.47
SO_2	PPM	0	0	0	0	0	0	0.00

Table 4.8: Measured Flue gas parameter at HRSG outlet (unit #2)

Parameter	Unit	2nd Port		3rd Port		4th port		5th port		Average
		2m	1m	2m	1m	2m	1m	2m	1m	
O_2	%	14.1	14.13	14.15	14.03	13.95	13.79	13.75	13.6	13.94
CO_2	%	3.92	3.94	4	3.95	4.2	4.1	4.2	4.2	4.06
CO	PPM	15	15	12	12	11	11	8	8	11.50
NOx	PPM	7	6	7	7	8	8	6	6	6.88
Temp	˚C	88.9	88.4	91	87.9	90	88.5	92	91.8	89.81
SO_2	PPM	0	0	0	0	0	0	0	0	0.00

During the same period the exhaust flue gas has recorded in DCS using online analyzer for unit – 1 and unit – 2. The average data for unit – 1 and unit – 2 are depicted in Table 4.9

Table 4.9: Flue gas parameters (DCS data)

Parameter	Unit	Unit – 1	Unit – 2
O_2	%	11.6	11.5
CO	PPM	1.3	12.9
NOx	PPM	19.3	17.1
Temperature	˚C	86.9	87.9
SO_2	PPM	0.1	0.2

Observation and Analysis

- The flue gas analyzer has measured at 2nd, 3rd, 4th and 5th port (unit – 2) of HRSG exhaust. Percentage of O_2 and flue gas exhaust temperature measured using Testo flue gas analyzer is nearly similar with DCS value.
- The CO measured in Unit – 2 is more than the unit – 1 CO. This may be due to Gas turbine combustor problem. Hence it is requested to check in next CI inspection.
- The CO_2 percentage is measured for unit – 1 and unit – 2 and found to be 4.21 and 4.06 respectively.

4.4 Performance gas heater analysis

The plant has installed shell and tube performance gas heater for heating the natural gas to 185^{o}C before supplying to the gas turbine. The design details of the performance gas heater is shown in the Table 4.10

Table 4.10: Performance gas heater design details

Type	TEMA "AEL"
Number of coolers	Two in series
Gas flow	51520 kg/hr
Inlet temperature of Gas	112°C
Outlet temperature of Gas	190°C
Operating pressure of Gas	31.4 Bar(g)
Pressure drop on Gas side	0.6 Bar
Heat Duty	2565000 kcal/hr
Heat Transfer Coefficient	302.56 kcal/Sq.m-hr-°c
Total number of tubes	358 (Per cooler)

The performance gas heater was tested for unit – 1 and unit – 2 and the results are depicted in Table 4.11.

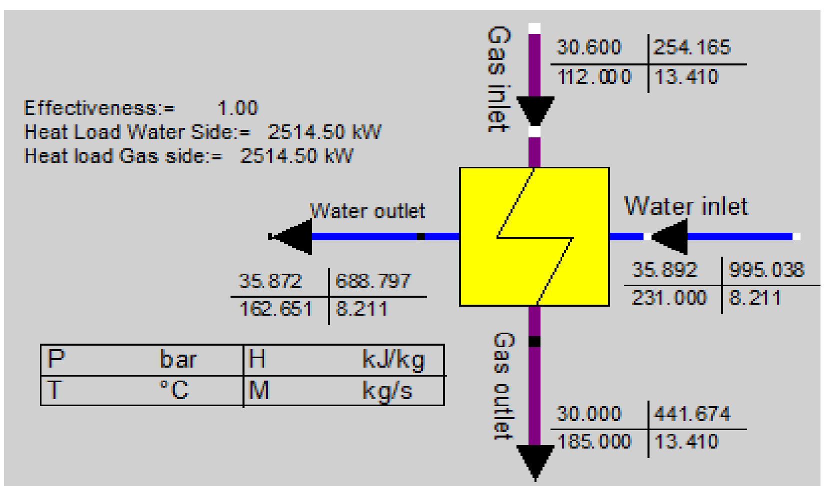
Table 4.11: Gas heater performance

Particulars	Unit	Design*	Unit – 1	Unit – 2
Gas flow	kg/s	13.41	9.77	12.80
Gas inlet temperature	ºC	112.00	135	132.55
Gas outlet temperature	ºC	185.00	187.88	181.54
∆ T of Gas	ºC	73.00	52.88	48.84
Feed water inlet temperature	ºC	231.00	225.4	233.99
Feed water outlet temperature	ºC	162.65	135.84	148.99
Feed water flow	kg/s	8.21	3.86	3.79
∆ T feed water	ºC	68.35	89.56	85

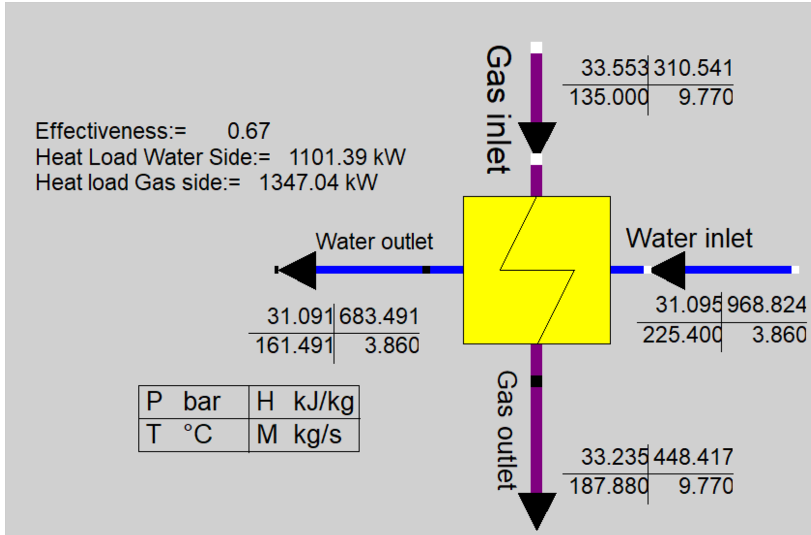
**Based on heat and mass balance diagram for 100 % load, Tamb=27 °C*

The energy and mass balance of the gas pre-heater for unit #1 & 2 is shown in the figure 4.2

Design



Unit 1



Unit 2

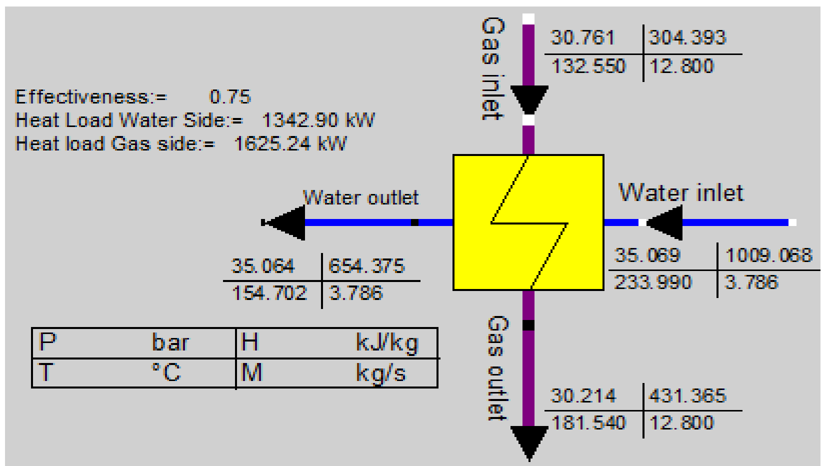


Figure 4.2: Performance heater Energy & Mass Balance

Observation and Analysis

- The gas heater is evaluated based on the data collected from site during field testing and the results are as shown in above table.
- Effectiveness of gas pre-heater is found to be 0.67 and 0.75 for unit 1 & 2 against design value of 1(considering no loss in design). This indicates the deterioration of the performance of the gas heater. Based on the data collected the feed water outlet temperature from the heat exchanger is 135. 84 ^{o}C for unit 1 and 148.99 ^{o}C for unit 2. Whereas as per mass and energy balance the calculated temperature of feed water outlet will be 161.49 and 154.72 for unit 1 & 2 respectively as shown in Figure 4.2.

- The available heat load of feed water in unit 1 heat exchanger is 1101.38 kW (947023 kcal/hr), where as the required heat load to increase the gas temperature from 135 ^oC to 187.88 ^oC is around 1347.04 kW (1158249 kcal/hr). This indicates the energy imbalance across the heat exchanger. This leads to lower effectiveness of the heater. To achieve the required balance the minimum feed water flow rate should be 5.14 kg/s, which will improve the effectiveness to 0.75. The feed water outlet temperature will be around 166 ^oC and the heat loss will be minimize to 1.25 kW (1075 kcal/hr). Similarly the required feed water flow in unit 2 heat exchanger should be 4.86 kg/s, with improved effectiveness of 0.82 and heat loss reduced to 3.15 kW. Feed water temperature at the outlet of heat exchanger will be around 159.2 ^oC.

Recommendation

- The temperature from the gauge has been considered for performance calculation of unit 1 gas Preheater and mentioned in Table 4.11.
- The drain from the gas heater is at temperature of around 140 ^oC and flows to the condenser and the heat energy in the heater drain is un-utilized. Hence it is suggested to pass the drain from gas heater to the deareator. Expected saving by implementing this measure is workout to be,

Parameter	unit	Unit 1	unit 2
Present condenser load	kcal/hr	122373948	137927690
proposed condenser load	kcal/hr	120514298.1	135896956.7
Percentage of saving	%	1.5	1.5
proposed energy saving in CWP	KW	28.74	27.795
Annual running hours	hrs/yr	5606.4	5606.4
power saving	kWH	161127.936	155829.888
Energy cost	Rs/kWh	2.75	3.75
Annual Energy Saving	Rs.Cr	0.044	0.058
Investment	Rs.Cr	0.025	0.025
Payback	Month	7	5

CHAPTER – 5

HRSG PERFORMANCE

HRSG is the component of bottoming steam cycle in CCPP process and it absorbs waste heat that is exhaust from the GT for producing steam at rated parameters suitable for electricity generation by STG. In a typical CCPP plant ST is selected according to the condition of the steam delivered by HRSG. Hence, HRSG performance will critically affect the closed cycle heat rate, overall system efficiency and power output. Each unit of OTPC has one HRSG of horizontal, natural circulation, water tube, top supported, fully drainable, triple Pressure with reheat type. The design detail is shown in Table 5.1 and process flow & arrangement of pressure parts/ heat exchangers are shown in Figure 5.1.

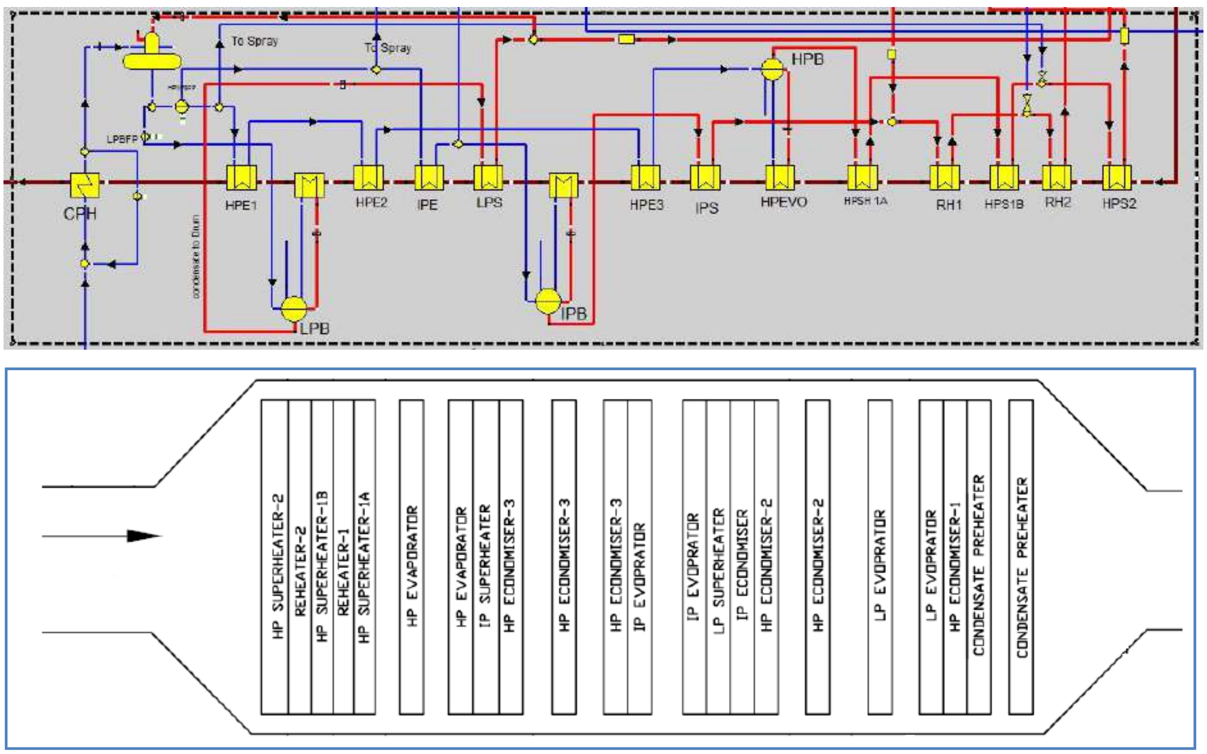


Figure 5.1: HRSG process flow and arrangement diagram

The design & actual measured parameters are taken during HRSG 1 & 2 in operation having generating capacity of 238.22 t/h and 288.3 t/h and the analysis are depicted in below sections. Actual operating parameters were taken from DCS in CCR as well as from local. Local measurement was taken for flue gas analysis using flue gas analyzer.

Temperature measurement was taken using infrared thermometer & digital temperature indicator at local.

Table 5.1: HRSG Design specification

HRSG Type	Horizontal, natural circulation, water tube, top, supported, fully drainable, modular design, triple pressure with reheat type waste heat boiler.
GT fuel	Natural Gas
HRSG fuel	Unfired
Heat source	GT Exhaust gas
Maximum Capacity	289TPH

5.1 HRSG Performance

Both the units are having one horizontal type HRSG each capacity of 289 T/h. The unit is designed to generate 130.91 MW from each steam turbine. The main operating parameters in design condition are shown in Table 5.2.

Table 5.2: critical design parameters of HRSG

Parameters	**Value**
HP Feed Water Pressure, temperature, flow	158 kg/cm^2,152.1°C ,289.6 TPH
HP Drum Pressure, temperature ,level	145 kg/cm^2,339°C,MWL 100mm Above CL
HP Drum Metal Temperature	339 °C
HP DESH Inlet Pressure, Temperature	139 kg/cm^2,449 °C
HP DESH Outlet Pressure, Temperature	138.5 kg/cm^2,449 °C
HP SH Metal Temperature	580°C
HP Main Steam Pressure, temperature, flow	134 kg/cm^2,540°C,289.6 TPH
CBD Pressure, Temperature, level	3.8 kg/cm^2,540°C,600mm
HPSH Spray Water Inlet Pressure, temperature, flow	91 kg/cm^2,152.1 °C,20 TPH
IP Feed Water Pressure, temperature	100 kg/cm^2,150.2 °C,65TPH
IP Feed Control Station inlet Pressure, temperature, flow	36.6 kg/cm^2,236 °C,30.8 TPH
IP Feed Control Station inlet Pressure, temperature, flow	36.6 kg/cm^2,236 °C,30.8TPH
IP Drum Pressure, temperature, level	36.6 kg/cm^2,246°C,NWL at CL
IP Main Steam Pressure, temperature, flow	34.6 kg/cm2,330°C,35.6 TPH
LP Feed Water Pressure, temperature, flow	6.6 kg/cm^2,149.6 °C,36.7 TPH
LP Drum Pressure, temperature, level	5.1 kg/cm^2,159 °C,36,NWL at CL
LP Main Steam Pressure, Temperature, Flow	4.4 kg/cm^2,230°C,36.7 TPH
RH DESH Inlet Pressure, Temperature	33.9 kg/cm^2,461°C

RH Metal Temperature	570°C
CRH Inlet Pressure, Temperature	34.8 kg/cm^2,345°C
CRH Outlet Pressure, Temperature	33.2 kg/cm^2,540°C
HRH Outlet Pressure, Temperature	33.2 kg/cm^2,540°C
RH Spray Pressure, Temperature ,flow	22 kg/cm^2,150.2°C,12TPH
CPH Inlet Pressure, Temperature, flow	65 kg/cm^2,60°C,444.8 TPH
CPH Outlet Pressure ,Temperature, flow	65 kg/cm^2,141.5 °C,444.8 TPH
HRSG Inlet Pressure, temperature, flow (flue gas)	266.71mmWC,700 °C,2217.6 TPH

During energy audit the HRSG operation was observed and HRSG operating parameters from DCS of CCR were taken for both HRSG's running at 238.22 t/h (HRSG-1) and 288.3 t/h (HRSG-2) is presented in this report. Local measurements were also taken to measure flue gas parameters, temperature at various locations so as to estimate the HRSG efficiency. The thrust areas covered in this chapter including observations and analysis are:

- HRSG Efficiency
- Condensate Pre-heater performance
- LP circuit performance
- IP circuit performance
- Re-heater circuit performance
- HP circuit performance
- Observation & analysis

5.1.1 HRSG Efficiency

HRSG efficiency is calculated by both direct and indirect method with a steam generating rate of 238.22 t/h and 288.3 t/h in unit 1 & 2. The calculation is performed based on design & actual data collected during field testing is presented in Table 5.3.

Table 5.1: HRSG efficiency (a) Direct Method (b) Indirect method

(a)

Description	Unit	Design	Test	
Direct Method (Input/output)			HRSG-1	HRSG-2
HRSG inlet flow	kg/s	616.00	476.8	608.3
Energy input	kW	424430.16	347115.1	423169.98
Energy Out	kW	67310.14	50639.5	69005.55

Energy Used	kW	357120.02*	296475.7	354164.43
HRSG efficiency	%	84*	85.41	83.69

**Design details are calculated based on the design data available in technical diary and heat balance diagram.*

(b)

Description	Unit	Design	Test	
Indirect method (loss)			HRSG 1	HRSG 2
HP steam Flow	t/h	289.6	238.22	288.3
HP steam Enthalpy	kcal/kg	821.8	830.63	823.44
IP steam Flow	t/h	35.6	27.72	36.29
IP steam Enthalpy	kcal/kg	730.25	709.45	729.83
LP steam Flow	t/h	36.7	28.4	36.75
LP steam Enthalpy	kcal/kg	696.9	696.76	699.46
FW temp at HP BFP Outlet temp	°C	152.1	143.74	149.42
FW temp at IP BFP Outlet temp	°C	150.2	142.39	147.75
FW temp at LP BFP Outlet temp	°C	149.5	149.5	144.44
HRSH inlet temperature	°C	615.1	649.06	622.15
HRSG outlet temperature	°C	103	97.49	97.79
Flue gas flow rate	t/h	2217.6	1716.48	2189.88
HRSG efficiency	%	84*	79.32	82.65

**Design details are calculated based on the design data available in technical diary and heat balance diagram.*

Observation and Analysis

- HRSG-1 & 2 efficiency is evaluated both by direct method and loss method. The operating efficiency of HRSG by loss method is found to be 79.32 % and 82.65 % against design of 84%. There is deviation between both method of calculation (6.09% & 1.05 % for HRSH 1& 2 respectively) and it may be due to heat losses in the pressure parts and measurement uncertainty. It can be observed that the HRSG efficiency in full load condition is matches from both side calculation (I,e by direct and loss method) where as there is a large deviation in part load fraction.

5.1.2 Condensate Pre-heater performance

The condensate from CEP discharge flows to the condensate pre-heater at the temperature of 60^{o}C for heating the condensate water before deaerator. The critical parameters CPH inlet pressure, temperature, flow is 65 kg/cm^2, 60°C, 444.8 TPH. The same is heated in the condensate pre-heater and Critical outlet pressure, temperature; flow is 65 kg/cm^2, 141.5 °C, 444.8 TPH. The condensate pre-heater is serrated finned tubes type with the heat transfer surface area of 38789.6 m^2. A portion of the water from the Pre-heater outlet is taken to the Pre-heater Recirculation Pump suction. It then is being re-circulated and mixed with the feed water entering the Pre-heater inlet to increase the temperature of the incoming feed water prior to entering the deaerator. The condensate pre-heater circuit and flue gas circuit performance is provided in Table 5.4.

Table 5.2: Condensate pre-heater circuit

Particulars	Unit	Design	Unit 1	Unit 2
Water circuit				
CPH inlet flow	TPH	385.765	332.50	375.00
CPH input temperature	°C	60.00	59.76	60.00
CEP outlet pressure	kg/cm^2	25.0	24.31	22.97
CPH input energy	kcal/sec	6429.75	5519.50	6250.00
CPH output temperature	°C	141.50	135.53	143.19
Dearator pressure	kg/cm^2	4.79	3.66	4.09
CPH output energy	kcal/sec	15163.49	12517.70	14915.63
Energy gain in CPH	kcal/sec	8733.74	6998.20	8665.63
Flue gas circuit				
HRSG outlet temperature	°C	103.00	89.50	89.81
flue gas flow into HRSG	kg/sec	616.00	476.80	608.30
Specific Heat of flue gas	kcal/kg	0.28	0.28	0.28
Flue gas temperature at pre-heater inlet	°C	159.71	148.21	146.79

5.1.3 LP circuit performance

LP feed water from the suction of deaerator is discharged at a pressure of 10.4 kg/cm^2 by LP BFP to the LP drum. Rated LP feed water inlet pressure, temperature & flow is 6.6 kg/cm^2, 149.6°C, 36.7 TPH. The LP drum operates at pressure of 5.1 kg/cm^2. Design LP main steam parameters at out of HRSG is 4.4 kg/cm^2, 230°C and 36.7 TPH. The performance of LP circuit is provided in Table 5.5.

Table 5.3: LP circuit

Particulars	Unit	Design	Unit 1	Unit 2
LP feed water flow	t/h	36.7	28.17	23.566
LP feed water press	kg/cm^2	10.4	19.04	18.26
LP feed water temp	°C	149.5	140.09	144.6
Enthalpy of LP feed water	kcal/kg	150.7	141.0534	144.6
Energy from LP FW	kcal/sec	1536.303	1103.743	946.5677
LP Drum pressure	kg/cm^2	5.10	3.67	4.71
LP Saturation temperature	°C	151.85	139.84	148.87

LP main steam flow	tph	36.7	28.17	35.78
LP Steam Press	kg/cm^2	4.8	3.66	4.2
LP Steam Temp	°C	229	228.27	234.64
LP Steam Enthalpy	kcal/kg	696.9	697.77	700.414
Energy from LP steam	kcal/sec	7104.508	5460.05	6961.337
Energy gain from LP circuit	kcal/sec	5568.206	4356.307	6014.769
Approach	°C	2.246	-0.247	4.273

5.1.4 IP Circuit performance

The intermediate pressure (IP) feed water from intermediate stage of HP/IP- BFP at pressure of 43.60 kg/cm^2 enters the IP Drum through the IP Economizer (IPE). For fuel heating IP water tapping is taken from IPE inlet. Natural circulation is maintained in the IP Evaporator by means of down comers, which feed the water from the drum through distribution manifolds to the lower evaporator headers. The saturated steam from IP super heater mix with HP turbine exhaust steam and passes to the two re-heater stages for further heating before being expanded in IP turbine (IPT). The performance of the IP circuit is provided in Table 5.6.

Table 5.4: IP circuit

Particulars	Unit	Design	Unit 1	Unit 2
IP feed water flow	tph	65.159	25.83	44.03
IP feed water press(eco)	kg/cm^2	43.60	47.52	70.31
IP feed water temp(eco)	°C	150.2	142.39	147.75
Enthalpy of IP feed water	kcal/kg	151.7	143.84	149.658
Energy of FW	kcal/sec	2745.73	1032.03	1830.4
IP Drum pressure	kg/cm^2	36.60	31.3	36.90
IP Saturation temperature	°C	244.01	236.95	246.04
IP main steam flow	tph	35.8	13.69	36.29
IP Steam Press	kg/cm^2	36.6	27.95	33.77
IP Steam Temp	°C	246	288.43	327.95
IP Steam Enthalpy	kcal/kg	730.2	710.16	729.79
Energy from IP steam	kcal/sec	7261.43	2700.57	7356.689
Energy gain from IP circuit	kcal/sec	4515.71	1668.55	5526.288
IP feed water temperature from IP ECO	°C	231	225.4	233.99
Approach	°C	13.01*	11.549	12.049

**Design approach is calculated based on the design data available in technical diary and heat balance diagram.*

5.1.5 HP Circuit performance

HP feed water from HP/IP pump at a pressure of 158 kg/cm^2 and temperature of 152.1^{o}C is supplied to the HP drum via series of HP economizers (HPE) viz HPE1,HPE22 & HPE3. The saturated steam leaving the drum passes through series of HP super-heater (HPS) viz, HPS1A, HPS1B and HPS2 before being expanded in high pressure turbine (HPT) at a rated pressure and temperature of 134 kg/cm^2 and temperature of 540^{o}C. The performance of the HP circuit is provided in Table 5.7.

Table 5.5: HP circuit

Particulars	Unit	Design	Unit 1	Unit 2
HP feed water flow	tph	289.6	217.24	281.2
HP feed water press(eco)	kg/cm^2	158	125.73	141.9
HP feed water temp(eco)	°C	152.1	143.74	152.35
Enthalpy of HP feed water	kcal/kg	155.5	146.40	155.415
Energy of FW	kcal/sec	12509.11	8834.34	12139.63
IP Drum pressure	kg/cm^2	145.00	114.23	137.50
IP Saturation temperature	°C	151.85	139.84	148.87
HP main steam flow	tph	289.6	238.22	288.3
HP MS press	kg/cm^2	135	103.35	125.96
HP MS Temperature	°C	540	540.75	540
Enthalpy of HP MS	kcal/kg	821.8	830.55	824.5
Energy from HP MS	kcal/sec	66109.24	54959.34	66028.71
Energy gain from LP circuit	kcal/sec	53600.13	46124.99	53889.07

5.1.6 Re-heater Circuit performance

IP steam mix with CRH steam passes through Re heaters (RH1 & RH2). The reheated steam at a pressure of 34.2 kg/cm^2 and temperature of 540 °C leaves HRSG. The performance of the Re heater circuit is provided in table 5.8.

Table 5.6: CRH circuit

Particulars	Unit	Design	Unit 1	Unit 2
CRH flow	tph	269.45	238.22	288.30
CRH pressure	kg/cm^2	35.85	28.60	33.75
CRH temperature	°C	347.5	362.00	350.00
Enthalpy of CRH	kcal/kg	740.30	751.93	742.61
Energy of CRH	kcal/sec	55408.37	43467.64	52180.52
IP feed water flow	tph	65.16	25.83	44.03
IP feed water press(eco)	kg/cm^2	0.00	47.52	70.31

IP feed water temp(eco)	°C	0.00	142.39	147.75
Enthalpy of IP feed water	kcal/kg	151.70	143.84	149.66
Energy of FW	kcal/sec	2745.73	1032.03	1830.40
HRH pressure	kg/cm^2	33.30	27.68	31.98
HRH temperature	°C	540	540.89	536.50
Enthalpy of HRH	kcal/kg	846.00	848.33	844.99
Energy of HRH	kcal/sec	71732.58	52266.55	67892.92
Total energy into Re heater	kcal/sec	58154.10	44499.67	54010.92
Energy gain from Re heater	kcal/sec	13578.48	7766.89	13882.00

5.1.7 Flue gas performance

The flue gas exhaust from the gas turbine at the temperature around 630 deg passes through the Heat Recovery steam generator for utilizing the heat for generating the power through steam turbine. The performance of flue gas is provided in Table 5.9.

Table 5.7: Flue gas circuit

Particulars	Unit	Design	Unit 1	Unit 2
HRSG inlet temperature	°C	616.1	649.06	622.15
HRSG outlet temperature	°C	103	89.50	89.81
flue gas flow into HRSG	kg/sec	616	476.80	608.3
Specific Heat of flue gas	kcal/kg	0.25	0.25	0.28
Energy From Flue gas	kcal/sec	79017	66700	90670
Input energy to HRSG	kcal/sec	94879	77368	109920
output energy from HRSG	kcal/sec	15862	10668	15297
Energy utilized from flue gas	kcal/sec	79017	66700	94623

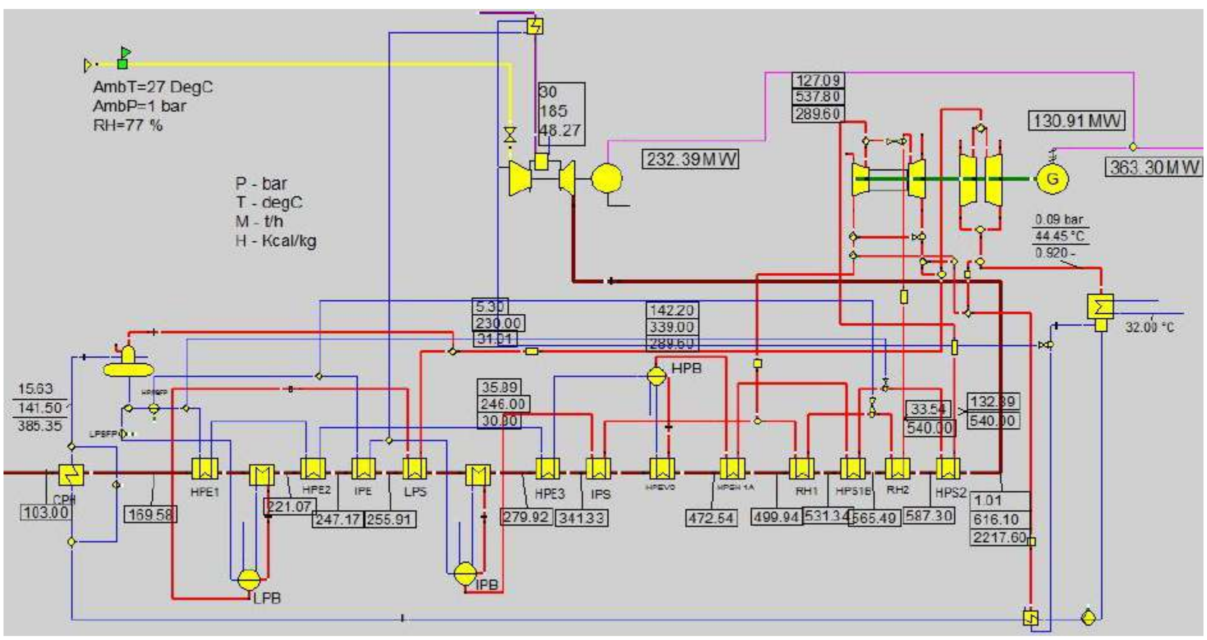
Observation & Analysis

- The energy gain in the condensate pre-heater is found to be 6998.20 kcal/sec and 8665.63 kcal/sec for unit -1 and unit –2 respectively with respect to the design value of 8733.74kcal/sec. The unit – 1 heat gain is lower side due to part load operation.
- Based on the flue gas outlet condition, the inlet flue gas temperature to CPH would be around 148.21°C and 146.79°C respectively for unit 1 and unit 2. However, the design would be around 159.71°C.
- The approach of LP circuit is calculated for both design and test condition and it shows that design approach is around 2.246°C, however unit 2 approach is 4.273°C.

This shows that LP feed water inlet temperature that flow to the LP drum should be more to achieve the design approach.

- The LP circuit approach for unit – 1 is -0.247 and is not possible. Hence it is recommended to calibrate the temperature measurement equipments.
- The pinch is not calculated due to the non availability of temperature in flue gas side.
- The energy gain in both LP circuit and IP circuit is higher than the design for unit – 2. This shows that heat transfer in LP evaporator, super heater and IP economizer, evaporator and super heater is better.
- However, the energy gain in HP and Re-heater circuit is lower than the design value.
- To calculate the approach, pinch and details performance of HRSG, it is recommended to install temperature meter and pressure gauge.

Overall mass and energy balance diagram generated in Ebsilon® Professional platform is shown in figure 5.2, for both design and operating scenario. The flue-gas temperature profile is generated based on the design information and recorded water/steam side temperature measurements.



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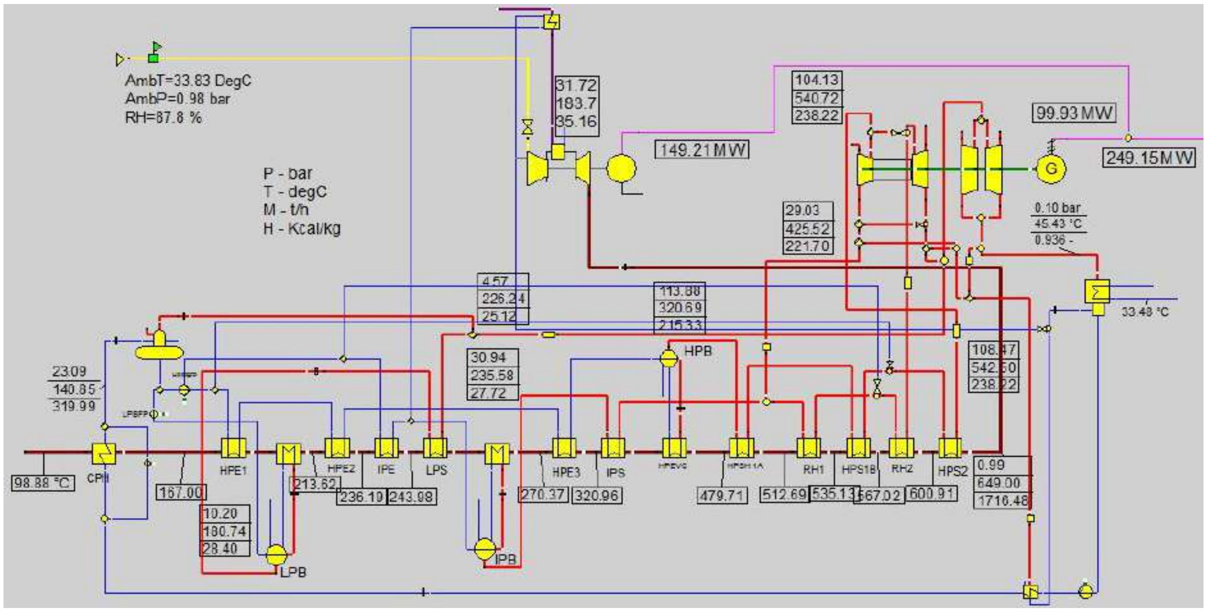

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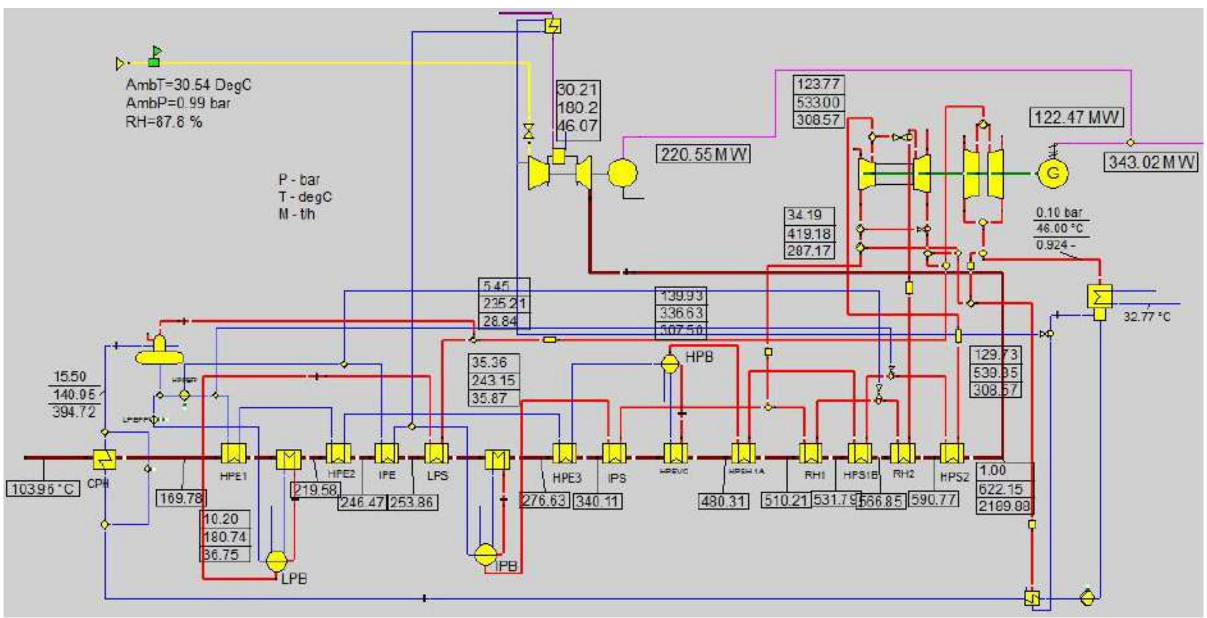


(c)

Figure 5.1: Overall mass and energy balance diagram (a) design, (b) Unit1 operating & (c) Unit 2 operating

CHAPTER- 6

TURBINE & CONDENSER PERFORMANCE

The power station consists of 2 nos of 130.91 MW capacity individual STGs connected to each HRSG. The running capacity of steam turbine is based on the steam supplied from the HRSG. In other words, the running capacity of steam turbine will directly depend on the gas turbine loading and GT flue gas exhaust.

6.1. Design Specification

The station is equipped with (2 X 130.91 MW) of two cylinders reheat condensing turbine to generate additional power by utilizing the flue gas. The steam after expanding through HP turbine (HPT) is reheated in the re-heater returned to the IP turbine (HPT). Then the reheated steam after expanding through IP and double flow stages of LP turbine is exhausted to the condensers at the exhaust part of the LPT. Additional LP steam is also mixed with the IP exhaust and passed to the LP turbine. The design details of the turbine are shown in Table 6.1.

Table 6.1: Design details of Turbine

Design Details	
Manufacturer	BHEL, Hyderabad
Type	Two cylinder reheat condensing turbine
No of Casings	2
Nominal HP steam temperature, pressure	540 °C,129.6 kg/cm^2
Nominal IP steam temperature, pressure	540 °C,34.2 kg/cm^2
Nominal LP steam temperature, pressure	261.2 °C,4.48 Kg/cm^2
HP Turbine stages	23 stages single flow
IP turbine stages	21 stages single flow
LP turbine stages	18 stages, dual flow
Rated Steam temperature, pressure HPT inlet	537.8 °C, 129.6 kg/cm^2
Before 1st HP drum stages pressure	126.8 kg/cm^2
HP cylinder exhaust temperature, pressure	347.3 °C, 35.85 kg/cm^2
IP cylinder stop valve inlet temperature, pressure	539.6 °C, 33.30 kg/cm^2
LP turbine inlet temperature, pressure	281.2 °C, 4.80 kg/cm^2
LP turbine exhaust pressure	0.095 ata

**As per plant personal, however, based on technical diary the value is different*

Parameters comparison at different load of design condition is given below in Table 6.2:

Table 6.2: Comparison of Turbine parameters

Description	Unit	Design				
Loading	%	100	90	80	70	60
Steam Turbine output	MW	130.91	121.8	115.5	106.5	97.5
HP inlet steam flow	t/h	289.6	270.6	257.4	237.8	218.2
IP Inlet steam flow	t/h	289.8*	285.779	272.896	252.67	233.102
LP Inlet steam flow	t/h	354.33	327.507	308.974	284.865	261.584
HP steam pressure	ata	129.6	121.44	115.7	107.2	98.66
IP steam pressure	ata	33.3	31.21	29.8	27.8	25.47
LP steam pressure	ata	4.8	4.44	4.18	3.86	3.54
Condenser vacuum	ata	0.095	0.0907	0.0877	0.0841	0.0807

**As per plant personal, however, based on HMBD the IP steam flow is 305.045*

6.2 Turbine Performance Evaluation

In this section, following system and subsystems have been analyzed to assess their operating condition performance, power consumption pattern and compare with reference condition. The one hour's average values for calculating the performance assessment of turbine and condenser has taken from the DCS.

The systems includes

- Turbine efficiency
- Water steam cycle efficiency and heat rate
- Turbine pressure survey
- Condensers
- Specific steam consumption

6.2.1 Turbine Efficiency

The rated output of the generator is 130.91 MW with main steam entering in the HPT with 129.60 kg/cm^2 (a) pressure and 537.8^{o}C temperature. Steam pressure and temperature at the inlet of IPT is 33.30 kg/cm^2(a) and 539.6 ^{o}C and at LPT inlet 4.80 kg/cm^2(a) & 261.2^{o}C. The HP, IP and LP turbine cylinder efficiency is computed based on the data collected during field study and the results are shown in Table 6.3.

Table 6.3: Turbine operating efficiency

Parameter	Unit	Design*	Unit 1	Unit 2
ST Load	MW	130.91	99.93	122.46
HP Turbine				
HPT inlet steam pressure	kg/cm^2 (a)	129.6	104.4	126.2
HPT inlet steam Temperature	°C	537.8	540.75	533.00
HPT inlet steam enthalpy	kcal/kg	821.8	829.86	819.7
HPT exhaust steam pressure	kg/cm^2 (a)	35.85	29.6	34.86
HPT exhaust steam Temperature	°C	347.3	362.00	350.00
HPT exhaust steam enthalpy	kcal/kg	740.3	751.446	742.08
HP turbine efficiency	%	89.1	85.28	87.72
HP shaft power	MW	26.1	20.52	24.19
IP Turbine				
IPT inlet steam pressure	kg/cm^2 (a)	33.3	28.68	32.98
IPT inlet steam Temperature	°C	539.6	540.89	537.87
IPT inlet steam enthalpy	kcal/kg	846	847.79	845.18
IPT exhaust steam pressure	kg/cm^2 (a)	4.88	3.64**	4.49**
IPT exhaust steam Temperature	°C	264.5	256.91**	256.09**
IPT exhaust steam enthalpy	kcal/kg	714.6	711.79	710.74
IP turbine efficiency	%	95.8	93.2	95.3
IP shaft power		49.19	41.12	47.77
LP Turbine				
LPT inlet steam pressure	kg/cm^2 (a)	4.8	3.97	4.56
LPT inlet steam Temperature	°C	261.2	227.09	234.64
LPT inlet steam enthalpy	kcal/kg	713.1	696.84	700.04
LPT exhaust steam pressure	kg/cm^2 (a)	0.095	0.1	0.103
LPT exhaust steam Temperature	°C	44.5	47	47.05
LPT exhaust steam enthalpy	kcal/kg	571.2	576.65	566.92
LP turbine efficiency	%	89.1	83.0	88.8
LP shaft power		57.72	46.69	56.54

**Design efficiency has calculated based on HMBD data,*

**As operating condition data was not available hence the same has been generated from the ebsilon model and validated using the curve fit from the HBD data.

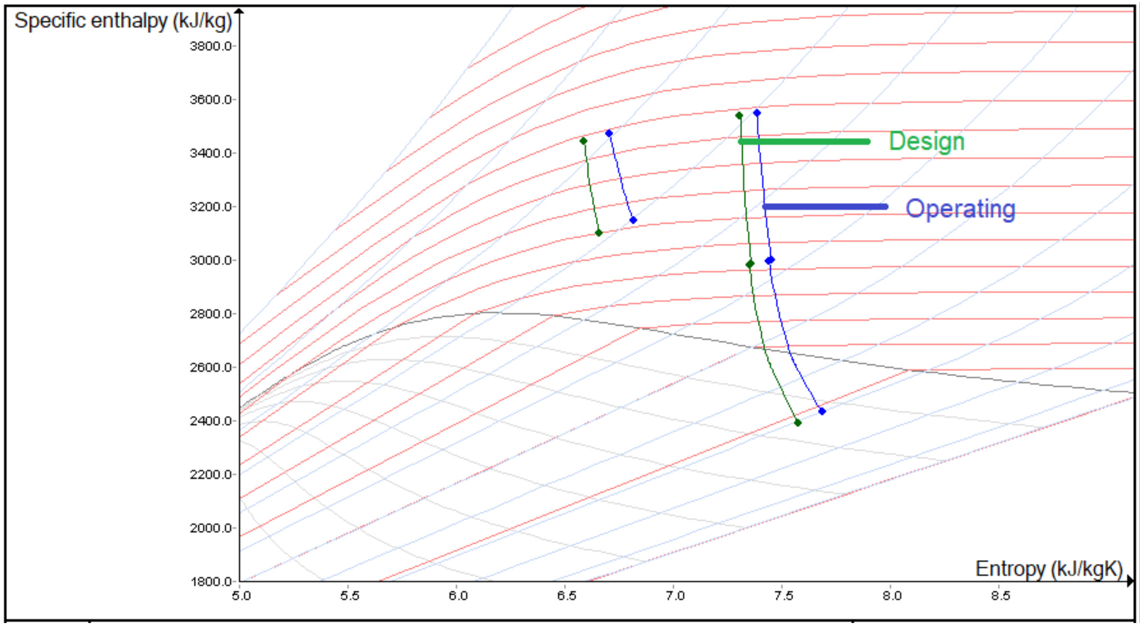


Figure 6.1: h-s diagram of turbines for unit – 1

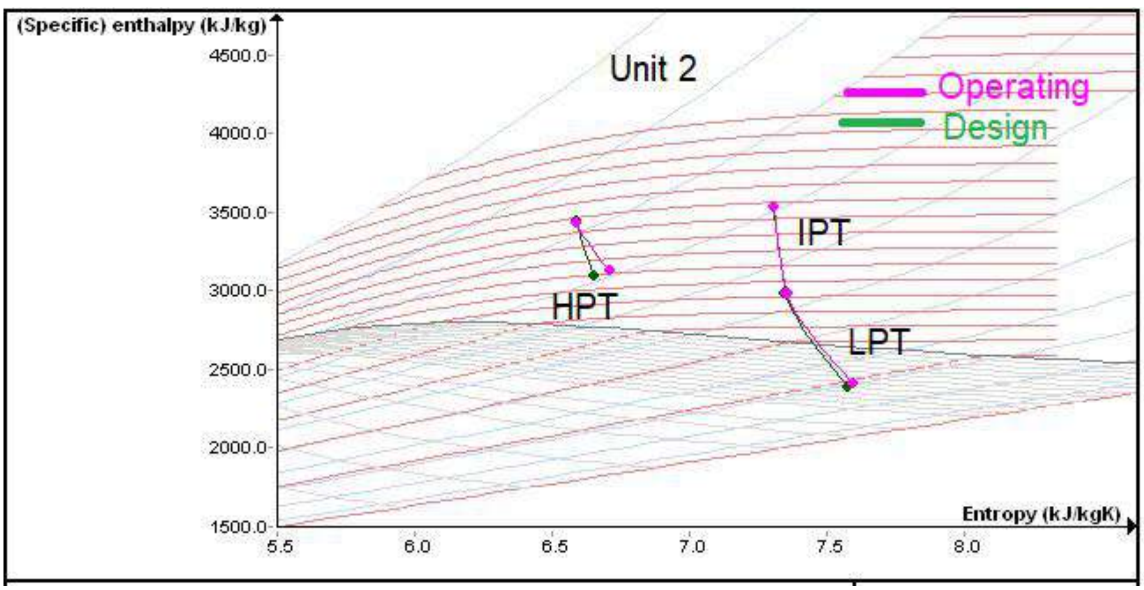


Figure 6.2: h-s diagram of turbines for unit – 2

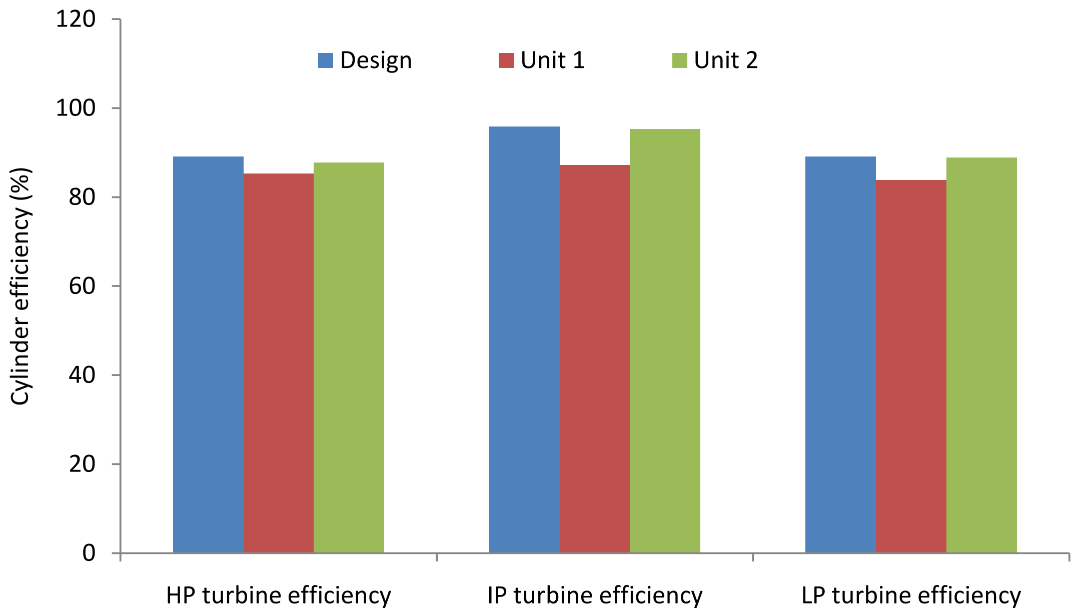


Figure 6.3: Steam turbine cylinder efficiency comparison

Observation and Analysis

- HP, IP and LP Turbine cylinder efficiency as per test data is found to be 85.28%, 93.2 % and 83.0% for unit #1 against the design value of 89.1%, 95.8% and 89.1% respectively. The unit #1 ST generation is 99.93 MW. The h-s diagram is shown in figure6.1. This shows there is a deviation occurring in the HPT against the design. The HPT delivers a shaft power of 20.52 MW from HPT. Based on this the ST is operating at 108 MW.
- Unit #2 Turbine cylinder efficiency as per test data is found to be 87.72%, 95.3% and 88.8% for HPT, IPT and LPT respectively. The unit #2 STG is operating at 128.5 MW during audit. The h-s diagram of unit 2 turbines is shown in figure 6.2. As shown in figure the HPT efficiency is deteriorated compared to design due to high enthalpy loss in the extraction stages as well as exit stage. The exit temperature of HPT in unit 2 is recorded as 350.00°C against design of 347.3°C.
- The turbine efficiency of both units has calculated based on the DCS details. The dryness factor for unit #1 and unit #2 is calculated and found to be 0.92907 and 0.91158 respectively.

Recommendation

- The comparison of HPT Exhaust / Throttle Pressure Ratio w.r.t. HBD is as given below for unit 1.

	HPT exhaust pressure	Throttle pressure	HPT exhaust/Throttle pressure
HBD	29.68	107.21	0.27684
Test (unit 1)	29.6	104.4	0.28366

The increase in pressure ratio in unit 1 indicates possibility of increase in turbine clearances.

- It is suggested that the gland seal / inter-stage seal strips condition as well as its clearances may be checked at the next available opportunity.
- Periodic assessment of turbine efficiency to be carried out using calibrated instruments to trend deterioration in performance and formulate corrective action plan also to monitor the extraction parameters.
- Trend the HPT efficiency (to track the degradation).
- The pressure ratio of HPT exhaust to throttle pressure should also be monitored, trend and analyze for correlating the possible changes in turbine operating condition.
- It is suggested to provide online measurement of IPT exhaust pressure and temperature which is presently not available. It is suggested that the pressure ratio of IPT exhaust to IPT inlet should also be monitored.

6.2.2 Turbine Pressure Survey

The pressure survey of turbine is compared with the design and the same is presented in Table 6.4. The plot is shown in below figure for comparing the design parameter and operating parameter.

Table 6.4: Turbine pressure survey

Parameter	Unit	Design	Unit – 1	Unit – 2
MS pressure	kg/cm^2	129.60	104.35	126.84
CRH pressure	kg/cm^2	35.85	29.60	34.75
HRH pressure	kg/cm^2	33.30	28.68	32.98
LPT inlet pressure	kg/cm^2	4.80	3.97	4.73
Condenser vacuum	kg/cm^2	0.0950	0.10	0.103

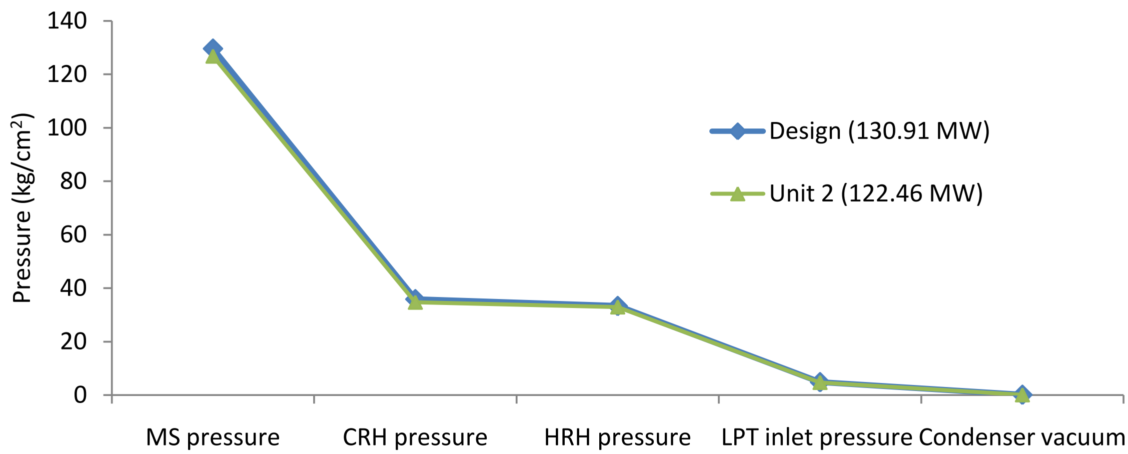


Figure 6.4: Turbine pressure survey

Observation and Analysis

- Based on the data collected a pressure drop test is carried out for operating load vis-à-vis design load and the plot is shown in above diagram. As the Unit #1 steam turbine is operated part load the analysis was carried out only for unit #2. In low pressure region the curve lies above the reference line. This may be due to some restriction to flow somewhere between two tapping points or it may happen that there is general worn/damage in the turbine internal seals or worn diaphragm seals. Also a decrease in pressure ratio as shown in below table indicates possibilities of roughness in HPT.

	HPT exhaust pressure	Throttle pressure	HPT exhaust/Throttle pressure
HBD	35.85	129.6	0.27662
Test (Unit 2)	34.86	126.2	0.27624

6.2.3 Water-Steam cycle heat rate

The heat rate of steam bottoming cycle has calculated based on the input energy and output power generation. The turbine heat rate is calculated based on the formulae,

Turbine Heat Rate **=** $Q_0 + (Q_1\text{-}Q_2)\text{+}(Q_3\text{-}Q_4)/\text{kW}$

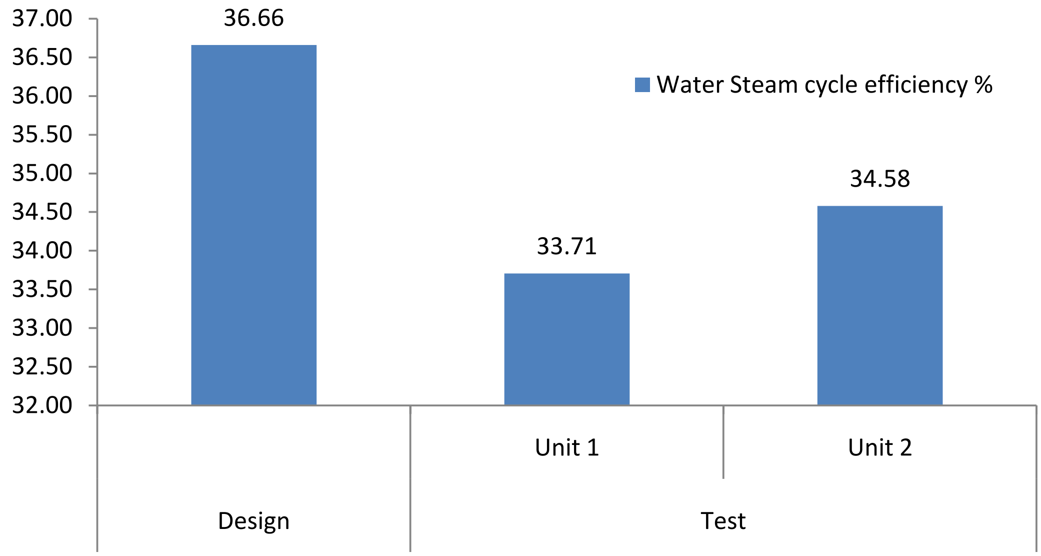
Q_0 = HP Turbine inlet energy

Q_1 = IP Turbine inlet energy

Q_2 = HP Turbine exhaust energy

Q_3 = LP Turbine inlet energy

Q_4 = LP Turbine exhaust energy
kW = Turbine output power



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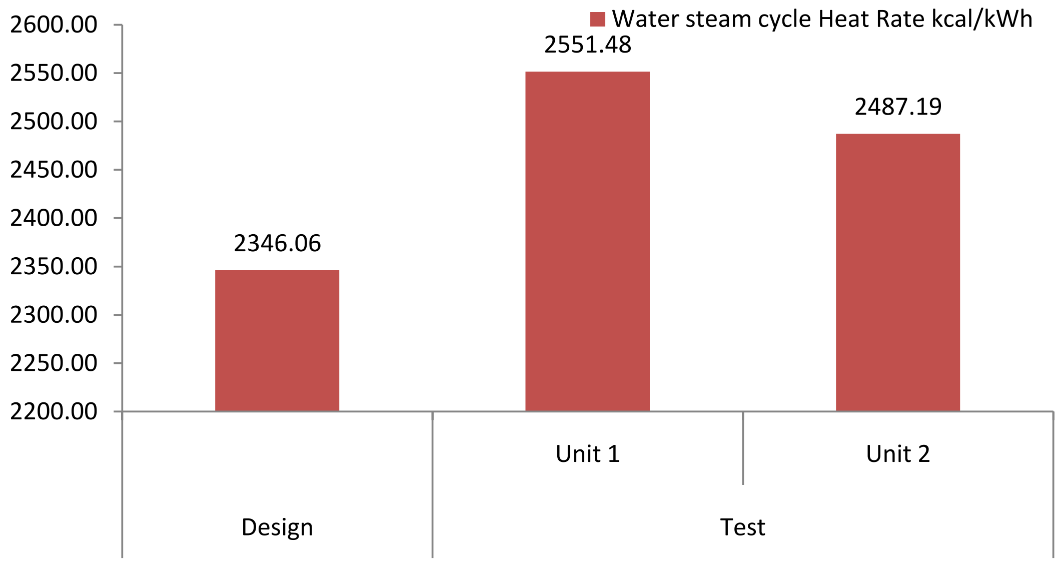


(b)

Figure 6.5: Bottoming cycle (a) efficiency, (b) heat rate

Observations and Analysis

- The average main steam temperature for unit – 1 and unit – 2 is recorded as 540.75^{o}C at 68.58 % loading and 533^{o}C at 94.41 % loading, against design value of 537.8^{o}C at 100 % load.
- The overall bottoming cycle efficiency is calculated to be 33.71 % and 34.58 % against design of 36.66 % for unit 1 &2 respectively.
- Water-steam cycle heat rate is calculated as 2551.48 kcal/kWh and 2487.19 kcal/kWh against design of 2346.06 kcal/kWh for unit 1 & 2 respectively. There is no correction curve available for steam bottoming cycle. The only parameter which may have impact on bottoming cycle heat rate will be CW temperature. The same will have also influence in combined cycle heat rate. Hence the impact of CW temperature is considered in the corrected CCPP heat rate.
- The reheat steam temperature in unit 1 and 2 was 540.89 ^{o}C and 536.50 ^{o}C against design value of 539.6^{o}C at full load. As per polynomial regression analysis the design reheat steam temperature at 99.93 MW and 122.46 MW is found to be 538.30 ^{o}C and 537.82 ^{o}C.
- The condenser pressure was 0.1000 kg/cm^2 in unit 1 and 0.103 kg/cm^2 in unit 2 against the design value of 0.095 kg/cm^2. This shows that efficiency of both units may affect due to poor condenser vacuum.

6.3. Condenser Performance

Each STG is provided with one two pass condenser having total cooling surface area of 10404 m^2 and 16000 number of tubes with size of 23x1x10000 mm (O.D x Thickness-Length). Design CW inlet temperature is 32^{o}C and condenser pressure is 0.095 at. The design details of surface condenser is provided in Table 6.5

Table 6.5: Design Specification of condenser

Description	Unit	Particulars
Shape		Rectangular
Type		Shell & Tube
Quantity of steam	t/Hr	355.193
Enthalpy of condensing steam	kcal/Kg.	571.2
Condenser Vacuum	at	0.095
Cleanliness factor		0.8
Size of tubes (O.D x Thickness-Length)	mm	23x1x10000

Total Number of tubes	Nos.	16000
Cooling surface area	Sq.M	10404
Quantity of cooling water	Cu.m/Hr	21000
Cooling water inlet temperature	ºC	32
Cooling water outlet temperature	ºC	41
Resistance on water side	MWCL	6
Material of tubes		Aluminum Brass
No. of water side passes	No	2

There are two particularly important relationships which should be established: the CW temperature rise with load and the terminal temperature difference (TTD) with load. For a given CW inlet temperature it follows that the back pressure in the condenser also depends in part upon the TTD. To evaluate the performance of condensers, circulating water inlet and outlet temperature, flow, have been measured and vacuum and hot well temperatures recorded form DCS. The condenser effectiveness is calculated based on DCS details and provided in Table 6.6.

Table 6.6: Condenser effectiveness

Description	**Units**	**Design**	**Unit – 1**	**Unit – 2**
Water Inlet Temperature	ºC	32.00	34.44	33.37
Water Outlet Temperature	ºC	41.00	41.98	42.46
Δ T of Water	ºC	9.00	7.54	9.09
Condenser Vacuum	kg/cm^2(a)	0.0950	0.1000	0.1030
Design average temperature	ºC	36.500		
Saturation Temperature	ºC	44.43	45.43	46.00
Hot Well Temperature	ºC	44.43	46.57	48.28
Initial Temperature Difference	ºC	12.43	10.99	12.64
Terminal Temp. Difference	ºC	3.43	3.45	3.55
Log mean Temperature Difference	ºC	6.99	6.51	7.15
Condensate Sub cooling	ºC	0.00	-1.14	-2.28
Condenser effectiveness		0.72	0.69	0.72
Condenser heat Load	kcal/hr	2219700	120514298	135896957
Heat Transfer Coefficient	kW/m^{2}K	0.72	0.57	0.71

Table 6.7: Vacuum loss due to various factors

Parameters	Unit	Design	Unit – 1	Unit – 2
Load	MW	130.9	99.93	122.46
Condenser back pressure	mmHg	69.878	73.556	75.762
CW inlet Temp	^{O}C	32.00	34.44	33.37
CW Outlet Temp	^{O}C	41.00	41.98	42.46
Delta T	^{O}C	9.00	7.54	9.09
Delta P	kg/cm^2		0.84	0.84
Sat.Temp	^{O}C	44.43	45.43	45.43
TTD	^{O}C	3.43	3.45	2.97
vacuum deviation due to CW inlet				
Expected sat temp at actual CW inlet	^{O}C		45.371	45.802
Corresponding Back pressure	mmHg		73.335	74.977
Deviation due to CW inlet	mmHg		3.457	5.099
Vacuum loss deviation due to CW Flow/ Heat load & CW rise				
Expect saturation temp	^{O}C		46.271	44.863
Corresponding Back pressure	mmHg		74.585	71.423
Deviation due to CW flow/Heat load & CW rise	mmHg		4.707	1.545
Net Loss	mmHg		8.164	6.644

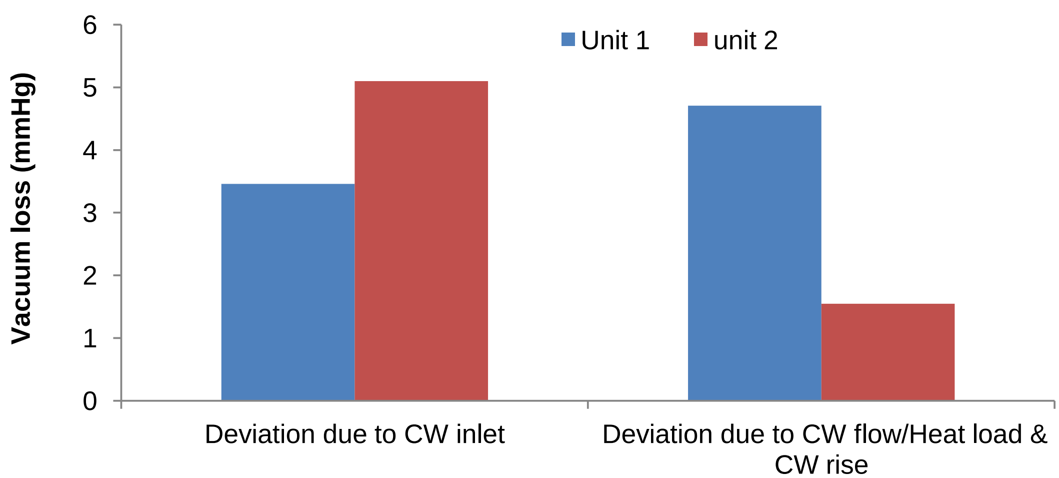


Figure 6.6: Vacuum loss variation

Observation and Analysis

- Condenser vacuum is recorded as 0.1000 kg/cm^2 (a), and 0.103 kg/cm^2(a) at inlet CW temperature 34.4ºC and 33.37ºC in Unit-1, and Unit-2 respectively against design of 0.095 kg/cm^2(a) at inlet temperature 32ºC.
- DP across condenser in both the units is around 0.84kg/cm^2 which is more than the design DP value i.e 0.6kg/cm^2 which indicated possible clogging within the condenser.
- During measurement of condenser flow in unit 2 it was observed that there is around 2000m^3/hr flow difference in between LHS side and RHS side condenser flow.
- During field visit unit – 1 was in part load operation and seven CT fan were in operation.
- Vacuum losses due to various reasons are projected in Table 6.7 and Figure 6.6. Based on the analysis the loss of vacuum mainly contributed by CW inlet temperature, which is calculated as 3.526 mmHG and 2.028 mmHG respectively in condenser of unit – 1 and unit – 2.

Recommendation

- It is recommended to increase the condenser tube cleaning frequency to get vacuum close to design.
- Based on the above analysis it can be concluded that the condenser performance is satisfactory.

CHAPTER –7

PERFORMANCE EVALUATION OF DEAERATOR

From de-aerator the feed water is pumped by feed pump to HRSG economizer section. Following performance parameters of deaerator are evaluated. The design details and performance analysis of Deaerator is provided in Table 7.1 and Table 7.2 respectively.

- Rise in condensate /feed water temperature
- TTD - Terminal temperature difference
- Heat Load
- Effectiveness
- LMTD: Log mean Temperature difference

Table 7.1: Design details of De-aerator

Description	Unit	Particulars
Make		BHEL, Hyderabad
Type		Spray-cum-Tray Type
Diameter x Thickness	mm	ID 2200x12
Header Length	mm	6676
Design Pressure	kg/cm^2(g)	6.5
Design Temperature	°C	330
Operating Pressure	kg/cm^2(a)	4.79
Operating Temperature	°C	149.5
Test Pressure	kg/cm^2(g)	8.45
Condensate inlet	kg/Hr	385765
Condensate Temperature	°C	141.5
Condensate Enthalpy	kcal/kg	142.5
Number of trays	Nos.	160
Number of spray valves	Nos.	28
Spray Valve capacity 15	T/Hr	15
Dissolved oxygen in feed water 0.005	cc/Lr	0.005
Inlet Steam Pressure	kg/cm^2(a)	4.79
Inlet Steam Temperature	°C	160
Inlet Steam Enthalpy	kcal/kg	696.9

Table 7.2: De-aerator Performance Analysis

Parameters	Unit	Design	Unit 1	Unit 2
Unit Load	MW	130.91	99.93	122.46
condensate inlet Temperature	ºC	141.5	135.56	143.27
condensate outlet Temperature	ºC	149.5	140	145.55
∆ T of Water	ºC	8	4.44	2.28
Steam pressure	kg/cm^2 (a)	4.79	4.66	5.09
Saturation temperature	ºC	149.498	148.477	151.77
Extraction Steam Temperature	ºC	226	228.27	234.64
Extraction Steam enthalpy	kcal/kg	696.9	696.8377	699.75
Drip Temperature	ºC	149.50	140	145.55
Drip enthalpy	kcal/kg	150.50	140.742	146.44
Condensate flow	tph	385.765	310.68	375.37
specific heat (at avg temp)	kcal/kg/ºC	1.02	1.02	1.02
TTD	ºC		8.477	6.22
Heat load	kcal/hr		1407007.58	872960.47
Extraction steam flow	t/h	5.69	2.53	1.58
Effectiveness			34%	27%

Observation and Recommendation

- The effectiveness is calculated to be 35% for unit 1 and 27% for unit 2. Data used for calculation purpose like temperature & pressure is taken from DCS datasheet.
- Effectiveness is found to be on lower side for both units' de-aerator. It may be due to measurement uncertainty of condensate inlet and outlet temperature. It is recommended to trend the temperature parameters and if required calibrate temperature and pressure sensor.
- Rise in temperature (TR) for unit is 4.44ºC and for unit 2 is 2.28ºC against the design TR value 8ºC. The lower temperature gain may be due to steam side fouling or may be due to low extraction steam flow than design.

CHAPTER –8

TURBINE AUXILIARY

Pumps are the major auxiliary load of the Unit. The Detailed Energy Audit in pumping system includes study of following pumps.

1. HP Boiler Feed Pumps (HPBFP)
2. LP Boiler Feed Pumps (LPBFP)
3. Condensate extraction pumps(CEP)
4. Cooling water pumps (CWP)
5. ACW pumps
6. DMCW pumps

Electrical power measurements in motors using Power analyzer, flow measurement using ultrasonic flow meter along with pressure reading were taken for all pumps and performance evaluation of pump was conducted to estimate overall efficiency and pump efficiency. To assess the performance of pumps following performance parameters have been evaluated,

- Flow
- Loading
- Efficiency
- Power consumption
- Specific energy consumption

8.1. Boiler Feed Pump

Total 8 numbers of BFPs (4 HPBFPs & 4 LPBFPs) provided for both the units, in which 2 HPBFP and 2 LPBFP runs in normal condition for the both units. In single unit 1 HPBFP and 1 LPBFP run. Design details of pump are depicted in Table 8.1.The process flow diagram of Boiler Feed pump is shown in the Figure 8.1

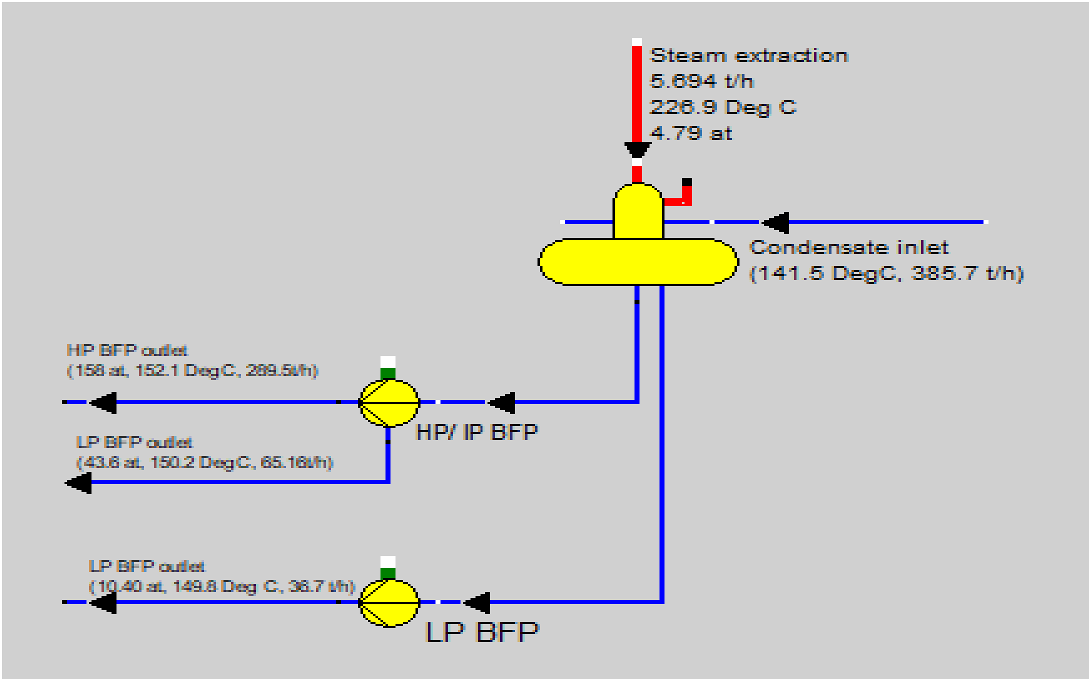


Figure 8.1: Process flow diagram of BFP

Table 8.1: Design details of HP/IP BFP

Description	Unit	Boiler Feed Pump Particulars
Pump Type		Radial flow, Single suction ,FK6D30
manufacturer		BHEL
Flow Rate	m^3/hr	500
Inlet water pressure	kg / cm^2	5.2
Outlet water pressure	kg / cm^2	183.48
Head	m	2000
No. of pumps per unit	Nos.	2
No. of Stages		6
Feed water temperature	°C	149.5
Pump efficiency at design point	%	80
Pump speed rated	RPM	4850
Motor Power	kW	4000

8.1.1 HP/IP BFP Performance Analysis

Towards the assessment of boiler feed pump performance the efficiency of running pump is evaluated based on the measured flow, power and pressure and provided in Table 8.2.

Table 8.2: HPBFP efficiency calculation

HP BFP	Unit	Design	Unit 1 (HPBFP –A)	Unit 2 (HP BFP – B)
Pump flow	M^3/hr	500	312.684	372.997
Total Head Developed	m	2000	1221.5	1476.0
Input Motor Power	kW	4000	1871	2229.00
Motor Efficiency	%	97.0	97.0	97.0
Pump Hydraulic power	kW		961.7	1381.7
Combined Overall Efficiency	%		51.40	61.99
Pump Efficiency	%	80	52.99	63.91
Percentage loading of flow	%		62.99	74.89
Percentage loading on motor	%		45.37	54.05
Specific consumption	kW/TPH	10.38	6.476	6.489
Percentage loading on head	%		61.075	73.8

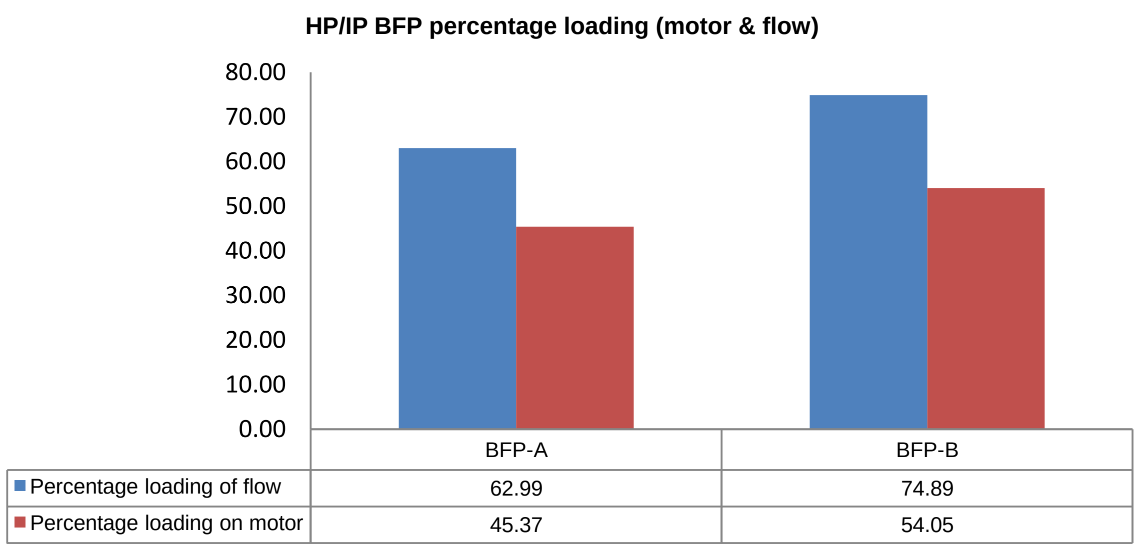


Figure 8.2: HP/IP percentage loading (motor & flow)

Observation & Recommendation

- Detail comparison of flow measured, value taken from DCS and mass balance is provided in Table 8.3

Table 8.3: HPBFP Mass Balance

Parameter	unit	Unit 1	Unit 2
HP Steam	TPH	238.22	288.3
IP Steam	TPH	27.6	36.29
IP Flow to gas preheater	TPH	13.69	13.63
IP FW spray to gas preheater	TPH	9.41	5.31
Total BFP suction flow	TPH	288.92	343.53
DCS suction flow	TPH	385	441.28
Measured suction flow	TPH	298.2	345
Recirculation flow	TPH	9.28	1.47

- Based on the HP/IP mass balance and measured water suction flow, the recirculation has calculated and found to be 9.28 TPH and 1.47 TPH for unit – 1 and unit – 2 respectively. This shows that the recirculation in unit – 1 is more as compared to unit – 2. Hence it is recommended to check the recirculation passing and control the passing. The saving calculation by arresting the recirculation passing is provided in the below table 8.4

Table 8.4: HPBFP Recirculation arresting saving calculation

Description	Units	Unit 1
No. of pump running		1
Specific Power consumption (average of two pumps)	kW/TPH	6.476
Total feed water flow	TPH	288.92
Total BFP Flow	TPH	298.2
Difference	TPH	9.28
Total Power Consumed	Kw	1871
Total Power saving after Changing recirculation v/v	kw	60.096
Annual Running Hours	hrs	5606.4
Annual Energy Saving	Kwh/Yr	336921.12
Energy Cost	Rs./kwh	2.75
Annual Energy Saving	Rs Cr	0.093
Investment	Rs.Cr	0.100
Payback	month	13

Actual investment cost to be verified with Vendor

- BFP efficiency for unit 1 and unit 2 is found to be 52.99 % and 63.91 % respectively against the design value 80 %

- As per the figure 8.2 the percentage loading of flow is better than the motor power percentage loading. This may be due to flow control by hydro coupling control system.
- The flow and power of unit – 2 BFP is measured and found to be 343.53 TPH and 2229 KW. As per the characteristic curve shown in Figure 8.3 at normal operating condition the head for the measured flow is calculated as 1700 MWC against the measured head of 1476 MWC.
- Similarly, for unit – 1 the flow and power is measured and found to be 288.92 TPH and 1871 KW. As per the characteristic curve provided in Figure 8.3, at normal operating condition the head for the measured flow is calculated as 1790 MWC against the measured head of 1221 MWC.
- From the pressure profile it is evident that pressure drop along HP line of unit – 2 is found to be around 16 kg/cm^2 across the HP Feed control station and HP Economizer. This may be verified by comparing HP discharge pressure (151.7 kg/cm^2) and HP drums (135.72 kg/cm^2). The energy saving is shown in Table 8.5

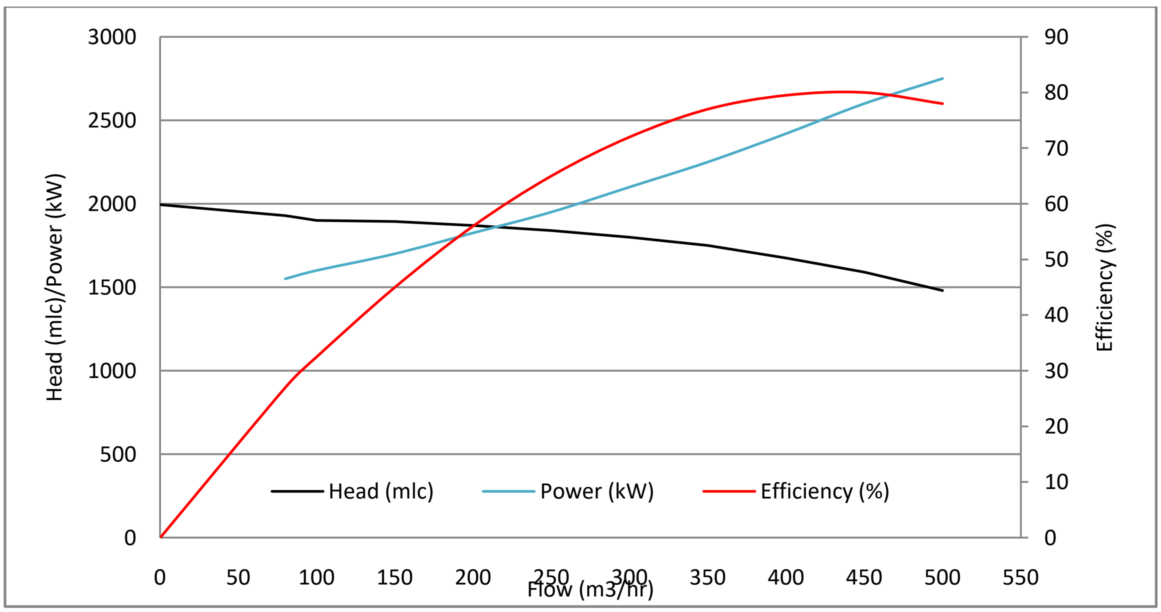


Figure 8.3: BFP Characteristic curve

- Likewise, the pressure drop along IP line of unit – 2 is found to be around 36 kg/cm2 across IP Economizer and IP feed control station. This shows that there is a huge pressure drop across IP Feed control station. Hence it is recommended to optimize the IP pressure drop across the FCS.

Table 8.5: HP Line FCS pressure optimization

Particulars	Unit	Unit 1	Unit 2
Number of HP BFP Running		1	1
DP across HP FCS	kg/cm^2	6	6
Proposed DP at HP FCS	kg/cm^2	1	1
Reduction	kg/cm^2	5	5
Power reduction	kW	50	50
Annual running hours	hrs/yr	5606.4	5606.4
Annual energy saving	kWh/yr	280320	280320
Energy cost	Rs/kWh	2.75	2.75
Annual Energy Saving	Rs.Cr	0.08	0.08
Investment	Rs.Cr	Nil	Nil
Payback	Month	Immediate	Immediate

8.1.2 LPBFP Performance Analysis

The plant has installed two LPBFP for each unit (one is running and another standby). The LPBFP absorbs water from the dearator and passes the water to LP Economizer with higher pressure. The design details of LP BFP is provided in below Table 8.6

Table 8.6: Design details of LPBFP

Description	Unit	Particulars
Flow Rate	m^3/hr	45
Head	mlc	130
No. of pumps per unit	Nos.	2
Motor Output Power	kW	32.61

The performance of the LP BFP has calculated based on the measured details and the same is provided in the Table 8.7

Table 8.7: LPBFP Performance

Particulars	Unit	Design	LP BFP – 1 A	LP BFP – 2 A
Pump discharge flow	M^3/hr	45	30.36	38.76
Total Head Developed	m	130	154.6	141.7
Input Motor Power	kW	32.61	21.92	23.74
Motor Efficiency	%	97.0	97.0	97.0

Pump Hydraulic power	kW		11.87	13.82
Combined Overall Efficiency	%		54.14	58.20
Pump Efficiency	%		55.81	60.00
Percentage loading of flow	%		67.46	85.68
Percentage loading on motor	%		65.20	70.62

Observation & Recommendation

- There is two LPBFP pump in each unit, one in running and one in standby. Flow was measured at the suction of individual pump. For calculating head, suction and discharge pressure is taken from DCS.
- The pump efficiency of LP BFP for Unit – 1 and unit – 2 is calculated and found to be 55.81 % and 60 % respectively.
- The discharge pressure of LP BFP is found to be approx 19 kg/cm^2 for both units however; the design FW temperature to HRSG and LP drum pressure is 6.6 kg/cm^2 and 5.1 kg/cm^2 respectively. During audit the LP drum pressure is 4.74 kg/cm^2. This shows that there is huge loss across LP FCS.
- Based on the pressure survey through, the loss across the LP FCS will be reduced by installing the Variable Frequency Drive control for LP BFP. The plant may operate by installing VFD and 100 % opening of FCS. The payback for VFD is provided in Table 8.8

Table 8.8: LP BFP VFD Installation

Description	**Unit**	**Unit1**	**Unit2**
Design flow	m^3/hr	45.00	45.00
Actual flow	m^3/hr	30.36	38.76
LP drum pressure	kg/cm^2	4.52	4.74
Actual discharge head	kg/cm^2	19.04	18.26
present power consumption	kW	21.92	23.74
Proposed power consumption	kW	12.06	13.06
Power saving	kW	9.86	10.68
Annual operating hours	hrs/yr	5606.40	5606.40
Annual Energy Saving potential	kWh	55279.10	59876.35
Energy Cost	Rs./kWh	2.75	2.75
Annual Monetary Saving	Rs. Cr	0.02	0.02
Investment for VFD	Rs Cr	0.05	0.05
Payback	Months	35.52	32.79

Actual investment cost to be verified with Vendor

8.2 Condensate Extraction Pumps (CEPs)

There are two CEPs and one is in operation in each of the unit. The performance of CEPs of both the units has been analyzed by measuring the flow, discharge pressure, power consumption and recording the condenser vacuum. Based on the measured data operating efficiency of pump have been compared with design. The CEP absorbs water from hot well of condenser and supplies water to the Condensate header and supplied to de-aerator. The rated capacity of pump is 410.00m^3/h with head of 250 m and power of 417 kW. The design detail of CEP is provided in Table 8.9.

Table 8.9: Design details of CEP

Description	**Unit**	**CEP Particulars**
Pump Type		EN5J40/210(Last stage dummy)
Flow Rate	m³/hr	410
Head	m	250
No. of pumps per unit	Nos.	2
Feed water temperature	°C	54.9
Pump efficiency at design point	%	66
Pump speed rated	RPM	1486
Motor Output Power	kW	600

8.2.1 CEP Performance Analysis

The performance of condensate extraction pumps of both the units have been analyzed by measuring the flow, pressure developed and power consumption of the pumps and it is shown in Table 8.10. The CEP pressure survey also carried out and provided in Table 8.11

Table 8.10: CEP performance

Particulars	Unit	Design	Unit- 1 (CEP – B)	Unit – 2 (CEP A)
Pump discharge flow	M^3/hr	410.00	332.96	391.95
Total Head Developed	m	250.00	252.10	238.67
Input Motor Power	kW	417.00	437.00	468.00
Motor Efficiency	%	0.95	0.95	0.95
Combined Overall Efficiency	%		51.74	53.84
Pump Efficiency	%	80	54.25	56.46
Percentage loading of flow	%	100.00	81.21	95.60
Percentage loading on motor	%	100.00	104.8	107.09
Specific consumption	kW/TPH	0.92	1.33	1.21
Percentage loading on head	%		100.84	95.47

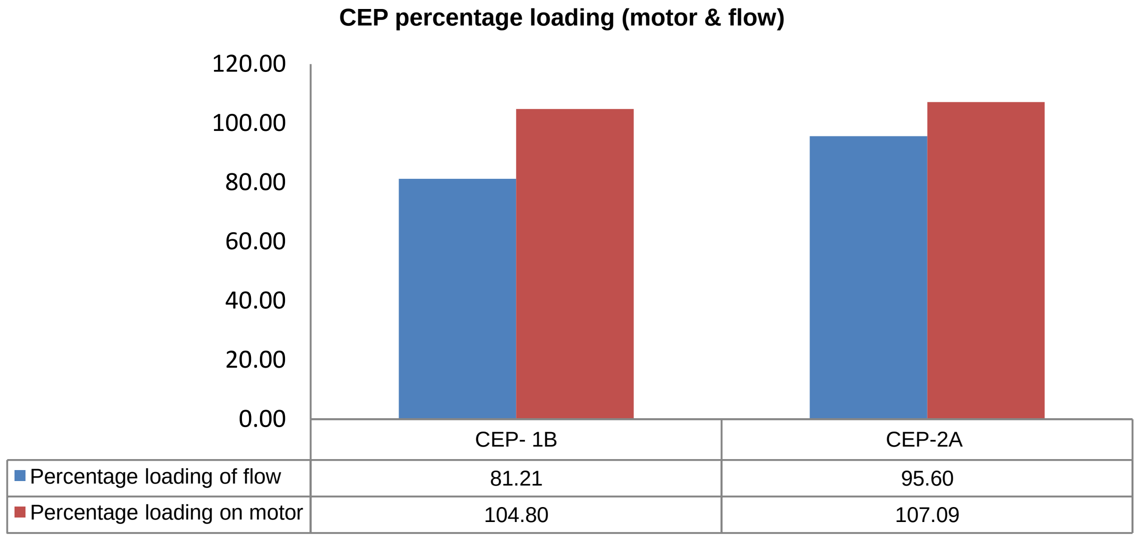


Figure 8.4: CEP percentage loading (motor & flow)

Table 8.11: CEP Pressure survey

	Units	UNIT 1	UNIT 2
CEP Suction Press.	Kg/cm^2	0.10	0.10
CEP dish. Press.	Kg/cm^2	25.31	23.97
De-aerator Press.	kg/cm^2	4.66	5.09

Observation and Analysis

- There are two CEP's for each unit, one in running and one in standby. Flow was measured at the suction of individual pump. For calculating head suction and discharge pressure is taken from DCS.
- CEP efficiency of unit#1 is found to be 54.25%, CEP of unit#2 is found to be 56.46 % respectively against design of 80%.
- As per the Figure 8.4, the percentage loading of CEP based on motor power and flow shows that the motor power consumption is higher however, the flow is less.
- The specific energy consumption of pump in both units is on higher side compared to design of 0.92.
- In unit – 1 CEP – B at flow $333m^3$/hr and head 252M, measured power consumption is 437 kW, but As per the characteristic curve provided in Figure 8.4 the power consumption of CEP 1A at said flow and said head should be 380 kW as against the measured value of 437 kW. Thus the pump is consuming 57kW more power as

compared to characteristic curve which can be saved. Similarly For Pump - 2A, at flow 391m^3/hr measured power consumption is 468 kW, but as per the Curve motor is consuming 54 kW more for the same flow. This can be achieved by maintaining the pump internals and reducing the head loss. Saving calculation is provided in table 8.12.

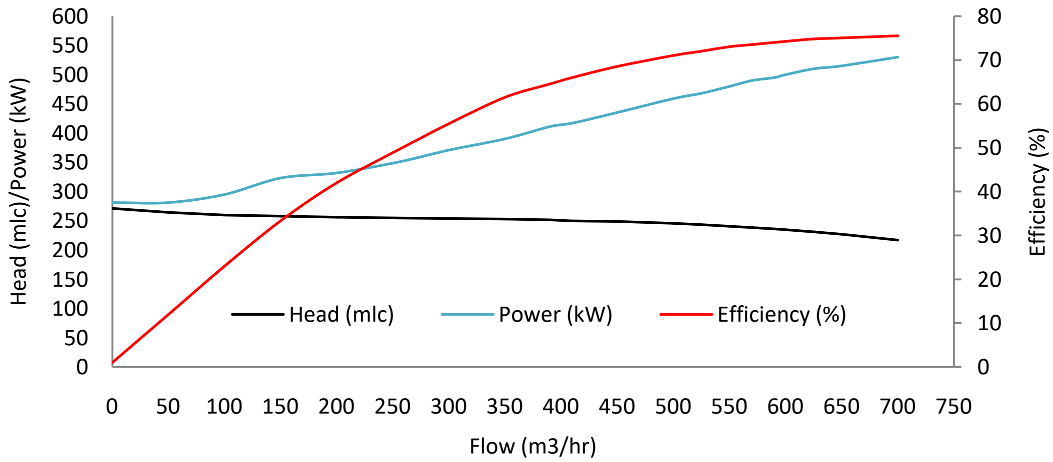


Figure 8.5: CEP Characteristic curve

Table 8.12: CEP Optimization saving

Power consumption as per curve	kW	380	414
Power consumption as measured	kW	437.00	468.00
Extra power consumption	kW	57.00	54.00
Annual operating hours	hrs/yr	5606.4	5606.4
Annual Energy Saving potential	kWh/yr	319564.8	302745.6
Energy cost	Rs/kWh	2.75	2.75
Annual Monetary Saving	Rs.Cr	**0.09**	**0.08**

- In operating condition one CEP is running. From the pressure profile in above table 8.11 it is evident that there is substantial pressure drop across the control valve. However, the variable speed option for the pump could be explored to save considerable amount of power. The discharge pressure of condensate pump varies from 25-23 kg/cm² where as De-aerator pressure is around approx 5.0 kg/cm² Throttling losses can be reduced effectively by employing variable speed option

Table 8.13: CEP VFD Installation

Description	**Unit**	**Unit1**	**Unit2**
Design flow	m^3/hr	410.00	410.00
Actual flow	m^3/hr	332.96	391.95
present power consumption	kW	437.00	468.00
Proposed power consumption	kW	350	374
Power saving	kW	87.00	94.00
Annual Energy Saving potential	kWh	487756.8	527001.6
Annual Monetary Saving	Rs.Cr	0.13	0.14
Investment for VFD	Rs Cr	0.3	0.3
Payback	Months	27	25

Actual investment cost to be verified with Vendor

8.3 Cooling Tower

The cooling towers performance was tested when the unit – 1 and unit – 2 was operating at part load and base load respectively. Table 8.14 depicts the design details of cooling tower. Parameters measured for performance test are:

- Hot water temperature
- Cold water temperature
- Makeup water temperature
- Air wet bulb temperature

Table 8.14: Design details of cooling tower

Description	Unit	Particulars
CT Basin Capacity	m^3	7000
No of Cooling Tower		2 for 2
No of Cells for each Tower		8(7 W+1 S)
Capacity for each Cell	m^3/hr	3428.57
CT inlet temperature	ºC	41
CT outlet temperature	ºC	32
Design Wet Bulb Temperature	ºC	27.25
Evaporation Efficiency	%	85
Calculated Blow down + Drift	m^3/hr	94
Calculated Makeup Water Flow Rate	m^3/hr	442.48
Calculated Makeup Water Flow Rate	m^3/hr	442.48
No of blades in each Fan		8
Blade Type		Aerofoil

Fan Speed	RPM	114
No of fans		8 x 2 = 16 Nos. plus 1 No. spare
Motor	kW	110

Cooling tower operating parameters have been measured to analyze the performance of pumps. The results are as follows:

The cooling tower range is calculated using following expression:

Range= T_1- T_2 ^{0}C

Where,
R Cooling range, ^{0}C
T_1 Hot water temperature, ^{0}C
T_2 Cold water temperature, ^{0}C

Cooling Approach

The cooling tower cooling approach is calculated as follows:

Approach= T_2- T_3 ^{0}C

Where,
A Cooling approach, ^{0}C
T_2 Cold water temperature, ^{0}C
T_3 Ambiant air wet bulb température, ^{0}C

$$\text{Effectiveness} = \frac{\text{Range}}{(\text{Range} + \text{Approach})} \times 100$$

Cooling tower operating parameters have been measured to analyze the performance of cooling tower. The results are provided in Table 8.15.

Table 8.15: Cooling tower performance

Cooling tower evaluation				
Parameters	**Unit**	**Design**	**Unit 1**	**unit 2**
Condenser vacuum	kg/cm2 (a)	0.0950	0.1000	0.1030
CT inlet temperature	ºC	41.00	41.98	42.46
CT outlet temperature	ºC	32.00	34.44	33.37
CW flow rate	m^3/hr	23999.99	19938.37	17872.22
Dry Bulb temperature	ºC		32.98	29.69

Wet Bulb temperature	ºC	27.25	30.35	28.58
Range	ºC	9.00	7.54	9.09
Approach	ºC	4.75	4.09	4.79
Effectiveness	%	65.45	64.86	65.51
Evaporation loss	m^3/hr	330.48	230.01	248.56
Cooling capacity	kCal/hr	215999.91	150335.31	162458.48
Power consumption of fans	kW	100.00	56.23	58.53
Flow /Cell	m^3/hr	3428.57	2848.34	2553.17
Evaporation loss/cell	m^3/hr		32.86	35.51
% Evaporation loss/cell	%		1.15	1.39

Table 8.16: CT Fans motor Loading

Cooling tower CT Fans U# 1							
Fans No.	Design (KW)	Efficiency %	amp	Voltage	P.F.	Power	% Loading
1	110	94.5	140	410.1	0.55	54.69	46.99
2			150	410	0.58	61.78	53.08
3			148	410.8	0.56	58.97	50.66
4			148	410	0.56	58.85	50.56
5			N/R				
6			130	411.4	0.54	50.02	42.97
7			150	412	0.52	55.66	47.82
8			142	411.2	0.53	53.60	46.05

Cooling tower CT fans U#2							
Fans No.	Design(KW)	Efficiency (%)	amp	Voltage	P.F.	Power	% Loading
1	110	94.5	148	418	0.54	57.86	49.71
2			150	418.5	0.57	61.97	53.24
3			149	418.5	0.53	57.24	49.18
4			146	418.6	0.51	53.98	46.38
5			150	419	0.5	54.43	46.76
6			158	419	0.53	60.77	52.21
7			162	419	0.54	63.48	54.54
8			N/R				

Observation & Recommendation:

- Effectiveness of cooling tower is calculated as 64.86% and 65.51 % for unit 1 and unit 2 respectively.

- Approach is found to be 4.09°C and 4.79°C for unit 1 and unit 2 respectively against the design approach of 4.75 °C. Range is found to be 7.54°C and 9.09°C for unit 1 and unit 2 respectively against the design range 9.
- As per the design data the evaporation loss is around 330.48 kg/hr during full load operation and the evaporation loss during audit is calculated around 230 kg/hr and 248 kg/hr for 1 and unit 2 respectively.
- Cooling tower is designed for 7 CT fans at full load .In unit 1 it is observed that unit is running at part load still 7 CT fans are in service. There is no approach available to measure CT fans Flow, hence only Power is measured for individual fans.
- For both the units, CT fans motor loading is around 50%, this is depicted in Table 8.16
- It is recommended to make proper approach for measuring the fan velocity so that fan efficiency and L/G ratio can be calculated.
- It is recommended to install VFD with automotive temperature controller, as motor loading at base load & part load operation is at 50 %. The saving calculation is shown in Table 8.17.

Table 8.17: CT Fan VFD Installation

CT Fans Saving by VFD installation		
present power consumption	kW	393.57
Proposed power consumption	kW	275
Power saving	kW	118.57
Annual Running hours	Hrs	5606.4
Energy cost	Rs/kWh	2.75
Annual Energy Saving potential	kWh	664750.85
Annual Monetary Saving	Rs.Cr	0.18
Investment for VFD	Rs Cr	0.14
Payback	Months	9

Actual investment cost to be verified with OEM/Vendor

- Cooling tower fans are of GRP type drawing 57 kW average. Replacement by efficient hollow FRP fan blades is recommended. The saving calculation is shown in Table 8.18

Table 8.18: CT Fan Blade replacement

Energy Saving by Replacing GRP blades with FRP blades in CT Fan		
No. of fans	Nos	8
Rated Power	kW	110
Rated voltage	V	415
Rated Speed	rpm	1500
Present Avg Power consumption	kW	56
Energy Savings	%	25
Avg Power consumption with FRP blades	kW	42
Avg Power Saving	kW	14
Annual Energy Savings	kWh	78489.6
Annual Monetary Saving	Rs.Cr	0.17
Investment	Rs Cr	0.16
Payback	Months	11

Actual investment cost to be verified with Vendor

8.3.1 Circulating Water Pump

Three circulating water pump (2 W + 1 S) is installed with the capacity of 12000m^3/hr for each unit in full load operation. The pump rated efficiency is 85% at total head 22mlc. Design Details and Performance analysis of pumps are shown in Table 8.19.

Table 8.19: CW pump Design

Circulating water pumps		
Manufacturer	BHEL (HYDERBAD)	
Number of pumps	Nos.	6 (Six)
Rated capacity	m^3/hr	12000
Total Head	MLC	22
Pump rated speed	RPM	490
Bowl efficiency at rated capacity	%	85
Pump shaft input power at rated capacity	kW	870.5
Circulating water pump Motor		
Manufacturer	BHEL	
Speed	RPM	496
KW rating	KW	1150
Current	A	128
Efficiency	%	95%
PF		0.82

The measured and analyzed parameters of the pumps are shown in the below Table 8.20.

Table 8.20: CW pump performance

CW			Unit 1		Unit 2	
Parameters	Unit	Design	CW 1A	CW 1B	CW 2A	CW 2C
Pump discharge flow	m^3/hr	12000.00	9713	10001	10573	10471
Total Head Developed	m	22.50	20.00	20.00	17.70	17.50
Input Motor Power	kW	1150.00	944.00	972.00	931.00	922.00
Motor Efficiency	%	0.95	0.95	0.95	0.95	0.95
Combined Overall Efficiency	%	63.98	56.08	56.08	54.78	54.16
Pump Efficiency	%	85.00	59.03	59.03	57.66	57.01
Percentage loading of flow	%		80.94	83.35	88.11	87.26
Percentage loading on motor	%		77.98	80.30	76.91	76.17
Specific consumption	kW/TPH	0.10	0.10	0.10	0.09	0.09

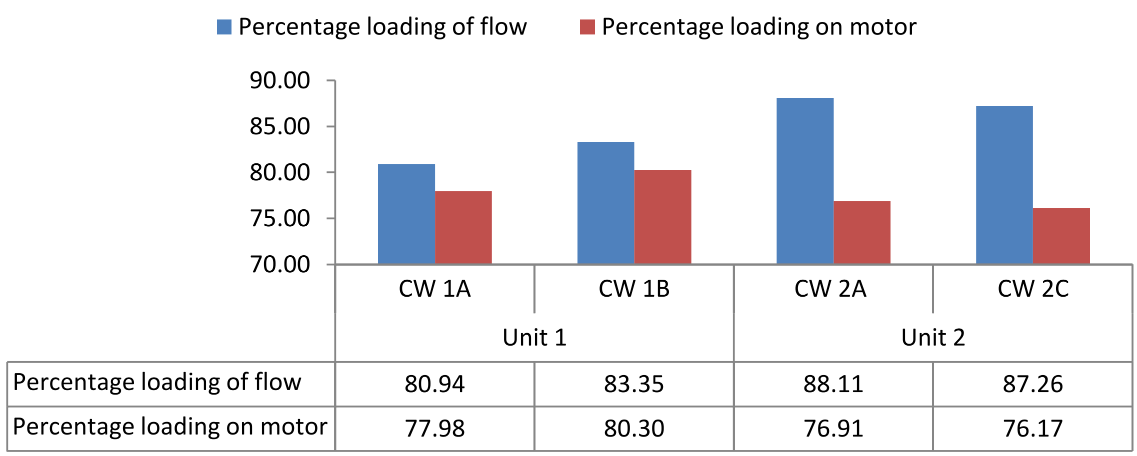


Figure 8.6: CW Percentage loading (flow & motor)

Observation & Recommendation

- Suitable approach is not available for measuring the CW flow at pump outlet, so flow has measured in each condenser outlet. Moreover, total CW pump flow has calculated by adding each measured condenser flow and ACW pump flow. As the ACW pump suction is through CW header outlet.
- As flow measurement of individual pumps were not possible, so measured flow were added and distributed according to power consumption for both CW pump

- During Flow measurement, it was observed that the LHS flow was more than RHS in both units. As difference in flow found in both units, so it may be due to the design as well as there might be some obstruction in the flow path.
- The efficiency of all CW pumps in both units is around 57 to 59 % and head developed is around 17 to 20 m, whereas the rated efficiency at rated head (22.5m) is 85%.
- Percentage loading in motor of CW 1A, CW 1B, CW 2A & CW 2B are found to be 79.98%, 80.30%, 76.91% & 76.17% respectively. This is shown in Figure 8.6
- Specific power consumption is within the design limit for all the four pumps.

8.3.2 ACW PUMP

Auxiliary cooling water (ACW) pumps takes suction from CW pump discharge header and circulates this cooling water in plate heat exchanger (PHE) to maintain the temperature of DMCW water. Two ACW pumps are installed for a single unit and in normal operating condition one pump is operated. The Pump design flow is 1950m^3/hr with developed head 14m.The flow was measured using ultra sonic flow meter and the same time power being measured with power analyzer. Suction and discharge pressure were recorded from local installed pressure gauges at the inlet and outlet of pump. The design details of pump and performance calculation data given in Table 8.21 and 8.22 respectively.

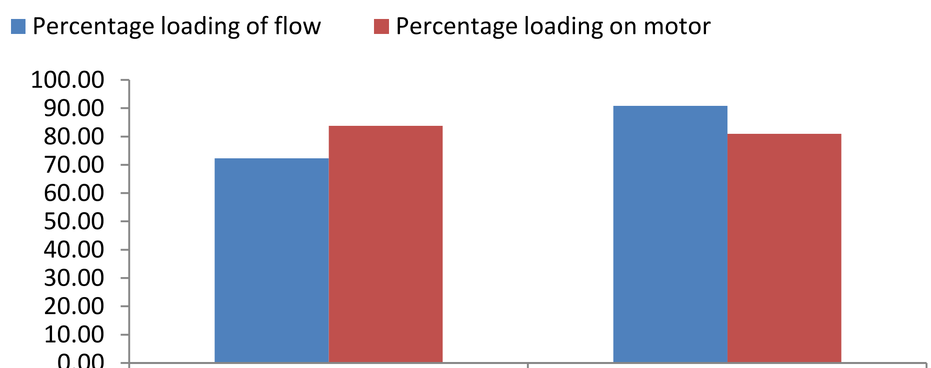
Table 8.21: Design details of ACW

Description	Unit	Data
Designation of the pump		ACW BOOSTER PUMPS
Manufacturer		FLOWIORE LIMITED
Model No.		F5821- 450X400
No of Pumps Total	Nos.	4 Nos (for 2 units)
Raled capacity	M3/hr	1950
Total dynamic head at rated capacity,	mwc	14
Pump rated speed	RPM	988
Motor rating	KW	110
Power factor	PF	0.84

Table 8.22: Pump Performance of ACW

Parameter	**Unit**	**Design**	**ACW 1B**	**ACW 2B**
Pump discharge flow	m^3/hr	1950.00	1410.00	1772.75
Total Head Developed	m	14.00	15.00	11.00

Input Motor Power	kW	110.00	97.06	93.74
Rated Motor power	kW	110.00	110.00	110.00
Motor Efficiency	%	0.95	0.95	0.95
Combined Overall Efficiency	%	67.63	59.38	56.69
Pump Efficiency	%	88.00	62.50	59.67
Percentage loading of flow	%	100.00	72.31	90.91
Percentage loading on motor	%	100.00	83.82	80.96
Specific consumption	kW/TPH	0.06	0.07	0.05



	ACW 1B	ACW 2B
Percentage loading of flow	72.31	90.91
Percentage loading on motor	83.82	80.96

Figure 8.7: ACW percentage loading (flow & Motor)

Observation

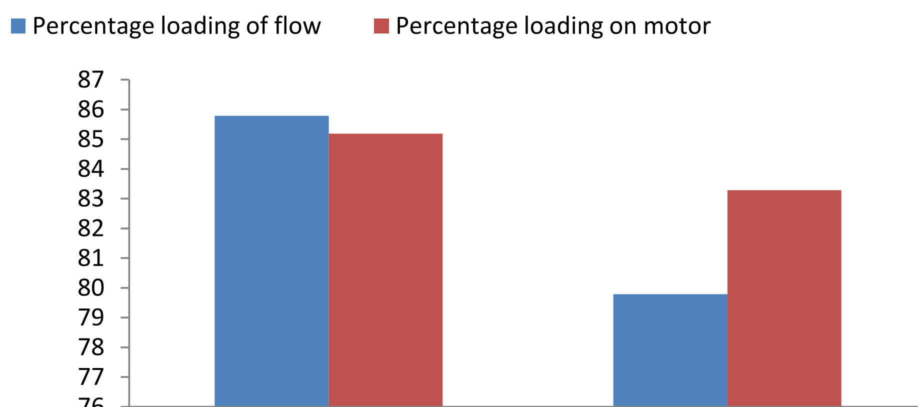
- Flow was measured at Pump suction line in both units and pressure recorded from pressure gauges installed at inlet and outlet of pump.
- Loading comparison of ACW in respect of flow and motor power is shown in Figure 8.6. ACW 1B & ACW 2B flow are found to be 1410 m^3/hr & 1772.75 m^3/hr against the design flow 1950 m^3/hr at the developed head 15m and 11m respectively.
- Specific energy consumption for both unit pumps is near to design.
- Overall pump performance is satisfactory.

8.3.3 DMCW PUMP

The performance calculation of DMCW pump is given in Table 8.23

Table 8.23: Pump Performance of DMCW

Parameter	Unit	Design	DMCW 1 B	DMCW 2 A
Pump discharge flow	m^3/hr	1730.00	1494.60	1390.00
Total Head Developed	m	44.00	39.20	39.80
Input Motor Power	kW	300.00	269.00	263.00
Motor Efficiency	%	0.95	0.95	0.95
Combined Overall Efficiency	%	69.14	58.94	56.92
Pump Efficiency	%	84.00	62.04	59.91
Percentage loading of flow	%	100.00	85.79	79.78
Percentage loading on motor	%	100.00	85.18	83.28
Specific consumption	kW/TPH	0.17	0.18	0.19



	DMCW 1B	DMCW 2A
Percentage loading of flow	85.79	79.78
Percentage loading on motor	85.18	83.28

Figure 8.8: DMCW Pump loading (flow & power)

Observation

- The performance of DMCW pumps of both the units have been analyzed by measuring the flow, pressure developed and power consumption of the pumps. Flow was measured using ultrasonic flow meter and at the same time power was measured by using power analyzer. Inlet and outlet pressure of the pump was recorded from local pressure gauges installed at inlet and outlet of the pump.

- The measured flow is 1496 m^3/hr and 1390 m^3/hr for the pump DMCW 1B, & DMCW 2A respectively. However during flow measurement it was observed that there is difference of approx 400m^3/hr between flows recorded with ultrasonic flow meter and flow showing at DCS.
- It is recommended to calibrate the DCS flow meter as there is difference observed between measured flow value and DCS value.
- DMCW pump efficiency of is found to be 62.04% and 59.91% for unit 1 and unit 2 respectively, against the design value of 84%
- Percentage loading of flow of Unit 1 DMCW 1B & Unit 2 DMCW 2A are found to be 85.79% & 79.78% respectively and motor loading is found to be 85.18% and 83.28% for unit 1 and unit 2 motor respectively. This is shown in Figure 8.7
- Specific power consumption in both units pump is found to be on higher side than design.
- Unit 1 & 2 DMCW pump is running with lower efficiency as compared with design , so pumps internals to be checked for improving the efficiency

CHAPTER- 9

FUEL FEEDING SYSTEM

Natural gas is fired in the Gas turbine is coming from the ONGC Natural gas reserves located in Tripura through dedicated piping. Before feeding to the gas turbine natural gas is passed through different micron size filters to remove impurities available in gas. In addition, pressure and temperature of the natural gas has also increased by the Gas Booster compressor. As per P & I diagram, the fuel feeding capacity for each unit is 63470m^3/hr.

The natural gas from reservoir is passed through Gas scrubber and coalscent filter section for removing suspended particles and aerosols. In between, these two section, OTPC has installed three Gas booster compressors (two in operation and one in standby) for increasing the pressure. The design details of Gas booster compressor is provided in the Table 9.1

Table 9.1: Design specification of GBC

Description	Data
Number Installed	THREE (2 W + 1 S)
DRIVER TYPE	ELECTRIC MOTOR
TYPE OF COMPRESSOR	CENTRIFUGAL COMPRESSOR
GAS HANDLED	NATURAL GAS
MANUFACTURER	BHEL
MODEL	BCL 406

9.1 Gas Booster compressor

The performance of the Gas booster compressor has been calculated as per the data taken from the DCS. The adiabatic efficiency of the GBC is calculated and mentioned the Table 9.2.

Table 9.2: Gas Booster compressor analysis

particulars		GBC 2	GBC 3
inlet pressure	kg/cm^2	13.5	13.5
discharge pressure	kg/cm^2	33.47	34.00
compression ratio	R	2.48	2.52
inlet temperature	K	301.10	301.45
air isentropic exponent = k	K	1.30	1.30
(K-1)/K		0.23	0.23
Compressor isentropic exit temp.	K	370.29	372.05

Compressor actual exit temp.	K	408.20	411.95
compressor efficiency	%	64.60	63.89

Observation & Analysis

- The adiabatic efficiency of the gas booster compressor is calculated from the details taken from the DCS details and found to be 64.60 % for GBC – 2 and 63.89 % for GBC – 3.
- The power measured for the GBC – 2 and GBC – 3 is measured and found to be 3824 KW and 3800 KW against the design of 3840 KW.

CHAPTER -10

LIGHTING

Lux measurements and power measurement of LDB were taken using the power analyzer and Lux meters. The parameters were measured to estimate the lux level for each location. OTPC has installed different types of lights with variety of input power in different areas. The detail lighting system load is provided in the Table 10.1

Table 10.1: Lighting system load

AREA	28 W (Tube Light)	400 W	70 W	150 W	250 W	40 W	125 W
Switchyard	396	144	32	19	18	N/A	N/A
D.G. Building	N/A	N/A	N/A	9	N/A	N/A	N/A
I & SA Compressor House	N/A	N/A	N/A	110	N/A	N/A	N/A
D.M. Plant	104	N/A	N/A	11	N/A	N/A	N/A
GBC	26	N/A	4	30	18	N/A	N/A
Cooling Tower	24	N/A	35	29	5	N/A	N/A
RW Pump House	18	N/A	3	10	N/A	N/A	N/A
River water intake pump	40	N/A	8	33	4	26	15
4 MT Switch Gear	208	N/A	N/A	N/A	N/A	N/A	N/A
GTG-1 & STG-1 Aux Area	40	N/A	8	43	12	N/A	15
Unit Control building	516	N/A	N/A	N/A	N/A	N/A	N/A
STG-1 Hall	108	37	N/A	N/A	N/A	N/A	5
Battery, Battery charger & UPS Room	276	8	N/A	N/A	N/A	N/A	N/A
Fire water	24	N/A	N/A	14	9	N/A	N/A
Boiler & HRSG	N/A	N/A	59	25	N/A	N/A	N/A
BFP Building	102	N/A	15	22	14	N/A	8
ETP	32	N/A	N/A	19	N/A	N/A	N/A
Total	**1914**	**189**	**164**	**374**	**80**	**26**	**43**

10.1 Power & Lux Measurement

The instantaneous lighting power consumption was measured and details are as follows.

Table 10.2: Lighting power consumption

Description	28 W Tube Light	400 Watt	70 Watt	150 Watt	250 Watt	40 W	125 W
Total connected load	1914	189	164	374	80	26	43

Measured power	53592	75600	11480	56100	20000	1040	5375
KW	53.592	75.6	11.48	56.1	20	1.04	5.375

The lux level at different location has been carried out using Testo lux meter and the readings are provided in Table 10.3

Table 10.3: Lux Measurement

Parameter	Unit	Readings
office Building		
Entry gate hall	Lux	200
Entry to steps	Lux	100
Unit - 1		
Switch gear control room	Lux	115
Near TIE 6.6 KV (1CB = 006) feeder	Lux	20
in front of ventilation MCC - 1	Lux	5
in front of DMCW pump - B (feeder)	Lux	150
exit of unit - 1 switch gear towards GT	Lux	5
Unit - 1 TG Floor		
Towards HP turbine	Lux	110
LP turbine left side/right side	Lux	200
infront of generator	Lux	150
HP turbine	Lux	200
Near gas line @ zero meter	Lux	80
Near NGT	Lux	30
Gas turbine zero meter	Lux	25
In front of DMCW 1 B	Lux	134
In front of DMCW 1A	Lux	120
In front of plate heat exchanger	Lux	120
Hot well are	Lux	185
mall 34 valve	Lux	130
unit NGT/NGR	Lux	10
Vacuum pump area	Lux	150
unit -2		
In front of generator	Lux	100
Right side of turbine	Lux	100
Left side of turbine	Lux	90
In front of turbine	Lux	70
unit - 2 ladder near GT - 2	Lux	50

zero meter near GT -2	Lux	40
unit - 2 main oil tank	Lux	30
unit - 2 MA2L - 34	Lux	25
In front of CEP - 2A & 2 B	Lux	120
Near vacuum pump	Lux	50

Observation-

- As per the pictorial presentation shown below which was measured during the field study on the day of audit. The measured lux was found on higher recommended lux level. The BIS standard for lighting lux level is provided in Annexure.

Main control Building Entrance area Main control Canteen walk way area

Figure 10.1: Pictorial diagram of Main control building entrance

- In Switchgear room light was switch on even when no occupancy was there during day time. Separate lighting circuit should be there for minimum lighting .As per the pictorial presentation shown below
- As per discussion with plant personal, the process of installing voltage regulator for lighting system is already initiated.

U#1 Switchgear area U#2 Switchgear area

Figure 10.2: Pictorial diagram of Unit 1 and Unit 2 Switch gear area

Recommendation-

- Only minimum lighting should be on all time or 50% lighting should be on during day time when no occupancy is there.(All plant switchgear room) Separate switches for minimum lighting in identified area The Energy saving is calculated for optimizing the lighting is shown in Table 10.4

Table 10.4: ECM for lighting optimization

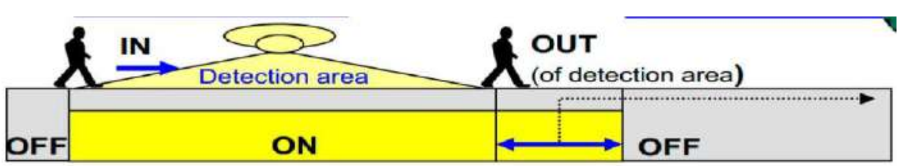
Sl. No.	Location	Fitting type	Quantity	Day time requirement	energy saving yearly (kWh)
1	Switchyard MCC Room	2x28W Tubelight Fitting	20 set	10 set	4905.6
2	Switchyard Cable Celler Room	2x28W Tubelight Fitting	19 set	10 set	4415.04
3	Switchyard battery & HVAC rooms	2x28W Tubelight Fitting	17 set	9 set	3924.48
4	Inside DG Building	150W HPSV	6 nos.	3 set	7884
5	Inside Compressor house	150W HPSV	6 Nos.	4 Nos	2628
6	DM Plant inside	2x28W Tube light	18 set	9 set	4415.04
7	DM plant MCC Room	2x28W Tube light	8 set	4 set	1962.24
9	GBC MCC Room	2x28W tubelight	13 set	6 set	3433.92
10	CT MCC Room	2x28W tubelight	12 Nos.	6 set	2943.36
11	CT pump house Room	250W HPSV	5 nos.	3 nos	4380
		70W HPSV	11 nos.	6 nos	3066

12	Raw water MCC Room	2x28W tubelight	9 set	4 set	2452.8
13	ETP MCC Room	2x28 W Tubelight	8 set	4 set	1962.24
14	BFP area MCC Room	2x28W tubelight	17 set	8 set	4415.04
15	Top floor	150W HPSV	8 nos.	4 Nos	5256
16	Fire water MCC Room	2x28W tubelight	9 set	5 set	1962.24
17	Battery& charger bank room	2x28W tubelight	38 set	19 set	9320.64
18	HVAC chiller room	2x28W tubelight	28 set	14 set	6867.84
19	HVAC room	2x28W tubelight	20 set	10 set	4905.6
20	Total energy saving in kWh				81100.08
21	Energy saving in Rs. Cr				0.022303
22	Investment				Nil
23	Payback				Immediate

- Nature switch is best solution for outdoor unit lighting system. It works on Infrared sensing which is tuned by nature itself .It works on road light and outdoor lights.
- Install timer in lighting circuit so that unnecessary lights should not glow during day time.
- Install an inductive transformer in the lighting MCC. It will reduce the APC as well as the life of light.
- Nature switch operated by illumination level(Application for outdoor lights)
- Operating luminance level

  For switching on <60 lux for> 30 sec

  For switching off >100 lux for> 30 sec
- Passive Infrared sensor (PIR) control can be installed in Administrative building and switchgear room. It works on occupancy basis. Time and distance can be set in the sensor. Diagram explaining the PIR sensor is provided in the below Figure



CHAPTER -11

AIRCONDITIONING AND VENTILATION SYSTEM

OTPC has installed Vapour compression refrigeration system of different capacity is installed to provide cooling requirement. In addition, stand alone AC unit is also installed. The Detailed Energy Audit in HVAC system includes study of following equipments.

1. Chiller plant
2. AHU
3. Chilled water pump
4. Condenser water pump
5. Cooling tower

11.1 Chiller plant

The design detail of chiller plant is provided in the Table 11.1

Table 11.1: Design details of HVAC

Description	Data
Make	Voltas – Kolkata
Location of the system	Main control Room building
HVAC Capacity	150 TR
Type	Water cooled screw compressor
MANUFACTURER	BHEL
Chiller Model	GSWCDXR170-1

During audit, the chiller B was running. Measurements of chiller pump, condenser pump and cooling tower were collected from the daily log sheet. The parameters were measured to estimate the performance of chiller. The results presented in below Table.

Table 11.2: Performance evaluation of Chiller system

Description	Unit	Design	Data
Chilled water pump flow	m^3/hr	91	95
Chilled water inlet temperature	^oC	12	12
Chilled water outlet temperature	^oC	7	7
Chiller B delivered	TR		157.08
Chiller B power consumption	KW	138	123.44
Specific power consumption			0.785

11.2 AHU

The plant has installed various rating Air handling units at different location to supply cool air to the room. The power measurement was carried out for AHU at different location. The results of the power measured is shown in below table

Table 11.3: AHU Power measurement

AHU	Unit	Power
0 meter	kW	3.69
4.5 meter	kW	6.26
11.5 meter	kW	8.04
17.5 meter (unit - 1)	kW	6.14
17.5 meter (unit - 2)	kW	6.14

11.3 Chilled water pump

The HVAC system has two chilled water pump (one running and one standby). The design details of Chilled water pump is provided in table 11.4

Table 11.4: Chilled pump design details

Description	Data
Make	KIRLOSKAR BROTHERS LTD.
Motor KW	9.3 KW
Pump efficiency	77 %
Total head	21 M
Discharge Flow	91 CMH
pump Model	**CE80/26**

The performance of the chilled pump is calculated and provided in the Table 11.5

Table 11.5: Performance evaluation of Chilled water pump

Description	Unit	Design	Chilled water pump B
Pump discharge flow	m^3/hr	91.00	95.00
Total Head Developed	m	21.00	18.00
Input Motor Power	kW	9.30	7.94
Motor Efficiency	%	0.95	0.95
Combined Overall Efficiency	%		58.72
Pump Efficiency	%	71.00	61.81
Percentage loading on motor	%		85.33
Specific power consumption	kW/TPH		0.08

percentage loading on head	%		85.71

11.4 Condenser water pump

The HVAC system has two condenser water pumps (one running and one standby). The design details of condenser water pump is provided in table 11.6

Table 11.6: condenser pump design details

Description	Data
Make	KIRLOSKAR BROTHERS LTD
Motor KW	18.5 KW
Pump efficiency	71 %
Total head	24 M
Discharge Flow	143 CMH
pump Model	DB100/32

The performance of the condenser water pump is calculated and provided in the Table 11.7

Table 11.7: Performance evaluation of condenser water pump

Description	Unit	Design	Condenser water pump B
Pump discharge flow	m^3/hr	143.00	145.00
Total Head Developed	m	24.00	11.00
Input Motor Power	kW	18.50	14.09
Motor Efficiency	%	0.95	0.95
Combined Overall Efficiency	%	50.55	30.85
Pump Efficiency	%	71.00	32.48
Percentage loading on motor	%	100.00	76.15
Specific consumption	kW/TPH	0.13	0.10
percentage loading on head	%		45.83

11.5 Cooling Tower

The HVAC plant has two cooling tower for cooling the condensed water. One cooling tower for each Chiller. The performance evaluation of cooling tower has calculated and provided below

Table 11.8: Performance evaluation of Cooling tower

Parameters	Unit	Data
CT inlet temperature	ºC	31.10
CT outlet temperature	ºC	29.00
Condensed water flow rate	m^3/hr	

Dry Bulb temperature	ºC	26.50
Wet Bulb temperature	ºC	26.40
Range	ºC	2.10
Approach	ºC	2.60
Effectiveness	%	44.68

Observation-

- The specific power consumption of the water cooled screw chiller is calculated and found to be 0.785 KW/TPH.
- The chilled pump and condenser pump efficiency has been evaluated and found to be 61.81 % and 32.48 % respectively against the design value 71 %.
- The condenser pump efficiency is very low. This may be due to low operating head. Based on the pump performance curve, head should be around 22 M for the operating parameter. But the operating head is around 11 M. Hence it is recommended to check the piping and pump internal.
- The chilled water pump works satisfactory.
- The cooling tower of Chiller 1 and Chiller 2 has evaluated and effectiveness of the plant is around 44.68 %.
- During audit one chiller was in operation and another was in standby. In the same manner, one cooling tower is dedicated to one chiller. Hence one cooling tower should run during audit. However, two cooling tower was in operation.
- The cooling tower fills is not in good condition. Hence it is recommended to maintain the cooling tower properly and stop one CT fan. The energy saving calculation is provided below.

Parameter	Unit	Data
Number of CT Fan running		2
power consumption of HVAC CT Fan B	KW	3.28
power consumption of HVAC CT Fan A	KW	3.4
Power saving	kW	3.28
Annual running hours	hrs/yr	5606.4
Annual energy saving	kWh/yr	18388.99
Energy cost	Rs/kWh	2.75
Annual Energy Saving	Rs.Cr	0.01
Investment	Rs.Cr	0.005

Payback	Month	12

Actual investment cost to be verified with Vendor

- The AHU provided for each floor is working in partial load. Cooling load of AHU may vary frequently and there is no control to optimize the energy consumption. It is proposed to install Variable Frequency Drive for all AHUs with temperature feedback system to optimize the energy consumption

Parameter	Unit	Data
Number of AHU running	No	5
Power consumption of AHU	KW	30.27
power saving	KW	4.5405
Annual running hours	hrs/yr	5606.4
power saving	kWH	25455.86
Energy cost	Rs/kWh	2.75
Annual Energy Saving	Rs.Cr	0.007
Investment	Rs.Cr	0.015
Payback	Month	26

Actual investment cost to be verified with Vendor

CHAPTER -12

AUXILIARY PUMPING

Performance of following pump has evaluated during audit by conducting flow measurement and power measurement using ultrasonic flow meter and power analyzer

1. Raw water pump
2. Hydrant pump
3. Degasser pump

12.1 Raw water pump

The Raw water pump is the main equipment for providing the necessary water to the plant from the water reservoir. The performance of the raw water pump has been evaluated based on the reading measured using ultrasonic flow meter and power analyzer. The result of the raw water performance is provided in Table 12.1

Table 12.1: RAW water pumps performance

Parameter	Unit	Design	RAW A	RAW B	RAW C
Pump discharge flow	m^3/hr	585.00	565.80	579.00	503.20
Total Head Developed	m	20.00	21.00	20.00	22.00
Input Motor Power	kW	45.00	49.25	48.32	46.00
Rated Motor power	kW	45.00	45.00	45.00	45.00
Motor Efficiency	%	0.933	0.933	0.933	0.933
Combined Overall Efficiency	%	70.85	65.74	65.31	65.58
Pump Efficiency	%	84.00	70.46	69.99	70.29
Percentage loading of flow	%	100.00	96.72	98.97	86.02
Percentage loading on motor	%	100.00	102.11	100.18	95.37
Specific consumption	kW/TPH	0.08	0.09	0.08	0.09

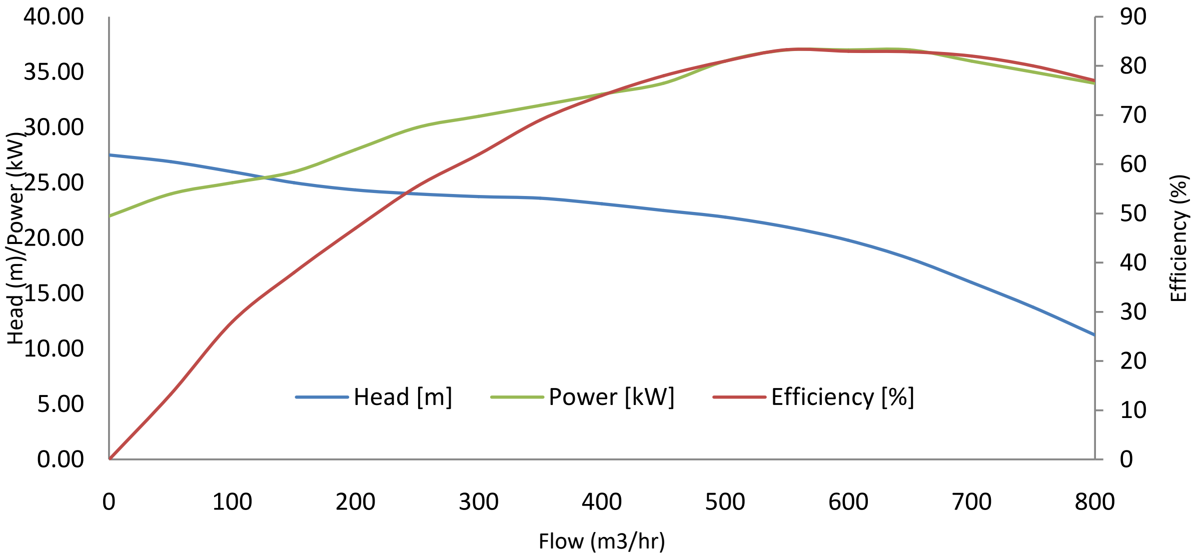


Figure 3: Raw water pump characteristic curve

Observation & Recommendation:-

- The performance of raw water pumps have been analyzed by measuring the flow, pressure developed and power consumption of the pumps. Flow is measured using ultrasonic flow meter and at the same time power is measured by using power analyzer. Head is calculated from pressure transmitter installed at outlet of pump.
- The measured flow is 565m^3/hr, 579m^3/hr and 1390m^3/hr for the pump A, B & C respectively at the developed head between 20 to 22m for all the three pumps.
- It is recommended to calibrate the pressure gauge installed at the outlet of pump, pressure fluctuation was observed during flow measurement.
- Pump efficiency is found to be 70.46%, 69.99% and 70.29% for pump A, B & C respectively, against the design value of 84%
- Specific power consumption is found to be on higher side than design.
- From the pump characteristic curve shown in Figure 12.1, power consumption for all the three pumps should be approx in between 35kw to 38kw at the measured flow and head. But the actual consumed power is in between 46 kW to 49 kW.
- It is recommended to check the internals of the pump as it taking more power than the design kW.

12.2 Hydrant pump

The performance of the hydrant pump has been evaluated based on the reading measured using ultrasonic flow meter and power analyzer. The result of the motor hydrant & spray pump performance is provided in Table 12.2. Meanwhile, the performance of diesel hydrant & spray pump is shown in Table 12.3.

Table 12.2: Hydrant pumps performance

Parameter	Unit	Design	Motor hydrant 1	Motor hydrant 2	Motor Spray
Pump discharge flow	m3/hr	273.00	225.0	196	222
Total Head Developed	m	94.34	92.00	94.00	88.00
Input Motor Power	kW	110.00	75.52	68.98	84.52
Rated Motor power	kW	110.00	110	110	110
Motor Efficiency	%	0.95	0.95	0.95	0.95
Combined Overall Efficiency	%		74.69	73.06	63.13
Pump Efficiency	%	80.00	78.62	76.91	66.45
Percentage loading of flow	%		82.42	72.07	81.50
Percentage loading on motor	%		65.22	59.57	72.99
Specific consumption	kW/TPH	0.40	0.34	0.35	0.38

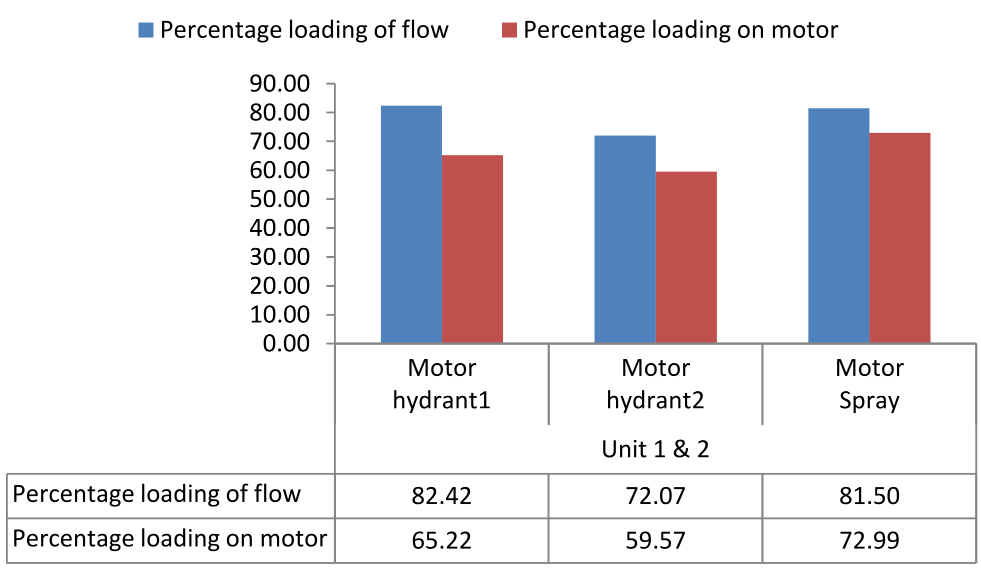


Figure 4: Hydrant pump percentage loading (motor & flow)

Table 12.3: Diesel Hydrant pumps performance

Parameter	unit	Design	Diesel hydrant	Diesel Spray
Pump discharge flow	m3/hr	273.00	221.25	210.00
Total Head Developed	m	94.34	98.00	98.00
Input Bowl Power	kW	90.53	88.00	86
Rated Bowl power	kW	90.53	90.53	90.53
Bowl Efficiency	%	80.00	80.00	80.00
Pump Hydraulic power		70.18	59.08	56.08
Total Bowl power	kW	90.65	88.12	86.12
Input power	kW	92.50	89.92	87.88
Combined Overall Efficiency	%	75.87*	65.71	63.82
Pump Efficiency	%	80.00	67.05	65.12

**Design combined overall efficiency is calculated based on the design data*

Observation: -

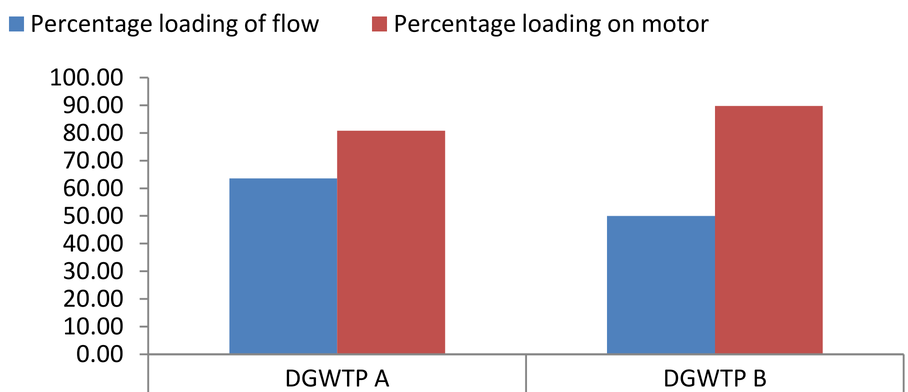
- Overall pump performance is satisfactory.
- During the time of audit it was observed that the Diesel hydrant was getting too hot within 5 mins of running, that must be kept under observation.
- Flow measurement of diesel Hydrant pump and diesel hydrant spray has carried out and found to be 220 m^3/hr and 210 m^3/hr. Discharge pressure was 9.8 kg/cm^2.
- The Diesel hydrant and Diesel spray pump efficiency has calculated based on the measured flow and pressure and it is found to be 67.05% and 65.12 respectively against the design value of 80 %.
- As per the hydrant pump loading figure shown in Figure 12.2, the percentage loading with respect to flow & motor power for hydrant pump 1, hydrant pump 2 and spray is found to be 82.42% & 65.22%, 72.07% & 59.57% and 81.50% &72.99% respectively.

12.3 Degasser water pump

The performance of the degasser pump has been evaluated based on the reading measured using ultrasonic flow meter and power analyzer. The result of the degasser water performance is provided in Table 12.4

Table 12.4: Degasser pumps performance

Parameter	Unit	Design	DGWTP A	DGWTP B
Pump discharge flow	m3/hr	21.00	13.36	10.49
Total Head Developed	m	35.00	33.59	36.00
Input Motor Power	kW	5.50	5.17	5.74
Rated Motor power	kW	5.50	5.50	5.50
Motor Efficiency	%	0.86	0.86	0.86
Combined Overall Efficiency	%	36.42	23.65	17.93
Pump Efficiency	%	49.40	27.50	20.85
Percentage loading of flow	%		63.62	49.95
Percentage loading on motor	%		80.84	89.75
Specific consumption	kW/TPH	0.26	0.39	0.55



	DGWTP A	DGWTP B
Percentage loading of flow	63.62	49.95
Percentage loading on motor	80.84	89.75

Figure 5: Degasser water pump percentage loading (motor & flow)

OBSERVATION:-

- The performance of Degasser pump have been analyzed by measuring the flow, pressure developed and power consumption of the pumps. Flow is measured using ultrasonic flow meter and at the same time power is recorded. Head is calculated by Pump law.
- The measured flow is 13.36 m^3/hr, 10.49m^3/hr for the pump A and B respectively. Design flow is 21m^3/hr.
- The measured current consumption during audit is 8.25 Amp and 9.18 Amp for DGWTP A and DGWTP B respectively.

- It is recommended to calibrate the pressure gauge installed at the inlet of pump, pressure fluctuation was observed during flow measurement.
- Pump efficiency is found to be only 27.50% and 20.85% for pump A and B respectively; against the design value of 49.40%.It may be due to the low flow.
- Specific power consumption is found to be on higher side than design.
- As per the degasser water pump loading figure shown in Figure 12.3, the percentage loading with respect to flow & motor power for DGWTP A and DGWTP B is found to be 63.62% & 80.84% and 49.95% & 89.75% respectively.
- The loading percentage of flow is less; however the motor power loading is more this may be due to pump internals. Hence it is recommended to check the internals of the pump.

CHAPTER -13

INSTRUMENT AIR COMPRESSOR (IAC)

The plant has installed two instrument air screw compressor with the capacity of 15 NM^3/min for the compressor air requirement. The operating pressure of the compressor is 8.5 bar. The design details of the instrument air compressor is provided in Table 13.1

Table 13.1: Design Details of IAC

Parameter	Design specification
Make	Atlas Copco (India) Ltd.
Type of compressor	Oil Free Screw
Capacity of each Air compressor	15 NM^3/Min
Discharge pressure at rated condition	8.5 bar
KW rating of drive motor	132 kW
Total Numbers	2

The power consumption of Instrument air compressor has measured using power analyzer and provided in table 13.2

Table 13.2: Power Consumption of IAC

Parameter	Voltage (V)	Current (A)	Power Factor	Power (kW)
Instrument Air Compressor A	437.4	52.1	0.8	31.58
Instrument Air Compressor B	450	53.47	0.84	35.01

Observation & Recommendation:-

- While audit, both Instrument air compressor was in service, IAC – A in loading condition and IAC – B in unloading condition.
- Based on the Technical diary, kW input required to the compressor in loading condition and unloading condition is found to be 119 kW and 27 kW respectively.
- The power required for running the both compressor is calculated to be 146 kW. Hence the power consumption of both IAC for a particular day is calculated and found to be 3504 kWh.
- As per above analysis, it is recommended to keep one IAC in service and another IAC in standby condition.

- By keeping the one IAC in standby condition, the unloading power consumption of 27 kW will be reduced.

Description	Unit	IAC
Loading Power consumption	kW	192.00
Unloading power consumption	kW	27.00
Power saving	kW	27.00
Annual operating hours		5606.40
Annual Energy Saving potential	kWh	151372.80
Energy Cost	Rs./kwh	2.75
Annual Monetary Saving	Rs. Cr	0.04
Investment for VFD	Rs. Cr	NIL
Payback	Months	Immediate

CHAPTER -14

HT and LT MOTORS

Measurements of all HT motors of HRSG, turbine & BOP area were taken using the Power Analyzer, which measures Voltage, Current, kW, and P.F. etc. The parameters were measured to estimate the electrical loading of the motors. The measurements taken are tabulated and presented in below Table.

14.1 Power Measurement

The instantaneous power consumption was measured in all auxiliary loads and details are as follows.

Table 14.1: Common switch gear

Sl. No	Date	Equipment Name	Design	Efficiency (N)	Voltage(kV)	Current	PF	Power(KW)	TRN POWER (KVA)	% LOADING
1	9/8/2017	Admin Building 1	1600 KVA	N/A	7.12	8	0.74	76	102.70	6.42
2	9/8/2017	Admin Building 2	1600 KVA	N/A	6.93	8	0.69	73	105.80	6.61
3	9/8/2017	Gas Station 1	1600 KVA	N/A	7.12	17	0.834	175	209.83	13.11
4	9/8/2017	Gas Station 2	1600 KVA	N/A	6.92	16	0.874	176	201.37	12.59
5	9/8/2017	Gas Booster Compressor-B	3840 kW	96	7.11	338	0.919	3824	4161.04	95.6
6	9/8/2017	Gas Booster Compressor-C	3840 kW	96	6.92	16	0.874	175	200.23	4.38
7	9/8/2017	Raw water switchgear 1	1600 KVA	N/A	7.11	12	0.735	109	148.30	9.27
8	9/8/2017	Raw water switchgear 2	1600 KVA	N/A	6.92	14	0.729	122	167.35	10.46
9	9/8/2017	River water Intake 2	1000 KVA	N/A	6.93	10	0.87	106	121.84	12.18
10	9/8/2017	S.T 1	25000 KVA	N/A	7.11	389	0.91	4337	4792.27	19.17
11	9/8/2017	S.T 2	25000 KVA	N/A	6.92	411	0.90	4431	4934.30	19.74
12	9/8/2017	STN Service Transformer(TRF) 1	2000 KVA	N/A	7.12	16	0.711	140	196.91	9.85
13	9/8/2017	STN Service Transformer(TRF) 2	2000 KVA	N/A	6.94	24	0.661	191	288.96	14.45
14	9/8/2017	Switch Yard TRF 1	500 KVA	N/A	6.82	2	0.452	14	30.97	6.19
15	9/8/2017	Switch Yard TRF 2	500 KVA	N/A	6.91	5	0.2	12	60	12

Table 14.2: Unit 1 Power consumption

Equipment Name	Design	EFFICIENCY	Voltage(kV)	Current	PF	Power(KW)	TRN POWER IN (KVA	%LOADING

CT PMCC 1	1600 KVA	N/A	6.569	40	0.831	381	458.48	28.66
CW Pump A	1150 kW	95	6.567	107	0.78	944	1218.06	77.98
Excitation Transformer	2000 KVA	N/A	6.564	65	0.294	216	734.69	36.73
HP BFP A	4000	97	6.567	196	0.842	1871	2222.09	45.37
STG PMCC1	1600 KVA	N/A	6.566	34	0.727	283	389.27	24.33
UAT 1C to 1CA		N/A	6.571	434	0.756	3747	4956.35	N/A
CEP -B	600	95	6.569	46	0.837	437	522.10	69.19
CT PMCC 2	1600 KVA	N/A	6.542	31	0.856	261	304.91	19.06
CW Pump B	1150	95	6.583	109	0.781	972	1244.56	80.30
DMCW-B	300	95	6.566	27	0.855	269	314.62	85.18
GT PMCC 2	1600 KVA	N/A	6.574	34	0.799	314	392.99	24.56
STG PMCC 2	1600 KVA	N/A	6.569	8	0.77	75	97.40	6.09
UAT 1C to 1CB		N/A	6.566	255	0.818	2357	2881.42	N/A

Table 14.3: Unit 2 Power consumption

Sl. No	Date	Equipment Name	Design(KW)	EFFICIENCY	Voltage (kV)	Current	PF	Power(KW)	POWER(KVA)	% LOADING
1	9/8/2017	CT PMCC 1	1600 KVA	N/A	6.659	38	0.841	375	445.90	27.87
2	9/8/2017	CW Pump A	1150	95	6.654	105	0.769	931	1210.66	76.91
3	9/8/2017	Static Excitation	2000 KVA	N/A	6.656	90	0.388	412	1061.86	53.09
4	9/8/2017	HP BFP B	4000	97	6.675	229	0.86	2229	2591.86	54.05
5	9/8/2017	STG PMCC 1	1600 KVA	N/A	6.657	14	0.794	129	162.47	10.15
6	9/8/2017	UAT 1C to 2CA		N/A	6.657	315	0.728	1735	2383.24	N/A
7	9/8/2017	CEP -A	600	95	6.657	48	0.844	468	554.50	74.1
8	9/8/2017	CT PMCC 2	1600 KVA	N/A	6.681	29	0.843	281	333.33	20.83
9	9/8/2017	CW Pump C	1150	95	6.667	104	0.766	922	1203.66	76.17
10	9/8/2017	DMCW-A	300	95	6.651	26	0.851	263	309.05	83.28
11	9/8/2017	GT PMCC 2	1600 KVA	N/A	6.671	34	0.8	323	403.75	25.23
12	9/8/2017	STG PMCC 2	1600 KVA	N/A	6.656	29	0.709	240	338.50	21.16
13	9/8/2	UAT 1C to		N/A	6.566	255	0.8	2357	2881.42	N/A

	017	1CB					18			
14	9/8/2017	TIE from 0CA		N/A	6.656	90	0.388	412	1061.86	N/A
15	9/8/2017	UAT 1C to 2CB		N/A	6.66	420	0.822	4005	4872.26	N/A

Table 14.4: LT Motor Power consumption

S.NO.	EQUIPMENT NAME	DESIGN(KW)	EFFICIENCY	VOLTAGE	CURRENT	P.F	POWER	% LOADING
1	LP BFP 1A	30	91	409	36.41	0.85	21.92	66.50
2	LP BFP 2A	30	91	406.7	39.65	0.85	23.74	72.01
3	ACW 1A	110	95	422	160	0.83	97.06	83.83
4	VACCUM PUMP 1A	110	95	422	165	0.85	102.51	88.53
5	IAC 1	132	95	437.4	52.1	0.8	31.58	22.73
6	IAC 2	132	95	450	53.47	0.84	35.01	25.19
7	ACW 2A	110	95	410	165	0.8	93.74	80.95
8	VACCUM PUMP 2 B	110	95	410	185	0.86	112.98	97.57
9	HYDRANT WATER PUMP A	110	95	435.5	154.5	0.62	72.25	62.40
10	HYDRANT WATER PUMP B	110	95	428.5	154.9	0.6	68.98	59.57
11	SPRAY WATER PUMP	110	95	434.2	156.1	0.72	84.52	73.00
12	RWP B	45	93.3	434	75.6	0.85	48.30	100.15
13	RWP A	45	93.3	426.2	78.5	0.85	49.25	102.12
14	RWP C	45	93.3	426.3	73.3	0.85	46.00	95.38
15	DGWTP-A	5.5	86	426	8.25	0.85	5.17	80.90
16	DGWTP-B	5.5	86	425	9.18	0.85	5.74	89.81

Table 14.5: Cooling Tower 1 Power consumption

S.NO.	EQUIPMENT NAME	DESIGN(KW)	EFFICIENCY %	AMP	VOLTAGE	P.F	POWER	% LOADING
1	CT FAN1	110	94.5	140	410.1	0.55	54.69	46.99
2	CT FAN 2			150	410	0.58	61.78	53.08
3	CT FAN 3			148	410.8	0.56	58.97	50.66
4	CT FAN 4			148	410	0.56	58.85	50.56
5	CT FAN 5			N/R				
6	CT FAN 6			130	411.4	0.54	50.02	42.97

7	CT FAN 7			150	412	0.52	55.66	47.82
8	CT FAN 8			142	411.2	0.53	53.60	46.05

Table 14.6: Cooling Tower 2 Power consumption

S.NO.	EQUIPMENT NAME	DESIGN(KW)	EFFICIENCY (%)	AMP	VOLTAGE	P.F.	POWER	% LOADING
1	CT FAN1	110	94.5	148	418	0.54	57.86	49.71
2	CT FAN 2			150	418.5	0.57	61.97	53.24
3	CT FAN 3			149	418.5	0.53	57.24	49.18
4	CT FAN 4			146	418.6	0.51	53.98	46.38
5	CT FAN 5			150	419	0.5	54.43	46.76
6	CT FAN 6			158	419	0.53	60.77	52.21
7	CT FAN 7			162	419	0.54	63.48	54.54
8	CT FAN 8			N/R				

Observation and Analysis

- Installation of Energy Meter in all HT motors for accurate and reliable measurement of electrical parameters (voltage, current, power, frequency, etc.).Integrated Modbus communications capability allows easy integration with energy monitoring systems for Efficiency of Motors.
- As per Table 13.1, two transformers supplies power to the admin building and the loading of these transformers is found to be at 6.42% & 6.61%. Due to this low load operation transformer loss are high. So, to reduce the no load losses of transformer, off one transformer and put load to other transformer.
- As per Table 13.4, Voltage measured at IAC feeder MCC bus is on higher side, as the motor design or rated voltage is 415V but bus voltage was found to be 450V. This may increases magnetization losses in transformer.

Recommendation

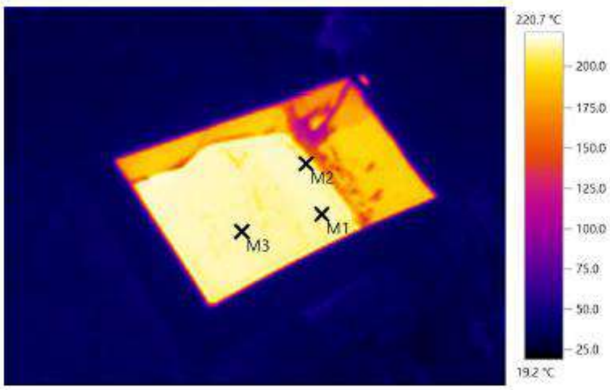
- There may be a possibility that both the Admin building Transformer feeder 1&2 can be switched off and the load can be switched to LT feeder by LT switchgear. So it reduces transformer full load losses and part load losses.
- The voltage to the IAC feeder should be reduced to the standard 415 V by tap changing. this 2.5% reduction in voltage may provide power saving of 0.65 %.

CHAPTER– 15

INSULATION SURVEY

Insulation Audit was carried out during the detailed energy audit to identify the damaged area of insulation in the boiler area, Turbine and associated steam lines. Surface temperatures were measured using non-contact infra red thermometer and the measurements are presented below. :

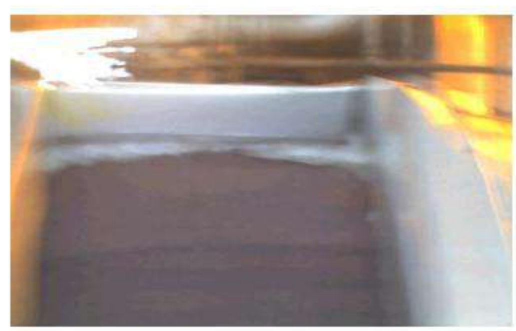
Unit 1 IP drum top name plate side



Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	213.3	0.95
Measure point 2	209.9	0.95
Measure point 3	212.9	0.95

Observation:
Insulation for the IP drum top is not provided and the tempreture is around 210°C. Thus needs proper insulation.

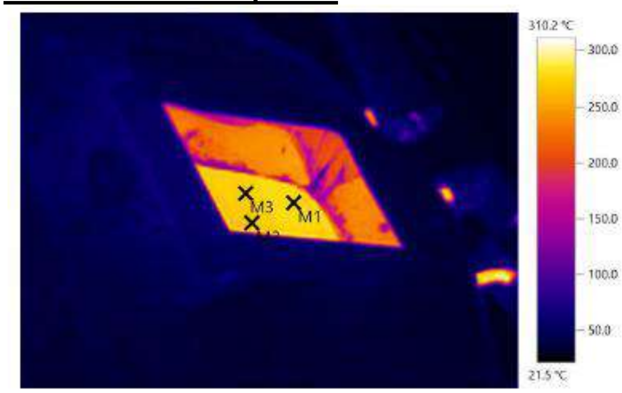
Unit 1 LP drum top area



Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	141.2	0.95
Measure point 2	138.2	0.95
Measure point 3	141.3	0.95

Observation:
Insulation is not provided on top of the LP drum and the tempreture is around 140°C. This needs proper concern and provide proper insulation.

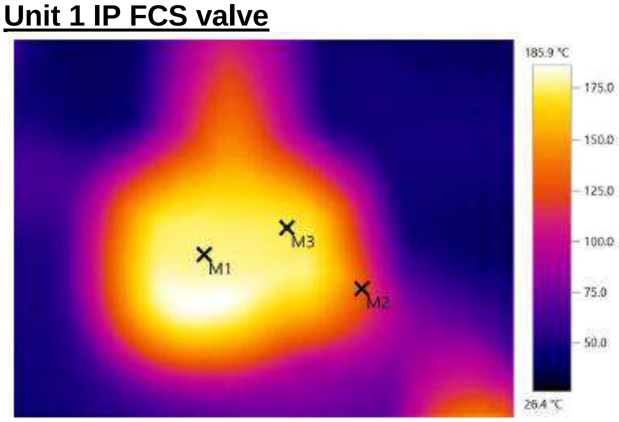
<u>Unit 1 HP drum top area</u>



Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	277.1	0.95
Measure point 2	269.2	0.95
Measure point 3	273.2	0.95

Observation:
There is no insulation on the top of the HP drum and the tempreture is around 270°C.

<u>Unit 1 IP FCS valve</u>

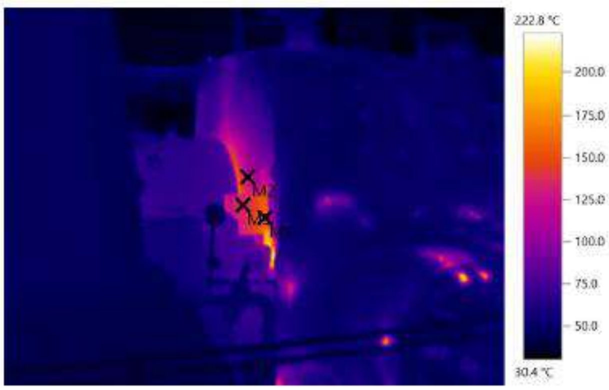


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	176.8	0.95
Measure point 2	129.8	0.95
Measure point 3	172.9	0.95

Observation:

IP FCS Valve is not insulated. The tempreture was around 150°C which seems to be the heat loss. It needs proper insulation.

<u>Unit 1 IP side cover</u>

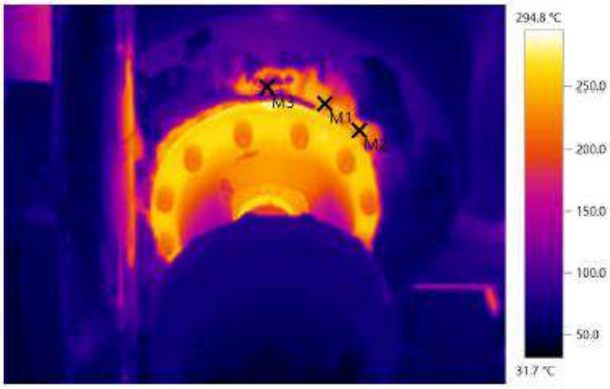


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	160.4	0.95
Measure point 2	122.7	0.95
Measure point 3	131.9	0.95

Observation:

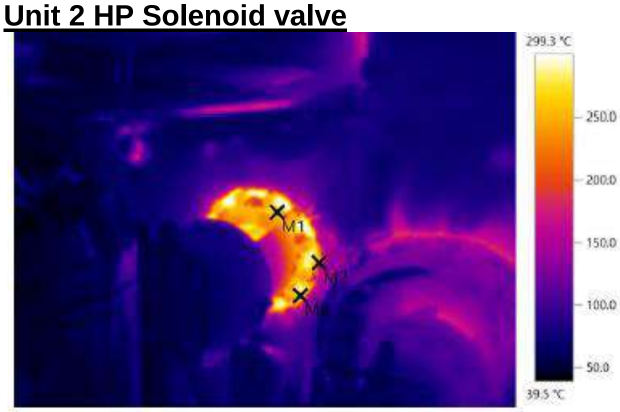
Turbine IP side is not insulated. The temperature was 140°C. However for unit -2 the temperature is within range for the same location. Hence it needs insulation.

Unit 1 HP solenoid valve HP 1



Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	247.5	0.95
Measure point 2	239.0	0.95
Measure point 3	199.0	0.95

Unit 2 HP Solenoid valve

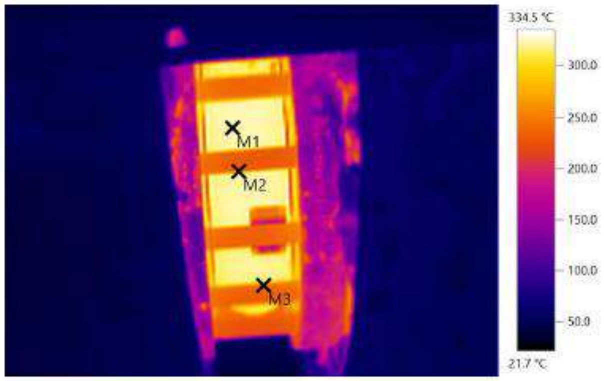


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	268.1	0.95
Measure point 2	230.1	0.95
Measure point 3	264.8	0.95

Observation:

HP solenoid valve of unit – 1 and unit – 2 is not insulated. The temperature for unit 1 and unit 2 is found to be around 220°C and 250°C respectively. This may cause heat loss across valve. Hence it needs proper insulation.

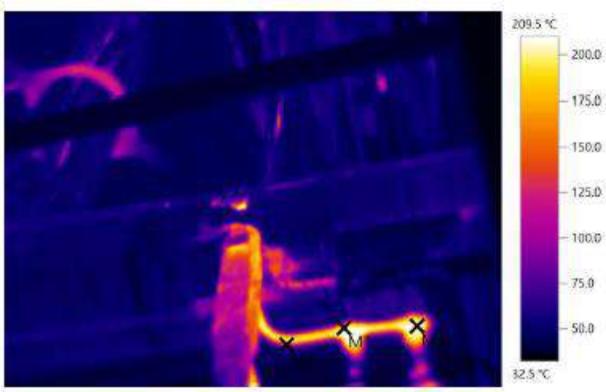
Unit 2 Compressor air inlet air purging line



Observation:

There is no insulation in compressor air pugging line to GT. Needs proper insulation to reduce the heat loss.

Unit 2 CRH line near condensed port

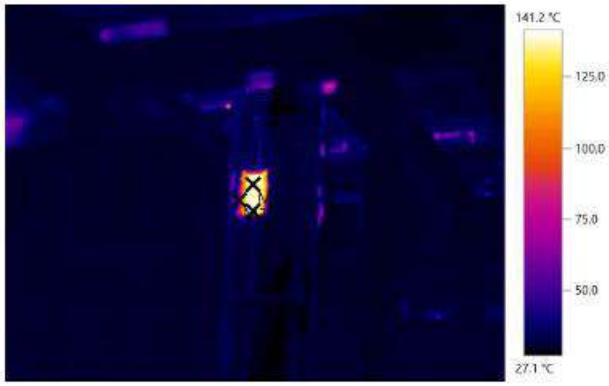


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	191.4	0.95
Measure point 2	122.5	0.95
Measure point 3	208.1	0.95

Observation:

The temperature of CRH line near condenser port was 180°C .It need to be proper insulated.

Unit 2 LP down comer

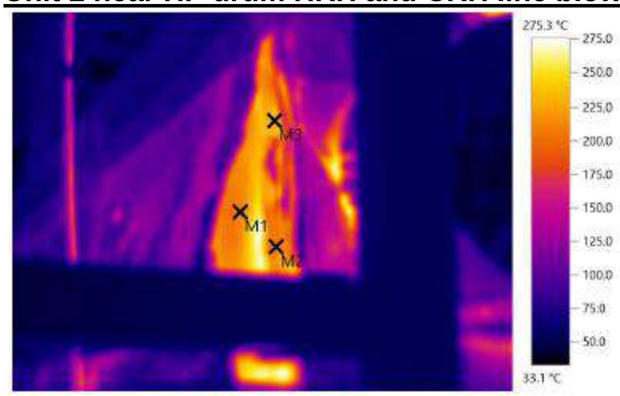


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	139.0	0.95
Measure point 2	137.8	0.95
Measure point 3	52.8	0.95

Observation:

The insulation was damaged in LP down comer the temperature which is slightly greater than the ambient temperature.

Unit 2 near HP drum HRH and CRH line blow down

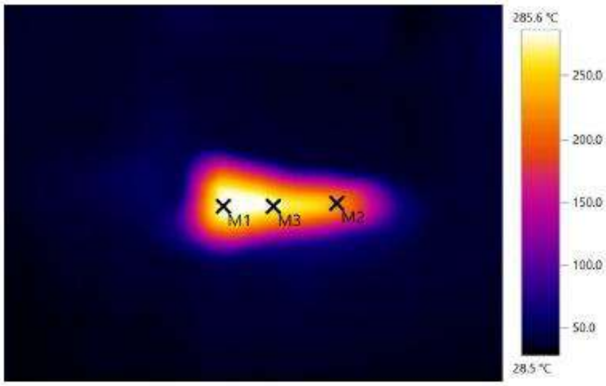


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	211.4	0.95
Measure point 2	205.7	0.95
Measure point 3	229.8	0.95

Observation

There is insulation damage in near HP drum HRH and CRH line blow down. The average temperature is 215°C.

IP outlet line near Drum after IMS 38 MOV

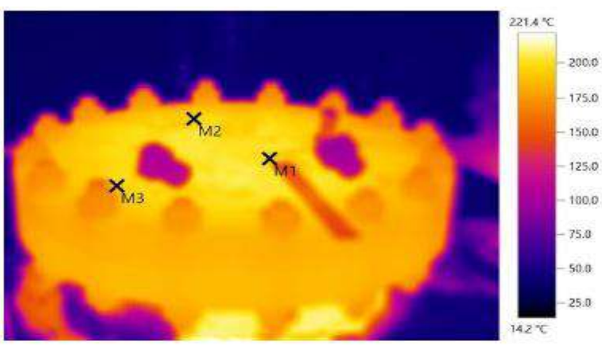


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	282.5	0.95
Measure point 2	229.7	0.95
Measure point 3	278.4	0.95

Observation

Insulation is not for IP outlet line near drum after IMS 38 MOV. The temperature is around 240°C. It needs proper insulation.

LP main steam line near LMS 14 valve

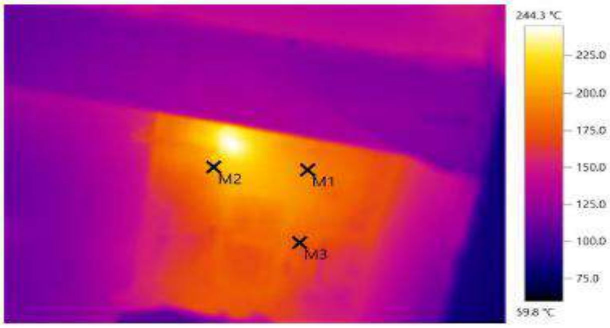


Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	197.1	0.95
Measure point 2	197.6	0.95
Measure point 3	194.0	0.95

Observation

Insulation for LMS 14 valve is not provided. Hence the surface temperature of valve is around 195°C.

Unit 2 Re heater Suction main hole



Measurement Objects	Temp. [°C]	Emiss.
Measure point 1	194.0	0.95
Measure point 2	205.3	0.95
Measure point 3	178.2	0.95

Observation:
There is no coating on the man hole of reheater suction and the tempreture is around 200°C. Thus needs proper coating.

ANNEXURE

A: Formulas

Overall Station Heat Rate kcal/kWh = $\frac{Q \text{ X } H}{P}$ x 100

Where Q = Natural Gas Consumption in SCM
H = Inferior Calorific value of Natural gas in kcal/SCM
P = Total CCPP power output (GT + ST) in kWh

Air Compressor Efficiency (%)= $\frac{\text{Theoretical Temperature rise across the compressor}}{\text{Actual Temp rise}} \times 100$

GT Compressor efficiency = $\frac{(T2s - T1)}{(T2 - T1)} \times 100$

$$\frac{T2s}{T1} = \frac{P2}{P1}^{\left(\frac{\gamma - 1}{\gamma}\right)}$$

Where T2s = Adiabatic discharge air temp
T1 = Inlet air temperature in Kelvin
T2 =outlet air temp in Kelvin
P2 =air outlet pressure
P1 = inlet air pressure
γ =Compression coefficient.

GT EFFICIENCY

Overall Gas Turbine Efficiency (Compressor + GT) = $\frac{\text{Power Output} \times 860 \times 100}{\text{Fuel Input} \times \text{GCV}}$

Turbine efficiency (%) = $\frac{\text{Actual entalpy drop}}{\text{Isentropic enthalpy drop}}$ x 100

Turbine Heat Rate = $Q_0 + (Q_1\text{-}Q_2)+(Q_3\text{-}Q_4)$/kW
Q_0 = HP Turbine inlet energy
Q_1 = IP Turbine inlet energy
Q_2 = HP Turbine exhaust energy
Q_3 = LP Turbine inlet energy
Q_4 = LP Turbine exhaust energy
kW = Turbine output power

Condenser and heater

TTD (^oC) = $T_{sat} - T_{fwout}$

DCA (^oC) = $T_{drain} - T_{fwin}$

Temperature rise (^oC) = $T_{fwout} - T_{fwin}$

Extraction steam flow = $\frac{\text{FWflow } (h_{fwout} - h_{fwin}) + \text{Drain in flow } (h_{drnout} - h_{drnin})}{(h_{ext} - h_{drnout})}$

Heat load (kcal/hr) = $\text{FW Flow} * \text{Sp. heat} * \text{Temperature rise}$

Effectiveness = $\frac{T_{fwout} - T_{fwin}}{T_{sat} - T_{fwin}}$

Cooling Tower (CT)

a)	CT Range (^0C)	=	[CW inlet temp (^0C) - CW outlet temp (^0C)]
b)	CT Approach (^0C)	=	[CW outlet temp (^0C) - Wet bulb temp (^0C)]
c)	CT Effectiveness (%)	=	100×(CW temp - CW out temp) / (CW in temp - WB temp)
d)	L/G Ratio (kg/water/kg air)	=	Total CW water flow in CT (kg/hr) / Total air flow in CT (kg/hr)
e)	CT heat loading (kcal/hr)	=	CW flow (m^3/hr) × ΔT (^0C) × density of water (kg/m^3)
f)	CT evaporation loss (CMH)	=	CW circulation (CMH) × CW Temp. difference across CT in ^0C rate / 675
g)	% evaporation loss in cooling tower	=	Evaporation loss in CMH × 100 / CW circulation rate CMH
h)	Purge (CMH)	=	Evaporation (CMH) / (COC-1)

Pump

Energy Consumption (P_{pow}) = $\sqrt{3}\ V\ I\ \cos\emptyset$ in kW

Fluid kW (F_{kW}) = $\frac{Q * 9.81 * H * \rho}{3600} \times 100$ in kW

Where, Q is the flow (m^3/s) and H is the differential head (mmWC) and ρ is the specific gravity of fluid at operating temperature (kg/m^3)

Combined efficiency (η_c) = $\frac{\text{Fluid kW}}{P_{pow}} \times 100$ in %

or

Combined efficiency (η_c) = $\frac{Q*9.81*H}{P_{pow}} \times 100$ in %

Where , η_c is the combined efficiency of pump (%), P_{pow} is the motor power (kW), Q is the flow (m^3/s) and H is the differential head (mmWC).

Pump efficiency (η_P) = $\frac{\text{Combined efficiency}}{\text{Motor efficiency}} \times 100$ in %

Motor efficiency (η_{mot}) = given by OEM

Pump Efficiency as per performance curve = Pump Efficiency derived from performance curve of the pump at operating parameters like Flow, RPM

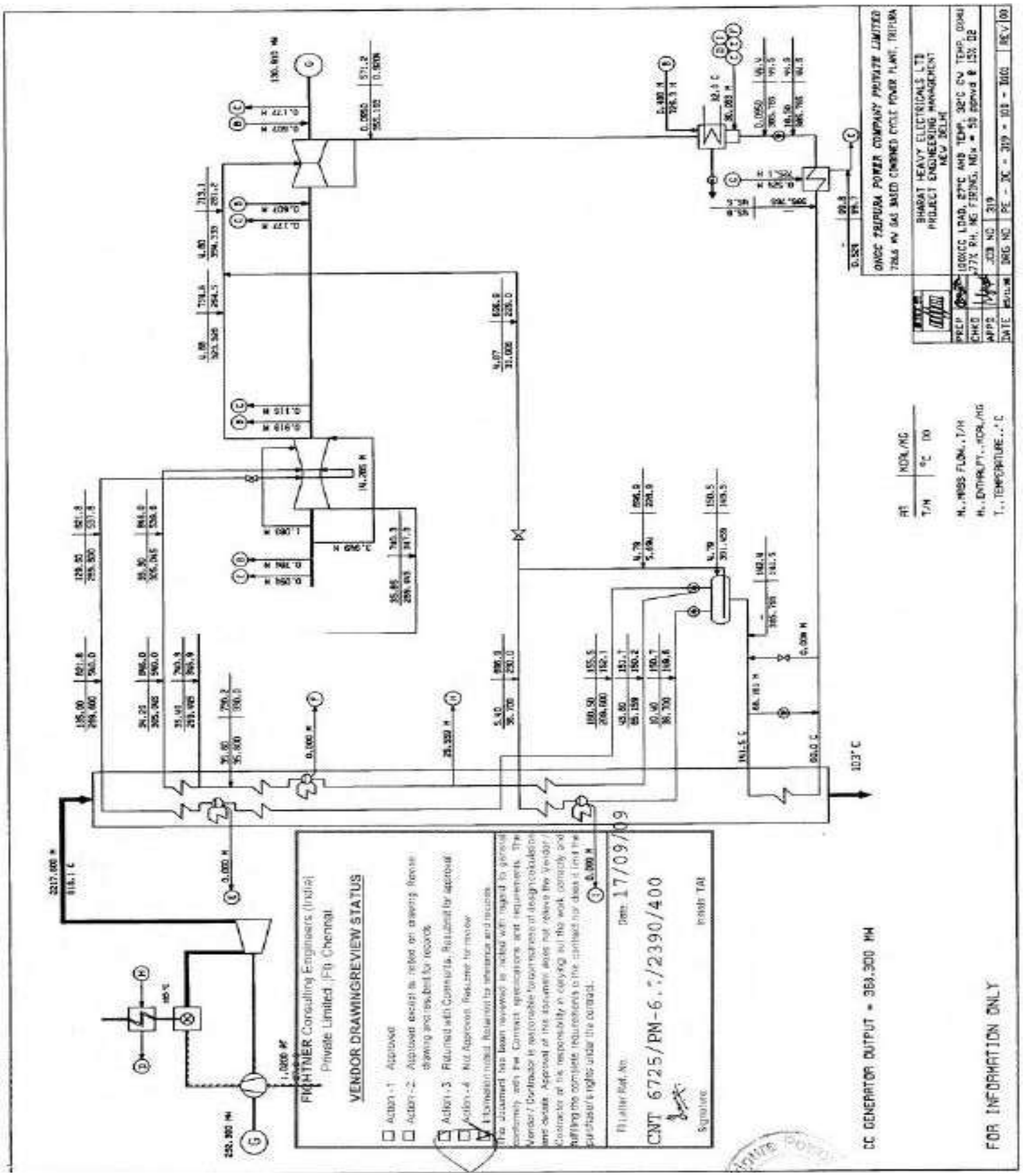
Specific Consumption = $\frac{\text{Measured kW}}{\text{flow rate}}$

Percentage loading on flow = $\frac{\text{Measured flow}}{\text{Rated flow}} * 100$ in %

Percentage loading on motor = $\frac{\text{Measured power}}{\text{Rated power} * \eta_{mot}} * 100$ in %

Percentage loading on head = $\frac{\text{Actual head}}{\text{Reference head}} * 100$ in %

B: Heat and Mass Balance Diagram



C: Operating Data

Description	Unit	Unit 1	Unit 2
GT 1 Load	MW	149.24	220.55
ST 1 Load	MW	99.93	122.46
Total Load	MW	249	343.01
GT 1 exhaust temp	°C	649.06	622.15
GT 1 inlet air temp	°C	33.83	30.54
HRSG inlet pressure	mmW	96.94	164.84
GT1 air inlet pressure	mmW	44.5	70.69
GT 1 CPD	bar	10.53	13.99
GT 1 Compressor outlet temp	°C	378.88	415.13
Fuel temp before exchanger	°C	101.29	132.55
Fuel temp after exchanger	°C	187.88	181.54
Fuel pressure before exchanger	kg/cm2	33.44	33.32
Fuel pressure after exchanger	kg/cm2	32.89	32.58
Fuel gas pressure	kg/cm2	31.35	29.81
Fuel gas temp	°C	183.7	180.23
Fuel flow rate	kg/sec	9.766	12.842
GT IGV	%	60.34	88
GT 1 exh. Mass flow	TPH	476.8	608.3
CEP outlet pressure	kg/cm2	24.31	22.99
CEP outlet flow	TPH	332.96	391.95
Condensate temp LTE inlet	°C	59.76	59.99
condensate temp LTE outlet	°C	135.53	143.08
DEA press	kg/cm2	3.43	4.09
LP drum pressure	kg/cm2	3.67	4.74
LPS outlet STM temp to LP Turbine	°C	228.27	234.64
LPs outlet STM press to LP Turbine	kg/cm2	3.66	4.56
LP turbine inlet temp	°C	227.09	257.48
LP turbine inlet pressure	kg/cm2	2.97	3.73
LP Turbine inlet steam flow	TPH	28.4	35.84
IP BFP inlet temp	°C	135.57	143.27
IP BFP inlet Pressure	kg/cm2	3.58	4.09
IP BFP Suction flow	TPH	385.36	441.28
IP BFP outlet temp	°C	142.39	147.75
IP BFP outlet pressure	kg/cm2	47.53	70.31

IP FW flow	TPH	35.25	49.34
IP drum pressure	kg/cm2	31.3	36.9
IPS1 outlet STM temp	°C	288.43	327.95
IPS1 outlet STM pressure	kg/cm2	27.95	33.77
RH 1 inlet STM temp	°C	352.38	349.76
RH 1 inlet STM pressure	kg/cm2	27.78	32.92
HPT Exh. Pressure	kg/cm2	28.6	33.75
HPT Exh. Temp	°C	425.52	358.12
RH 1 outlet steam temp	°C	471.96	448.74
RH 3 outlet steam temp	°C	540.32	536.5
RH 3 outlet steam pressure	kg/cm2	27.95	31.98
IPT inlet temp.	°C	540.89	536.4
IPT inlet pressure.	kg/cm2	27.68	31.98
HPBFP outlet temp	°C	143.74	149.42
HPBFP outlet pressure	kg/cm2	125.73	151.69
HPBFP outlet flow	TPH	238.22	285.95
HP drum pressure	kg/cm2	114.23	137.5
HPS3 outlet steam temp	°C	542.5	539.35
HPS3 outlet steam pressure	kg/cm2	104.5	125.84
Steam temp HPT inlet	°C	540.75	539.35
Steam Pressure HPT inlet	kg/cm2	103.35	125.84
HPT inlet flow	TPH		288.3
LP exh.hood temp.	°C	47	47.49
Cond. Vacuum	kg/cm2(a)	0.1	0.103
Hotwell Temp	°C	46.57	48.28
Make up flow	TPH	4.07	1.36
CW inlet temp LHS	°C	34.47	33.38
CW outlet temp LHS	°C	42.57	42.61
CW inlet temp RHS	°C	34.4	33.35
CW outlet temp RHS	°C	41.38	42.3
CW flow	TPH	19938.4	17872.2
Hotwell LVL	mm	706.08	733.42
DEA LVL	mm	698.68	815.18
Reference pressure	Bar	0.98	0.99
Reference Temperature	°C	33.83	30.54
Reference Humidity	%	87.8	87.8

D: Recommended Values of Illumination (IS 6665.1972)

S.No	Industrial Building and Process	Average Illumination (Lux)
	General factor Area	
1	Canteens	150
2	Cloak rooms	100
3	Entrance, Corridors, Stairs	100
	Electricity Generating Station: Indoor Locations	
4	Turbine halls	200
5	Auxiliary equipment; battery rooms, blowers, auxiliary generators, switchgear and transformer chambers	100
6	Boiler houses (including operating floors) platforms, coal conveyors, pulverizers, feeders, precipitators, soot and slag blowers	70 to 100
7	Boiler house and Turbine house	100
8	Basements	70
9	Conveyor houses, conveyor gentries, junction towers	70 to 100
10	Control Rooms	
	I. Vertical control panels	200 to 300
	II. Control desks	300
	III. Rear of Control panels	150
	IV. Switch houses	150
	Electricity Generating Station: Outdoor Locations	
11	Coal Unloading area	20
12	Coal Storage area	20
13	Conveyors	50
14	Fuel Oil delivery headers	50
15	Oil storage tank	50
16	Catwalks	50
17	Platforms, boiler and turbine decks	50
18	Transformers and outdoor switchgear	100

ONGC Tripura Power Company Ltd

726.6MW CCPP, Palatana, Udaipur,

Gomati, Dist. Tripura - 799116.

SAFETY AUDIT REPORT

OF

M/S.ONGC TRIPURA POWER COMPANY LTD.

JANUARY 2023

Process Engineering Pvt. Ltd.

"Fostering Safety in Business"

719,720 & 722, Western Business Park,
Opp.S. D. Jain School, Vesu - Surat.
PIN - 395 007.
Ph. No. +91 - 8981100563.

- Global Knowledge- Local Application

ACKNOWLEDGEMENT

We express our sincere thanks to Management and Employees of M/s.ONGC Tripura Power Company Ltd. for their Co-operation and unstinted help without which the Safety Audit could not have been possible. The courtesy and Cordiality extended to the audit team is highly appreciated.

We do appreciate the best planning and constant co-operation Mr.Nagendra, Mr. Samiran Roy and all other Head of the department of respective plant for speedy completion of this assignment.

08.01.2023 **PROSAFE PROCESS ENGINEERING PVT. LTD.**

SURAT **AUTHORIZED SIGNATORY**

DISCLAIMER

This report was prepared by **M/s. Prosafe Process Engineering Pvt. Ltd. - Surat** as teamwork for**M/s.ONGC Tripura Power Company LtdThe** material in it reflects Prosafe's best judgment and experience of the Audit team members as in the light of the information available to them at the time of preparation.

However, as Prosafe cannot control the conditions under which this report may be used, **PROSAFE will not be responsible** for damages of any nature resulting from use of or reliance upon this report. Therefore, process & engineering concepts shall be applied for implementing the recommendation. Prosafe hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of Prosafe' Safety Audit Report.

AUDIT CERTIFICATE

We are pleased to certify that this Occupational Safety and Health Audit of M/s ONGC Tripura Power Company Ltd have been conducted by us on 5th& 6th January 2023.

Safety Audit is a legal requirement U/r 100 of Tripura Factory Rules 2007, u/r 10 of the Tripura Major Accident Hazard Control Rules 2001 and Rule 10 of the Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989.

This audit is carried out as per requirements of the above statutes and as per guidelines given in IS 14489: 1998.

We have sincerely tried to adhere to the terminology and methodology of IS 14489: 1998 and gone through the maximum details as suggested in Annex B & C thereof. The observations and recommendations are based on information supplied to us by the company and our plant visits. The detailed observation reportis attached.

The Executive Summary is given in the beginning to highlight the significant observations our audit report. We hope the compliance of audit points suggested in this report will make the company more safe and healthy.

The Third Party safety audit is valid for 1year as per MSIHC Rules 1989; hence next Audit will be due in January 2023.

08.01.2023 **PROSAFE PROCESS ENGINEERING PVT. LTD.**

SURAT AUTHORIZED SIGNATORY

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EXECUTIVE SUMMARY

The Executive Summary is intended for the overview of the safety management system & status of the overall performance. The following significant are the finding where immediate attention will help improving performance. This will help the top management to take cognizance for the forward path & necessary guidance to the line management.

1. Safety audit is carried out to ensure the sustenance of industrial safety, occupational health and environmental protection within the factory premises. It is based on the statutory requirements and IS 14489:2018. It was carried out during our visits on 5th& 6th January 2023.It includes examination of relevant records, observation of 512 questions as per IS annexure C, Opening and Closing meetings with HODs, discussion with many plant people and workers and actual shop floor inspection of the plant and machinery.
2. Our audit approach is not only technical, but, techno-legal. Engineering aspect is also seen through the law of the land i.e. our statutory engineering and other requirements.

STRENGTH - HSE MANAGEMENT: -

- Standard maintenance practice of all electrical equipment and records available.
- Testing and condition monitoring records available
- SOP of all activities available.
- WP issue LOTO System
- PPEs available
- ARC suit available in 6.6 KV control room
- Self breathing apparatus available in main control room.
- Good housekeeping of control rooms.
- Good Training schedule for all employee.
- Chlorine tonner storage area equipped with chlorine scrubber & chlorine kit.
- Fire protection system in the form of first aid fire extinguishers, fire hydrant system,CO_2 flooding system & aragonite system.
- Safety relief valves of carbon dioxide storage vessels are provided with calibration tags.
- MSDS are displayed in acid tank area& in chlorine tonner storage area.
- Safety posters displayed along road side. Cautionary boards about "PPE required beyond this point" are displayedin each plant.
- Separate arrangement is provided for storage of hazardous waste.
- Emergency telephone nos. are displayed at gas booster compressor area.
- Compliance of factories act and rules are observed.

OPPORTUNITY AVENUES FOR STRENGTHENING HSE MANAGEMENT

1. Combustible material is stored right under the power panel box. It is to be removed from the vicinity of the panel.

2. Poor cable glanding and single earthing is used for electrical pump motors near D.V #20. Provide double earthing to all electrical apparatus above 250V as per IS 3043.

3. There is no emergency exit on first floor of admin bldg. & training center.

4. There is no earthling on Main gate of Switch yard CEA 2010 reg cl.49(2)

1.0AUDIT OBJECTIVES AND SCOPE

1.1 AUDIT OBJECTIVES

Following objectives were considered in focus while conducting the audit:

- To provide the Auditee with an opportunity to assess its own OH&S system against OH&S system standard and identify areas for improvement.
- To carry out a systematic, critical appraisal of all potential hazards involving personnel, plant, services, operations and procedures.
- To ensure that OH&S system fully satisfy the legal requirements and those of the company's written policies, objectives and progress.
- To assess the effectiveness of the OH&S programs

1.2AUDIT SCOPE

Following are the key focus area while carrying out OH&S Audit;

- Organizational activity performed by company employees, contractors, transporters and other agencies within the factory premises.
- Applicable (Relevant) legal requirements pertaining to OH & S
- Management Commitment and Leadership
- System for keeping department safe
- Plans for compliance with routine Observation and Suggestion
- Commitment of line function responsibility for safety
- Accident and Incident Investigation and Analysis
- Emergency Preparedness Plan and its Mock drills
- Prioritization of risk for the department and action plan

- Safety Management of Contract Workers
- Training and Performance
- Hazardous Chemical Safety Management
- 34 Elements of IS 14489 “Code of Practice on OHS Audit”

√The Audit Scope was completed by assessing the relevant procedures, interaction with people and verification records and documentation.

2.0 AUDIT PROCESS AND APPROACH

2.1AUDIT PLAN

Following Audit Plan has been finalized after consultation with the client andcommunicated to all concerned.

1. Identification of the factory is given in Para3.1. Almost all key areas of manufacturing including storages and their safety management system wereincluded in the audit plan.
2. Audit team including ‘**Management Representation’** is decided and stated inPara 2.
3. Audit objectives and scope are stated in Para 1.1 and 1.2.
4. Schedule for audit activities, meetings, plant visits and interaction with employees, checking of statutory records and documents were mutually decided with the management.
5. It was also decided to use Annexure – B & C of IS: 14489; other relevant Indian Standards and provisions of the Factories Act & Rules as a guideline. Requirements of other Safety Acts & Rules were also considered. The company policy, manual and systems were also considered as other reference documents.

2.2AUDIT TEAM

This Audit is carried out as per IS 14489: 2018 and requirements under the Factories Act – 1948 &U/r 100 of Tripura Factory Rules 2007, u/r 10 of the Tripura Major Accident Hazard Control Rules 2001. We have deputed suitably Qualified and Experienced Auditors to perform this audit as under:

SR.NO.	NAME	QUALIFICATION	EXPERIENCE
1	Mr. Manoj Patel	Industrial Electronics, PDIS	> 25 Years
2.	Mr. P.A.Patel	B. E. Electrical	> 30 years

2.3 OPENING MEETING

An opening meeting was organized in M/s. ONGC Tripura Power Company Ltd. on 5th January 2023 for the purpose of introduction of audit team members and also to appraise the scope and methodology of the audit, informing the Auditee about requirements of the necessary documents, records and other relevant information.

In this opening meeting:

- Members of the Auditor and Auditee teams were introduced.
- Audit objectives and scope, plan and purpose of necessary documents and records were explained and discussed.
- A short summary of the methods and procedures was explained.
- Official communication links between the Auditee and auditors were established.
- Availability of the resources and facilities needed by us were confirmed.
- A schedule of plant visits was decided.
- The areas of audit were suggested and discussed.
- Date and time of the closing meeting and interim meetings were discussed.
- Queries of the management were replied.

2.4 DOCUMENTS AND RECORDS

Following documents and records were required from the Auditee for the purpose of investigation, necessary information and evidence to examine their OS&H systems.

1. Annexure B & C of IS: 14489.
2. Statutory Forms under the Factories Act & Rules and documents under the Environment Protection Act & Rules.
3. Formats and check list used by the organization as per their OH & S requirement e.g. Work Permit Systems, Safe Operating Procedures, Specific Formats etc.
4. Notices displayed in the factory premises.
5. Evidences collected from field visits, interrogation with the workers and supervisors, and information of physical observations, measurements and records etc.

3.0 BRIEF PROCESS AND HAZARD CONTROL

3.1 INTRODUCTION OF THE FACTORY

FROM PROSAFE PROCESS ENGINEERING PVT. LTD.				
NO.	**PARTICULARS**			
1.	Full Name & Address of the Factory	**ONGC Tripura Power Company Limited,** Udaipur, Palatana, Kakraban Road, 799105		
	Phone	0381-2363 714		
2.	Full Name & Address of the Occupier	**Sh. Sanil Namboodiripad** Udaipur, Palatana, Kakraban road, 799105.		
	Contact No.	+91 - 7694006538		
3.	Full Name & Address of the Manager	**Mr. Tapas Bhowmik** Udaipur, Palatana, Kakraban road, 799105.		
	Contact No.	+91 - 7058060469		
4.	Manufacturing Process	Generation of Power.		
5.	Product	Electricity		
6.	**Man Power (Including Workers, Trainees, Apprentice)**			
	Name of the Shift	**Male**	**Female**	**TOTAL**
a.	General (G)	148	3	151
b.	First (A)	35	0	35
c.	Second (B)	35	0	35
d.	Third (C)	35	0	35
TOTAL WORKERS		**253**	**3**	**256**

1.	Brief Company Profile / History	Gas based power plant.
2.	Land Area [Acre or Sq. Meter]	228 Acre
3.	Copy of HSE / Safety Policy	We are having EHS policy.
4.	Copy of last MOM of Safety Committee	last meeting was conducted on 22.10.2022
5.	ETP Capacity & Treated Water Usage	600 M^3& 60 M^3
6.	**The surrounding of the unit can be described as below:**	
	North Side	Main Road
	South Side	Agriculture land
	East Side	Agriculture land
	West Side	Agriculture land
7.	**Brief detail of fire fighting system:**	
	Fire Hydrant Points& No. of Hoses	Fire hydrant - 143 143 Hose boxes.
	Fire Water Tank Capacity	6000 M^3
	Fire Pump No. and Capacity	7 nos. pump.
	Sprinkler System Locations	All transformers Unit 1 & II area, Admin building and Control Room
	List of Fire Extinguisher’s	296 Nos.
	Foam Monitor / Water Monitor	3 Nos. water monitor
	Sand Buckets	50 Nos.
8.	Compliance report of previous Safety Audit Report (if done)	NA
9.	Copy of Last Mock Drill Report	Available
10.	HSE Training plan and Training records for Past 2 years	Available

LIST OF FIRE EXTINGUISHER'S			
NO.	**TYPE OF EXTINGUISHER**	**CAPACITY**	**QUANTITY**
1.	**2.**	**3.**	**4.**
1.	Water	9 ltr.	12
2.	Foam	9 ltr.	16
3.	ABC	2 kg.	2
4.	ABC	5 kg	6
5.	ABC	6 kg	39
6.	CO_2	4.5 kg	35
7.	CO_2	6.5 kg.	3
8.	CO_2	9 Kg.	10
9.	CO_2	22.5 kg.	7
10.	DCP	5 kg.	157
11.	DCP	25 kg.	7
12.	DCP	50 kg.	2
TOTAL			**296**

3.2 COMPANY PROFILE

Oil & Natural Gas Corporation Ltd. ("ONGC"), a Fortune 500 company of the Government of India, owns significant natural gas reserves in the North Eastern state of Tripura. However, these natural gas reserves were not developed commercially due to low industrial demand in the North-Eastern region.

The complexities of logistics and attendant costs limited the economic viability of transportation of gas to other parts of the country where gas is in deficit. In order to optimally utilize the gas available in Tripura and to supply power to the deficit areas of North Eastern States of India, ONGC along with Infrastructure Leasing and Financial Services Limited (IL&FS) and Government of Tripura (GoT) formed a Special Purpose Vehicle ONGC Tripura Power Company (OTPC) by entering into a Shareholders' Agreement (SHA) on September 18, 2008 to implement a 726.6 MW Combined Cycle Gas Turbine (CCGT) thermal power plant at Palatana, Tripura.

The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January, 2014 and the second block (363.3 MW) of the two blocks was declared under Commercial Operation from 24th March 2015. BHEL was the EPC contractor for setting up of the power plant.

The setting up of the power plant has helped in transforming the power scenario of the entire North-Eastern Region of the country and has assisted in catalyzing rapid economic development of the region. The generation project combined with linked transmission project and upstream gas supply project has brought in investments to the tune of Rs. 10,000 crores in the region.

A 400 kV D/C Transmission system connecting the OTPC power plant in Tripura to

Bongaigaon in Assam over a distance of around 650 Kms has been set up for evacuation of power from the power plant.

The development and operation of the transmission system was undertaken by North-East Transmission Company Limited (NETCL) a joint venture of OTPC, Power Grid Corporation of India Ltd (PGCIL) and the North Eastern Region beneficiary states. Inter-state and intra-state sub-transmission system and the distribution system within NER states were developed by PGCIL as the Central Transmission Utility (CTU).

3.3 PRODUCTS, RAW MATERIALS, HAZARDS & CONTROLS

3.3.1 LIST OF PRODUCTS

A list of products and their capacity are as under:

Sr. No.	Name of Product	Quantity
1.	Electrical Energy	726.6 MW.

3.3.2 LIST OF RAW MATERIALS AND PRODUCTS

Sr. No.	Name Of TheChemical	State	Hazards	Stored In	Place of Storage	Total Storage Capacity	Actual Qty. Stored	Control Measures Provided
1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**
RAW MATERIALS								
1.	Chlorine	Liquid	Toxic	Tonner	Compressed	20 Nos Tonner	14000 Ltr	Fire Suppression and detection system with Required PPE's are there.
2.	Sulphuric Acid	Liquid	Corrosive	Tank	Tank	20 Kl	20000 Ltr	Fire Suppression &Trained Fire team are there
3.	Hydrochloric Acid	Liquid	Corrosive	Tank	Tank	20 Kl	20000 Ltr	Fire Suppression & Trained Fire team are there
4.	Hydrogen Gas	Compressed Air	Flammable	Cylinder	Cylinder	8 nos.	373.6 Ltr	Fire Suppression & detection systems & with Trained Fire team are there
5.	Liquor Ammonia	Liquid	Toxic	Drum	Drum		609 ltr	

3.4PROCESS, HAZARDS AND CONTROLS

(A) PROCESS DESCRIPTION

The Plant is designed to generate up to 2*5 Nm^3 per hour of Hydrogen gas and 5 Nm^3 of Oxygen gas. The compression system is designed to compress the Hydrogen to a pressure of 150 Kg/cm^2.

1. Hydrogen Generation Plant

Hydrogen Generating systems consists of air-cooled rectifier complete withrectifier system, one bank of 06 electrolytic cells connected electrically in seriesfor operation at 4025 Amperes, one water seal and mist eliminator, as well as allinterconnecting piping, various protective devices and controls for operation.AC power at 400 Volts, 3 Phase, 50 cycles is supplied through the circuit breakerto Rectifier and transformer. In the Rectifier the voltage is reduced by the rectifiertransformer and converted to direct current at a voltage of up to 20 volts. Thecircuit breaker in the rectifier serves to isolate the rectifier and provide short circuitprotection. The breaker is also used for starting and stopping the rectifier. Directcurrent output of the rectifier is controlled by means of an SCR Control system.Rectifier output is adjusted by current control knob on the control panel andmeasured by a DC ammeter. DC power from the rectifier is supplied to electrolyticcells through copper bus bars. When DC current flows through the cells the waterin the cells is converted into hydrogen and oxygen gases. The rate of evolution ofgas is directly proportional to the DC current. At 4025 Amperes (the maximumallowable current with 06 cells in stream) the 06 cells will produce 10 cubic metersof hydrogen and 7.5 cubic meters of oxygen per hour (when measured dry at 0°Cand 760 mm mercury). The liquid in the cells (called the electrolyte) is a 28-30%by weight solution of Potassium Hydroxide in DM water. The PotassiumHydroxide is not used up when gas is generated, except for mechanical lossesdue to spillage and entrainment. The only raw material supplied to the cells apartfrom electric power is Demineralized water, to replace the water converted tohydrogen and oxygen.

From the cells the hydrogen and oxygen gases flow through collection headers toWater Seal. The Water Seal serves to equalize the hydrogen and oxygen gaspressures and to prevent reverse flow of gases from the low pressure hydrogengasholder when the cells are idle. Gas H2 from the cells are first sent to vent.After H2 gas purity has been checked by O2 Gas Analyzer from vent is diverted toGas holder. A manual gas analyzer provided to be checked once a day. H2 gas is diverted to Gas Holder by PV344. From the Water Seal it goes through Mist Eliminator to H2 Gas Holder.

Oxygen Gas is vented from Liquid Seal to atmosphere as of no use.The hydrogen & oxygen gases are cooled at the Gas Cooler by cooling water.Each cell is fitted with two gas coolers, one for each gas. The gases leaving thecell pass through the coolers before entering the gas header. In the gas cooler thegas is cooled and electrolyte (Mist) vapour is condensed and returned to the cellthrough an overflow pipe. The gasses are cooled by water. Water enters at thedistribution header, flows through the hydrogen and oxygen coolers of a cell inseries and then flows through a discharge hose to the cooling water collectionheader, and returned to the return water tank.Online continues gas analyzer provided to check the purity of Hydrogen (0-1%)gas. H2 gas less than 99% purity should not be diverted to Gas Holder. However,it is necessary to check the gas purity by manual gas analyzer once in 24 hours.A Manual gas purity tester is supplied for measuring the purities of Hydrogen andoxygen gases.Over a period of time cells will lose some Potassium Hydroxide due toentrainment and spillage, add potassium hydroxide to the cells.

2. Hydrogen Compression and Purification System

Hydrogen from the gas generating system flows to a mist eliminator where tracesof electrolyte mist, entrained in the hydrogen gas are removed. The mist separated from the hydrogen collects at the bottom of the mist eliminator vesselfrom which it overflows to waste.Hydrogen from the mist eliminator flows to the existing low pressure gas holder,mounted on which are four level switches for controlling the hydrogencompressor. The gas holder has provision that when this is full the gas can ventto atmosphere through flame arrester, without affecting the gasholder workingpressure. The gas then flows to the hydrogen compressor. The hydrogencompressor is a Four stage, oil lubricated compressor. The gas is compressed to150 kg/cm^2g.Hydrogen from the compressor flows to coalescing prefilter where oil anddroplets are removed, and then through Oil vapour filter where oil vapour is removed. From the filters, the hydrogen flows to catalytic purifier to remove O2impurity. Hydrogen purity better than 99.9% would be achieved, with O2 level of less than 1000 ppm. There are temperature gauges at inlet & outlet of catalytic purifier and its temperature is sensed so that the compressors trips at catalytic purifier over temperature (120ºC). The outlet gas from catalytic purifier is cooled in the after cooler, and passed through water droplet filter to remove moisture. The gas then passes through desiccant dryer which is fully automatic, dual column, heated" type dryer, capable of drying the hydrogen to a dewpoint (atmospheric) of minus 84ºC. The switch-over valve at the dryer is operated by Instrument Air (by user) and other operation is controlled by local PLC on Dryer. From the dryer the hydrogen flows through after filter where any dust particles entrained with the hydrogen gas are filtered out. It then flows through back pressure maintaining valve, set at 137 Kg/cm2g and then to cylinder filling manifold & pressure vessels. Differential pressure DP is sensed across the dust filter and gives an alarm and stops the compressor. A high pressure is sensed at pressure transmitter, gives an alarm and stops compressor at Pressure Of 150kg/cm^2g.

(B) PROCESS HAZARDS & CONTROLS

Sr. no.	Name of the hazardous process & operation	Material in the process/ operation with their quantity.	Operating parameter pressure (kg/cm2), temp.(0C) etc	Type of hazard possible (exothermic, run away, pressure/ toxic release, fire, explosion etc.	Control measures
1.	Chlorine dosing system	Chlorine	Room temp.	Toxic	Chlorine scrubber, chlorine kit, B.A.Set
2.	Hydrogen generation	Hydrogen	Room temp.& pressure 150Kg/cm2	Fire &explosion	Flame proof equipment, firefightingfacilities, use of non sparking tools

3.5 GENERAL HAZARD & CONTROL MEASURES

No.	Name of the Possible Hazard or Emergency	Place of Effect	Reason	Its effects on Persons, Property & Environment	Control Measures Provided
1.	**2.**	**3.**	**4.**	**5.**	**6.**
1.	Fire	• Flammable Chemicals • Combustible Materials	• Ignition • Spark • Hot Work • Static Charge	• Property Damage • Burn Injuries • Air Pollution	• Earthing & Bonding • Fire Extinguishers • Fire Hydrant System • Water Monitors
2.	Electric Hazards	• Panel Room • Anywhere in Plant	• Electric Shock • Short Circuit	• Burning Sensation • Electric Burn	• Earthing & Bonding

No.	Name of the Possible Hazard or Emergency	Place of Effect	Reason	Its effects on Persons, Property & Environment	Control Measures Provided
1.	**2.**	**3.**	**4.**	**5.**	**6.**
			• Spark	• Breathing Problem	• Gloves & Shoes • Fuses & Circuit breakers • Insulation & Isolation • LOTO System
3.	Material Handling	• Warehouse • Drum Handling	• Overload • Mishandling	• Body Pain • Slip & Trip	• Trolley • Stacker • Chain Pulley Block

No.	Name of the Possible Hazard or Emergency	Place of Effect	Reason	Its effects on Persons, Property & Environment	Control Measures Provided
1.	**2.**	**3.**	**4.**	**5.**	**6.**
					• Trained Plant Personnel
4.	Noise	• Compressor • D. G. Set	• Improper Maintenance	• Noise Pollution	• Periodic Maintenance

3.6OTHER HAZARDS & CONTROLS

No.	Name of hazardous chemicals	Quantity	Authorized Mode of Disposal or recycling or utilization or co-processing, etc.
1.	**2.**	**3.**	**4.**
1.	Transformer oil (waste oil)	15 Kl/Annum	Recycling
2.	Contaminated drum/barrel/containers	102kg/Annum	--

3.7APPLICABILITY OF THE HSE STATUTORY REQUIREMENTS (LICENSES, FORMS & NOTICES)

Looking to the above chemicals, their storage quantities and process parameters, applicability of some safety laws is discussed below: -

3.7.1 The Factories Act 1948 and Tripura Factory Rules 2007

a) The manufacturing process of this factory falls under Item No. 5 of Schedule 1 of the Factories Act, 1948 and nature of the manufacturing process falls u/s 2(cb) thereof. Therefore, the factory carries out **“Hazardous process**”. Therefore provisions of Chapter 4-A of the Factories Act- 1948 & Rules of Tripura factory Rules 2007 are applicable. Therefore, provisions of information to workers and authorities, health and safety policy, information of industrial wastes, MSDS, health records to workers, qualified supervisors, Factory Medical Officer, Occupational Health Centre, ambulance van, safety committee and decontamination facility are applicable. Hence, these provisions were checked during the audit. Non-conformity and suggestions are reported in Para 3.8 and Chapter-4.

b) Following chemicals are used in this factory and their prescribed TLV and STEL values under Schedule 2 of the Factories Act 1948& Table 1,2&3 of TFR 169 are as under:

No	Chemical	TLV	STEL
1.	Chlorine	1 ppm	3 ppm
2.	Sulphuric acid	1 ppm	-
3.	Hydrochloric Acid (hydrogen chloride fume)	5 ppm	
4.	Liquor Ammonia	25ppm	35 ppm

- Above permissible limits should not be exceeded in work environment (breathing zone) where workers are working. Necessary equipment to take samples of exposures of above chemicals (in breathing zone) and to measure their values (as stated above) should be utilized and shall be maintained.

c) Following chemicals used / evolved in this factory are listed in part IIcolumn 2 of Sch. 1 of Rule 2(1) of the Tripura Major Accident Hazard Control Rules 2001:

Sr. No.	Chemicals
1.	Chlorine
2.	Hydrogen
3.	Sulphuric acid
4.	Hydrochloric acid

Names of above chemicals are listed in part II column 2 of Sch. 1 of Rule 2(1) of the Tripura Major Accident Hazard Control Rules 2001 Therefore, it can be said that the factory uses **'Hazardous Chemicals'**.

❖ Storage Quantity of Hazardous Chemicals: -

Sr. No.	Chemical	Capacity
1.	Chlorine	20 tonners
2	Hydrogen	8 cylinders + 3.75 M3 X2 in water sealed gas holder
3	Sulphuric acid	20 KL
4	Hydrochloric acid	20 KL

- Storage quantity of Chlorine is more than the threshold quantity mentioned in Column 4 of Part I of Schedule 3 of Rule 2(1) of the Tripura Major Accident Hazard Control Rules 2001

❖ Therefore, this factory is classified as **a MAH (Major Accident Hazard)** Installation. Therefore, Rule 68,9,14 &16 ofthe Tripura Major Accident Hazard Control Rules 2001are strictly applicable. Therefore –

I. Provisions pertaining to development of MSDS and their information to workers,
II. Labeling of containers of hazardous chemicals,
III. Identification of major accident hazards and adequate steps to prevent major accident hazards,
IV. Steps to limit their consequences to persons and environment and to provide information, training and equipment including antidotes necessary to ensure their safety and health,
V. Notification of major accident to authorities and steps to prevent its recurrence,
VI. Approval and notification of sites,
VII. Updating of notification of sites, in case of any change in approved site,
VIII. Supplying further information required by the Chief Inspector of Factories,
IX. Preparation of On-site Emergency Plan and giving information for Off-site Emergency Plan to the concerned authorities,
X. Information and safety measures (Do's and Don'ts) to public likely to be affected.

d) Factory uses various chemicals in its manufacturing process hence Schedule XII of Rule 160 of The TFR 2007 is applicable hence impervious flooring, protective equipment, water facility, cautionary notice, transport facility, handling of corrosive substances, opening of valves, storage of chemicals, fire extinguishers shall be maintained..

e) General provisions of the Factories Act 1948 and the Tripura Factory Rules 2007 are always applicable. Attention is drawn towards sections No. 28 and 29 and Rules there under. Rules 72, 73 and 74 are applicable and strictly followed and its records in form No.13and 14 shall be maintained.

❖ FACTORY LICENSE: -

- Registration No.:3510311082766
- D.A.: 12.05.2010
- Maximum number of workers to be employed:750
- Maximum installed power in B.H.P.:726.5
- License is renewed under Rule 9:**From2023 to 2027**
- Granted to: The Managing Director, OTPC Ltd

❖ PLAN APPROVAL & STABILITY CERTIFICATE: -

No.	Plan Approval No. & Date	Issued Date	Due Date
1.	**2.**	**3.**	**4.**
1.	Revised Plan No 01/35/351/3510/35103/23	05.01.2023	NA

- Competent Person: Stability Certificate Not available.
- Certificate No.:

❖ Test Report of Pressure Vessel and Pressure Plant under section 31 and rule 61 in **FORM NO. 11**

No.	Identification of Vessel	Test Date	Due Date
1.	**2.**	**3.**	**4.**
1.	Compressed air receiver	1.10.2022	31.03.2023

- Competent Person: Er. D.Sharma

❖ Test Report of Examination of Lifting Machines, Ropes & Lifting Tackles under **in Form no. 13 & 14**

A: D-SHACKLE

SR. NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	DS/1/1	1 MT	YEARLY	25-09-2022	24-09-2023
2	DS/1/2	1 MT	YEARLY	25-09-2022	24-09-2023
3	DS/1/3	1 MT	YEARLY	25-09-2022	24-09-2023
4	DS/1/4	1 MT	YEARLY	25-09-2022	24-09-2023
5	DS/1/5	1 MT	YEARLY	25-09-2022	24-09-2023
6	DS/1/6	1 MT	YEARLY	25-09-2022	24-09-2023
7	DS/3.2/1	3.2 MT	YEARLY	25-09-2022	24-09-2023
8	DS/3.2/2	3.2 MT	YEARLY	25-09-2022	24-09-2023
9	DS/3.2/3	3.2 MT	YEARLY	25-09-2022	24-09-2023
10	DS/3.2/4	3.2 MT	YEARLY	25-09-2022	24-09-2023
11	DS/3.2/5	3.2 MT	YEARLY	25-09-2022	24-09-2023
12	DS/3.2/6	3.2 MT	YEARLY	25-09-2022	24-09-2023
13	DS/5/1	5 MT	YEARLY	25-09-2022	24-09-2023
14	DS/5/2	5 MT	YEARLY	25-09-2022	24-09-2023
15	DS/5/3	5 MT	YEARLY	25-09-2022	24-09-2023
16	DS/5/4	5 MT	YEARLY	25-09-2022	24-09-2023
17	DS/10/1	10 MT	YEARLY	25-09-2022	24-09-2023
18	DS/10/2	10 MT	YEARLY	25-09-2022	24-09-2023
19	DS/10/3	10 MT	YEARLY	25-09-2022	24-09-2023
20	DS/10/4	10 MT	YEARLY	25-09-2022	24-09-2023
21	DS/20/1	20 MT	YEARLY	25-09-2022	24-09-2023
22	DS/20/2	20 MT	YEARLY	25-09-2022	24-09-2023
23	DS/20/3	20 MT	YEARLY	25-09-2022	24-09-2023
24	DS/20/4	20 MT	YEARLY	25-09-2022	24-09-2023
25	DS/35/1	35 MT	YEARLY	25-09-2022	24-09-2023
26	DS/35/2	35 MT	YEARLY	25-09-2022	24-09-2023
27	DS/35/3	35 MT	YEARLY	25-09-2022	24-09-2023
28	DS/35/4	35 MT	YEARLY	25-09-2022	24-09-2023

B: FLAT SLING

SR. NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	FS/1/1	1 MT	YEARLY	24-09-2022	23-09-2023
2	FS/1/2	1 MT	YEARLY	24-09-2022	23-09-2023
3	FS/1/3	1 MT	YEARLY	24-09-2022	23-09-2023
4	FS/1/4	1 MT	YEARLY	24-09-2022	23-09-2023

SR. NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
5	FS/3/1	3 MT	YEARLY	24-09-2022	23-09-2023
6	FS/3/2	3 MT	YEARLY	24-09-2022	23-09-2023
7	FS/3/3	3 MT	YEARLY	24-09-2022	23-09-2023
8	FS/3/4	3 MT	YEARLY	24-09-2022	23-09-2023
9	FS/6/1	6 MT	YEARLY	24-09-2022	23-09-2023
10	FS/6/2	6 MT	YEARLY	24-09-2022	23-09-2023
11	FS/6/3	6 MT	YEARLY	24-09-2022	23-09-2023
12	FS/6/4	6 MT	YEARLY	24-09-2022	23-09-2023
13	FS/6/5	6 MT	YEARLY	24-09-2022	23-09-2023
14	FS/6/6	6 MT	YEARLY	24-09-2022	23-09-2023
15	FS/8/1	8 MT	YEARLY	24-09-2022	23-09-2023
16	FS/9/1	9 MT	YEARLY	24-09-2022	23-09-2023

C: WIRE ROPE SLING

SR. NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	WS/1/1	1 MT	YEARLY	24-09-2022	23-09-2023
2	WS/1/2	1 MT	YEARLY	24-09-2022	23-09-2023
3	WS/1/3	1 MT	YEARLY	24-09-2022	23-09-2023
4	WS/1/4	1 MT	YEARLY	24-09-2022	23-09-2023
5	WS/1/5	1 MT	YEARLY	24-09-2022	23-09-2023
6	WS/1/6	1 MT	YEARLY	24-09-2022	23-09-2023
7	WS/3/1	3 MT	YEARLY	24-09-2022	23-09-2023
8	WS/3/2	3 MT	YEARLY	24-09-2022	23-09-2023
9	WS/3/3	3 MT	YEARLY	24-09-2022	23-09-2023
10	WS/3/4	3 MT	YEARLY	24-09-2022	23-09-2023
11	WS/6/1	6 MT	YEARLY	24-09-2022	23-09-2023
12	WS/6/2	6 MT	YEARLY	24-09-2022	23-09-2023
13	WS/6/3	6 MT	YEARLY	24-09-2022	23-09-2023
14	WS/6/4	6 MT	YEARLY	24-09-2022	23-09-2023
15	WS/10/1	10 MT	YEARLY	24-09-2022	23-09-2023
16	WS/10/2	10 MT	YEARLY	24-09-2022	23-09-2023
17	WS/10/3	10 MT	YEARLY	24-09-2022	23-09-2023
18	WS/10/4	10 MT	YEARLY	24-09-2022	23-09-2023
19	WS/12/1	12 MT	YEARLY	24-09-2022	23-09-2023
20	WS/12/2	12 MT	YEARLY	24-09-2022	23-09-2023
21	WS/12/3	12 MT	YEARLY	24-09-2022	23-09-2023
22	WS/12/4	12 MT	YEARLY	24-09-2022	23-09-2023
23	WS/20/1	20 MT	YEARLY	24-09-2022	23-09-2023
24	WS/20/2	20 MT	YEARLY	24-09-2022	23-09-2023

SR. NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
25	WS/20/3	20 MT	YEARLY	24-09-2022	23-09-2023
26	WS/20/4	20 MT	YEARLY	24-09-2022	23-09-2023

D: CHAIN BLOCK

SR.NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	CB/0.5/1	0.5 MT	YEARLY	26-09-2022	25-09-2023
2	CB/0.5/2	0.5 MT	YEARLY	26-09-2022	25-09-2023
3	CB/0.5/3	0.5 MT	YEARLY	26-09-2022	25-09-2023
4	CB/0.5/4	0.5 MT	YEARLY	26-09-2022	25-09-2023
5	CB/1/1	1 MT	YEARLY	26-09-2022	25-09-2023
6	CB/1/2	1 MT	YEARLY	26-09-2022	25-09-2023
7	CB/1/3	1 MT	YEARLY	26-09-2022	25-09-2023
8	CB/1/4	1 MT	YEARLY	26-09-2022	25-09-2023
9	CB/1/5	1 MT	YEARLY	26-09-2022	25-09-2023
10	CB/1/6	1 MT	YEARLY	26-09-2022	25-09-2023
11	CB/2/1	2 MT	YEARLY	26-09-2022	25-09-2023
12	CB/2/2	2 MT	YEARLY	26-09-2022	25-09-2023
13	CB/2/3	2 MT	YEARLY	26-09-2022	25-09-2023
14	CB/2/4	2 MT	YEARLY	26-09-2022	25-09-2023
15	CB/2/5	2 MT	YEARLY	26-09-2022	25-09-2023
16	CB/3/1	3 MT	YEARLY	26-09-2022	25-09-2023
17	CB/3/2	3 MT	YEARLY	26-09-2022	25-09-2023
18	CB/3/3	3 MT	YEARLY	26-09-2022	25-09-2023
19	CB/3/4	3 MT	YEARLY	26-09-2022	25-09-2023
20	CB/3/5	3 MT	YEARLY	26-09-2022	25-09-2023
21	CB/3/6	3 MT	YEARLY	26-09-2022	25-09-2023
22	CB/3/7	3 MT	YEARLY	26-09-2022	25-09-2023
23	CB/5/1	5 MT	YEARLY	26-09-2022	25-09-2023
24	CB/5/2	5 MT	YEARLY	26-09-2022	25-09-2023
25	CB/10/1	10 MT	YEARLY	26-09-2022	25-09-2023
26	CB/10/2	10 MT	YEARLY	26-09-2022	25-09-2023
27	CB/10/3	10 MT	YEARLY	26-09-2022	25-09-2023
28	CB/10/4	10 MT	YEARLY	26-09-2022	25-09-2023

E: EYE BOLT

SR.NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	EB/6/1	0.07 MT	YEARLY	26-09-2022	25-09-2023
2	EB/6/2	0.07 MT	YEARLY	26-09-2022	25-09-2023
3	EB/8/1	0.14 MT	YEARLY	26-09-2022	25-09-2023
4	EB/8/2	0.14 MT	YEARLY	26-09-2022	25-09-2023

SR.NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
5	EB/8/3	0.14 MT	YEARLY	26-09-2022	25-09-2023
6	EB/8/4	0.14 MT	YEARLY	26-09-2022	25-09-2023
7	EB/8/5	0.14 MT	YEARLY	26-09-2022	25-09-2023
8	EB/8/6	0.14 MT	YEARLY	26-09-2022	25-09-2023
9	EB/10/1	0.23 MT	YEARLY	26-09-2022	25-09-2023
10	EB/10/2	0.23 MT	YEARLY	26-09-2022	25-09-2023
11	EB/10/3	0.23 MT	YEARLY	26-09-2022	25-09-2023
12	EB/10/4	0.23 MT	YEARLY	26-09-2022	25-09-2023
13	EB/10/5	0.23 MT	YEARLY	26-09-2022	25-09-2023
14	EB/10/6	0.23 MT	YEARLY	26-09-2022	25-09-2023
15	EB/12/1	0.34 MT	YEARLY	26-09-2022	25-09-2023
16	EB/12/2	0.34 MT	YEARLY	26-09-2022	25-09-2023
17	EB/12/3	0.34 MT	YEARLY	26-09-2022	25-09-2023
18	EB/12/4	0.34 MT	YEARLY	26-09-2022	25-09-2023
19	EB/12/5	0.34 MT	YEARLY	26-09-2022	25-09-2023
20	EB/12/6	0.34 MT	YEARLY	26-09-2022	25-09-2023
21	EB/14/1	0.49 MT	YEARLY	26-09-2022	25-09-2023
22	EB/14/2	0.49 MT	YEARLY	26-09-2022	25-09-2023
23	EB/16/1	0.7 MT	YEARLY	26-09-2022	25-09-2023
24	EB/16/2	0.7 MT	YEARLY	26-09-2022	25-09-2023
25	EB/18/1	0.8 MT	YEARLY	26-09-2022	25-09-2023
26	EB/18/2	0.8 MT	YEARLY	26-09-2022	25-09-2023
27	EB/20/1	1.2 MT	YEARLY	26-09-2022	25-09-2023
28	EB/20/2	1.2 MT	YEARLY	26-09-2022	25-09-2023
29	EB/20/3	1.2 MT	YEARLY	26-09-2022	25-09-2023
30	EB/20/4	1.2 MT	YEARLY	26-09-2022	25-09-2023
31	EB/20/5	1.2 MT	YEARLY	26-09-2022	25-09-2023
32	EB/20/6	1.2 MT	YEARLY	26-09-2022	25-09-2023
33	EB/22/1	1.5 MT	YEARLY	26-09-2022	25-09-2023
34	EB/22/2	1.5 MT	YEARLY	26-09-2022	25-09-2023
35	EB/24/1	1.8 MT	YEARLY	26-09-2022	25-09-2023
36	EB/24/2	1.8 MT	YEARLY	26-09-2022	25-09-2023
37	EB/24/3	1.8 MT	YEARLY	26-09-2022	25-09-2023
38	EB/24/4	1.8 MT	YEARLY	26-09-2022	25-09-2023
39	EB/27/1	2.5 MT	YEARLY	26-09-2022	25-09-2023
40	EB/27/2	2.5 MT	YEARLY	26-09-2022	25-09-2023
41	EB/30/1	3.6 MT	YEARLY	26-09-2022	25-09-2023
42	EB/30/2	3.6 MT	YEARLY	26-09-2022	25-09-2023
43	EB/30/3	3.6 MT	YEARLY	26-09-2022	25-09-2023
44	EB/30/4	3.6 MT	YEARLY	26-09-2022	25-09-2023
45	EB/30/5	3.6 MT	YEARLY	26-09-2022	25-09-2023
46	EB/30/6	3.6 MT	YEARLY	26-09-2022	25-09-2023
47	EB/30/7	3.6 MT	YEARLY	26-09-2022	25-09-2023

SR.NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
48	EB/36/1	5.1 MT	YEARLY	26-09-2022	25-09-2023

F: LIFTING AND PULLING

SR NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	LP/3-5/1	3/5 MT	YEARLY	26-09-2022	25-09-2023
2	LP/5-8/1	5/8 MT	YEARLY	26-09-2022	25-09-2023

G: HYDRA AND FORKLIFT

SR NO	IDENTIFICATION	CAPACITY	FREQ	TEST DATE	DUE DATE
1	HD/14/1	14 MT	YEARLY	26-09-2022	25-09-2023
2	FL/3/1	3 MT	YEARLY	26-09-2022	25-09-2023

❖ Test Report of Examination of hoist & Lift under rule 73 in **FORM NO. 13**

A: DOUBLE GIRDER EOT CRANE						
SL NO	**BLOCK***	**LOCATION/EQUIPMENT**	**CAPACITY**	**FREQ**	**TEST DATE**	**DUE DATE**
1	1	GAS TURBINE GENERATOR	50 MT	H/Y	01.10.2022	30.04.2023
2	2	GAS TURBINE GENERATOR	50 MT	H/Y	01.10.2022	30.04.2023
3	1	CW PUMP HOUSE	25 MT	H/Y	01.10.2022	30.04.2023
4	2	CW PUMP HOUSE	25 MT	H/Y	01.10.2022	30.04.2023
5	1	BFP BUILDING	15 MT	H/Y	01.10.2022	30.04.2023
6	2	BFP BUILDING	15 MT	H/Y	01.10.2022	30.04.2023
7	C	GAS BOOSTING STATION	20 MT	H/Y	01.10.2022	30.04.2023
8	C	TURBINE HALL	95/25 MT	H/Y	01.10.2022	30.04.2023
B: SINGLE GIRDER UNDERSLUNG CRANE						
SL NO	**BLOCK***	**LOCATION/EQUIPMENT**	**CAPACITY**	**FREQ**	**TEST DATE**	**DUE DATE**
1	C	CLARIFIED WATER PUMP HOUSE	5 MT	H/Y	01.10.2022	30.04.2023
2	C	RIVER WATER PUMP HOUSE	7.5 MT	H/Y	01.10.2022	30.04.2023
3	C	RAW WATER PUMP HOUSE	5 MT	H/Y	01.10.2022	30.04.2023
4	C	MECHANICAL WORKSHOP	8 MT	H/Y	01.10.2022	30.04.2023
5	C	Clarified water pump house	5 MT	H/Y	01.10.2022	30.04.2023
C: HOIST						
SL NO	**BLOCK***	**LOCATION/EQUIPMENT**	**CAPACITY**	**FREQ**	**TEST DATE**	**DUE DATE**
1	1	DMCW PUMP	5 MT	H/Y	01.10.2022	31.03.2023
2	C	LIFT MAINTENANCE	3 MT	H/Y	01.10.2022	31.03.2023
3	C	DM PLANT	3 MT	H/Y	01.10.2022	31.03.2023
4	C	HVAC CHILLER ROOM	3 MT	H/Y	01.10.2022	31.03.2023
5	1	VACUUM PUMP A	3 MT	H/Y	01.10.2022	31.03.2023
6	1	VACUUM PUMP B	3 MT	H/Y	01.10.2022	31.03.2023
7	2	VACUUM PUMP A	3 MT	H/Y	01.10.2022	31.03.2023
8	2	VACUUM PUMP B	3 MT	H/Y	01.10.2022	31.03.2023
9	1	BFP BUILDING	3 MT	H/Y	01.10.2022	31.03.2023
10	2	BFP BUILDING	3 MT	H/Y	01.10.2022	31.03.2023

11	C	DM WATER PUMPING STN	3 MT	H/Y	01.10.2022	31.03.2023
12	1	GSC FAN	3 MT	H/Y	01.10.2022	31.03.2023
13	2	GSC FAN	3 MT	H/Y	01.10.2022	31.03.2023
14	C	RIVER WATER GATE HANDLING	5 MT	H/Y	01.10.2022	31.03.2023
15	C	RAW WATER GATE HANDLING	3 MT	H/Y	01.10.2022	31.03.2023
16	1	CW GATE HANDLING	8 MT	H/Y	01.10.2022	31.03.2023
17	2	CW GATE HANDLING	8 MT	H/Y	01.10.2022	31.03.2023
18	C	CHEMICAL BUILDING	1 MT	H/Y	01.10.2022	31.03.2023
19	C	N2 PLANT	3 MT	H/Y	01.10.2022	31.03.2023
20	C	RW CHLORINATION	3 MT	H/Y	01.10.2022	31.03.2023
21	C	CW CHLORINATION	3 MT	H/Y	01.10.2022	31.03.2023
22	1	GTG E/S TURBINE SIDE	8 MT	H/Y	01.10.2022	31.03.2023
23	2	GTG E/S TURBINE SIDE	8 MT	H/Y	01.10.2022	31.03.2023
24	1	HRSG MATERIAL LIFTING	1 MT	H/Y	01.10.2022	31.03.2023
25	2	HRSG MATERIAL LIFTING	1 MT	H/Y	01.10.2022	31.03.2023
26	1	BFP BUILDING CHEMICAL LIFTING	1 MT	H/Y	01.10.2022	31.03.2023
27	2	BFP BUILDING CHEMICAL LIFTING	1 MT	H/Y	01.10.2022	31.03.2023
28	C	HVAC CHILLER GRADE TROLLEY	5MT	H/Y	01.10.2022	31.03.2023
29	1	GTG SLIP RING	3 MT	H/Y	01.10.2022	31.03.2023
D: PASSENGER LIFT						
SL NO	**BLOCK***	**LOCATION/EQUIPMENT**	**CAPACITY**	**FREQ**	**TEST DATE**	**DUE DATE**
1	C	CONTROL AND FACILITY BUILDING (3-27-11-001)	884 KG/13 PAX	H/Y	01.10.2022	30.04.2023

3.7.2 THE MANUFACTURE, STORAGE AND IMPORT OF HAZARDOUS CHEMICALS RULES, 1989, (AS AMENDED IN 2000)

Following chemicals used in this factory are listed in part I of Sch. 1 of MSIHC Rules:

Sr. No.	Chemicals
1.	Liquor Ammonia
2	Chlorine
3	Hydrogen
4	Sulphuric acid
5	Hydrochloric acid

- ➢ Therefore, it can be said that the factory uses 'Hazardous Chemicals'.
- ➢ Storage capacities of hazardous chemicals are as follow:

Sr. No.	Chemical	Capacity
1.	Chlorine	20 tonners
2	Hydrogen	8 cylinders + 3.75 M3 X2 in water sealed gas holder
3	Sulphuric acid	30 KL
4	Hydrochloric acid	20 KL
5.	Liquor Ammonia	609 kg

- ➢ Storage quantity chlorine is more than the threshold quantity mentioned in Part II of Schedule 3 of the said Rules.

  Therefore, this factory isclassified as a **MAH** (Major Accident Hazard) factory.
- ❖ Therefore, Rule 5 &7-9 and 13-15 of MSIHC Rules are applicable and information in Schedule 6 to 12 should be kept updated and submitted to the authorities as and when required.

3.7.3 The Chemical Accidents (EPPR) Rules, 1996

Looking to the quantities of the hazardous chemicals more than the threshold quantities mentioned in above para, these Rules are applicable. Therefore, the factory has become a member of the Local Crisis Group and District Crisis Group of the Off-site Emergency Plan made for the local (industrial pocket) area and the Tripura District respectively. It should aid, assist and facilitate the functioning of these groups. It is learnt that the district authorities have included the name of this factory for this purpose.

3.7.4THE PUBLIC LIABILITY INSURANCE ACT – 1991 & RULES - 1991

- From: M/s. **National Insurance Company Limited.,**
- Policy Number: Policy no.: **340100492210000021**
- Period: From 00:00 hours, on 01/06/2022 to **midnight** of 31/05/2023

3.7.5THE ENVIRONMENTAL LAWS

Consolidated Consent & Authorization No. **TSPCB/HOWM/21.** Date of Issue: **31.05 2021** and Valid up to**30.04.2026**from the **TSPCB** with respect of applicability of the Water Act – 1974, The Air Act – 1981 & Authorization under Hazardous & other Wastes (Management & Transboundary Movement) Rules – 2016 under Environment (Protection) Act – 1986 for the use of outlet for the discharge of trade effluent & emission due to operation of Industrial Plant for the manufacturing of its products.

3.7.6THE GAS CYLINDERS RULES 2016

- **License to Store Compressed Gas incylinder**
- Name of Gas: chlorine, 12 Nos. of Tonners
- License No. G/EC/TR/06/47(G 32614)
- Valid up to: **30.09.2025**

- **License to Store Compressed Gas in cylinder**
- Name of Gas:chlorine , 8 Nos. of Tonners
- License No. G/EC/TR/06/48 (G32817)
- Valid up to: **30.09.2025**

- **License to Store Compressed Gas in cylinder**
- Name of Gas: Hydrogen
- Activity : filling of hydrogen & Storage of Hydrogen
- License No. G/EC/TR/05/5 & G/HO/TR/06/5 (G31813)
- Valid up to: **30.09.2024**

3.7.7The Motor Vehicle Act, 1988 and the Central MV Rules, 1989

Because of the transport vehicles owned, hired and run by the factory, provisions of the Motor Vehicles Act and Rules are applicable. Necessary RC books, driving licenses and insurance policies are obtained. They should be kept renewed.

I. No driver shall be allowed or required to drive any vehicle without appropriate driving license.
II. All drivers to carry hazardous chemicals should be trained as required by Rule 135 of the Central Motor Vehicles Rules 1989.

III. Compliance of Rules 129 to 137 of the Central Motor Vehicles Rules 1989 is required in respect of transportation of hazardous chemicals by road tankers. This includes displaying of prescribed class labels, techno-graph fitted in motor vehicle, use of spark arrestor, responsibilities of the consignor, transporter and driver, emergency information panel on goods carriage, training to driver and reporting of accident by the driver etc.

3.7.8 CEA Regulation (measures relating in safety and electric supply) regulation 2010.

- Registration No. RIO/NER/238-OTPC/Palatana/49
- Inspection of electrical installation done on: 08.11.2022.
- Validity: upto 07.11.2023

3.7.9THE STATIC AND MOBILE PRESSURE VESSEL RULES – 1981

License to Store Compressed Gas in Pressure Vessel

- Unit name & No.: **ONGC Tripura Power Company Ltd, Unit - 1,**
- Name of Gas: CO_2
- License No. **S/HO/TR/03/4(S51791)**
- Valid up to: **30.09.2027**

License to Store Compressed Gas in Pressure Vessel

- Unit name & No.: **ONGC Tripura Power Company Ltd, Unit - 2,**
- Name of Gas: CO_2
- License No. **S/HO/TR/03/6(S51790)**
- Valid up to: **30.09.2027**

3.8PLANT WISE AUDIT OBSERVATIONS

SR.NO.	OBSERVATION	RECOMMENDATION
400KV SWITCH YARD AREA		
1.	There is no earthing on Main gate of Switch yard CEA 2010reg cl.49(2)	To provide
STG-1GT ,15.75/400kv,130MVA Bay 401 Y phase		
2.	Nest found on main isolator operating rod fulcrum	To remove withoutage
3.	R phase SF6 gas breaker pressure indicator glass is opaque.	To replace
4.	401 STG-1GT Bay nomenclature is not readable.	To rewrite.
5.	TR LAs separate earthing notfound	To ensure, as not traced
ICT1 Bay 403-89-BE		
6.	Earthing switch box second earthing not provided CEA 2010 reg cl 41(xii)	To be provide
4-89 BE ,BUS 2 CVT isolator R phase		
7.	Bird nest in upper side of mechanism rod.	To remove with outage
8.	Mechanism box is TOO dirty due to Birds drops	To maintain clean
9.	4-89-B-F1, Marshalling box hole opening found also Lizard in wiring.	To maintain vermin proofing
10.	Arrow marking for emergency exit from switch yard not found	To provide
11.	ICT1 hydrant DV house14 electrical control wiring box door open also metal shed of house is not complete.	To attend
12.	Emulsifier system main pipe vertical support is not fitted with foundation	To fix
13.	ITC1 OLTC conservator tank breather silica exhausted.	To replace
14.	On line moisture remover kiosk entry pipe line hole is open requires sealing.	To attend
15.	LC side(33kv) below trench is open and partly filled with oil. CEA 2010 reg. cl 44.2 xii	To attend.

SR.NO.	OBSERVATION	RECOMMENDATION
16.	33kv side OLTC control cable dressing is poor, requires with tray.	To attend.
17.	Fans Cooler control cubical cable glands open.	To seal cable gland holes.
18.	Cable trench cover slabs missing at various points.	To provide cover slabs
19.	High vegetation growth found on132 line kv Tower .	To remove with outage
20.	Near 132 kv yard Material (Pipes) storage found.	There should be no extra material store in switch yard.Toremove
ICT 2, 400/132kv,125MVA		
21.	Cable trench is open. CEA 2010 reg. cl 44.2 xii	To provide cover slabs
22.	Painting (Red) of Emulsifier system requires	To attend.
23.	Cooler control system panel door glass rubber sealing deteriorated	To replace rubbersealing.
24.	Main conservator tank breather silica part exhausted	To replace
DG Set Room		
25.	DG control panel back side nomenclature and insulating sheet not found	To attend
26.	MCC aux. panel board back side nomenclature not found	To attend
27.	Incomer2 panel side checker plate is jumping on walking not fixed with support	To correct.
28.	Emergency light not found	To provide
29.	Fire sensor not found	To provide
400KV SWITCH YARD CONTROLROOM		
30.	415V, DB NLP 1&ELP1 door found open.	To lock
31.	220V &48V Main charger panel doors found open	To maintain panel doors closed

SR.NO.	OBSERVATION	RECOMMENDATION
32.	Bus coupler relay panel back side door found open	To maintain panel doors closed
33.	48-volt DC PLCC battery bank all cell body deteriorated	To replace
6.6 KV breaker control room of unit 1		
34.	Rescue rod not found	To provide
MAIN CONTROL ROOM		
35.	Interlock bypass register is there for approvals but observed that on sr. no. 100 dated 1-7-2020 not get signed By VP/DGM (OTPC).	
36.	Real time data(Tan delta,DGA) of all main Transformers not available in main control for monitoring due to LAN Cable defect	To attend.
Misc. Point		
37.	ST1, hydrant system trench : near valve a vegetation plant observed	To remove
38.	BFP house; poor illumination observed, To maintain as per IS 6665;1972	To maintain lux level
Stores		
39.	Tube lights in rack passages at very low height and without guard on the tube light.	Guarding on tube lights is needed.
40.	One Emergency exit is blocked.	Ensure emergency exits are kept clear from any obstruction.
41.	Smoke detectors are not installed.	Required in stores.
42.	Combustible material is stored right under the power panel box.	Combustible to be removed from the vicinity of the panel.
43.	SWL on the shelves of the racks is not marked.	Mark SWL.
FIRE STATION& Fire system		
44.	There are no spare SCBA cylinders in the fire tenders.	Two spare tenders in each tender are recommended.
45.	Fire NOC is obtained dt. 29.08.2014 as one time NOC.	Good point.

SR.NO.	OBSERVATION	RECOMMENDATION
46.	DCP Fire extinguishers with punch type operation are obsolete.	New stored pressure ABC fire extinguishers with squeeze type operation is recommended.
47.	Deluge Valve #20 is found with the remote operation solenoid valve plugged, So the remote function is disabled. .	Review and take quick action.
48.	D.V #20 with bypass line is fitted with butterfly valve without a handle for operation.	Install the handle immediately.
49.	Poor cable glanding and single earthing is used for electrical pump motors near D.V #20.	Provide double earthing to all electrical apparatus above 250V as per IS 3043. Cable glands should be fitted properly to reduce stress and strain on cables and to prevent vermin entering inside.
SULPHURIC ACID TANKS.		
50.	Flange guards on some of the Sulphuric lines are missing and not fitted.	Flange guards prevents splash of chemical.
51.	Silica gel on the breather ventof H2SO4 tanks is exhausted.	Replace silica gel.
52.	Safety shower water pressure is low and inadequate for washing of eyes and body.	Ensure adequate water pressure is maintained in the safety shower water line.
CHLORINATION		
53.	One chlorine detector is showing 0.4 ppm value.	Check the same and do the needful.
54.	Electric panel doors are left open.Vermin and dust can enter form open doors and cause fault in panel.	Keep the panel door tightly shut.
PIPE RACK ON MAIN ROAD		
55.	A pit containing dry vegetation and tree branches is just below the rack where electric cables and pipelines are laid. This vegetation is afire load and	Remove the vegetation from the pit and relocate the dry vegetation storage area.

SR.NO.	OBSERVATION	RECOMMENDATION
	potential fire hazard that can damage the cables running nearby.	
HCl Storage Area.		
56.	Flange guards on some HCL lines are missing.	Fit flange guards.
57.	HCL drums are stored in open place that is not lined with acid proof tiles and neither any dyke wall around it to contain the HCL spill. This is violation of pollution control.	Review the same and make adequate storage facility for HCL drums.
58.	Dyke wall around the tank has opening. The purpose of the dyke wall is defeated.	Maintain the integrity of the dyke wall.
OHC		
59.	One FMO is available with four nurses and four ambulance drivers.	Good point.
60.	Medical checkup of one canteen food server was not found. Last record available was for year 2020-2021.	Canteen staff to be medially checked half yearly for any infectious diseases.
61.	Medical Oxygen cylinder storage of OHC is not proper. Following discrepancies are seen:+ • Empty and full cylinders are not segregated. • Cylinders are standing alone without chaining them to a firm support. • Oxygen cylinders are without safety caps. • There is no spare cylinder in ambulance. • Fuel in ambulance is only 50%	• Segregate empty & filled cylinders. • Chain the cylinders to a firm support to prevent free falling. • Fit safety caps. • Provide a spare oxygen cylinder. • Keep the tank full. Min. 75%.
CANTEEN		
62.	Chimney louvers are choked with oily and greasy material. Dripping of the same is found.	Clean the chimney louvers before they get choked.
63.	Medical checkup of canteen	Ensure.

SR.NO.	OBSERVATION	RECOMMENDATION
	employees as per the hygienic standards to ensure.	
ADMIN BLDG.		
64.	There is no emergency exit from the first floor of admin building.	To do the needful.
TRAINING CENTRE		
65.	Emergency exit at first floor is not provided.	Do the needful.
66.	Dry grass in the plant premises is a potential jungle fire hazard.	Dry grass cleaning to be done periodically.
COMPRESSED GAS CYLINDERS		
67.	Integrity of the compressed gas cylinders is not checked.	Ensure the hydraulic test of the cylinders is done every three years and retain their certificates for cross verification.

4.0 CHECKLIST COMPLIANCE AUDIT AS PER IS 14489:2018

Observations including non-conformities by the auditors are given below in Annexure B to C. Standard Requirements for the Auditare also suggested in the last column.

ANNEXURE – B (IS 14489:2018)

(Clause 5.3.3)

Types of Records to be examined during the Safety Audit

NO.	ITEMS	OBSERVATIONS
❖	❖	❖
1.	OS & H Policy	Yes
2.	Safety Organization Chart	Yes
3.	Training Records on Safety, Fire & First Aid	Available with OMS
4.	Record of Plant Safety Inspections	Available with OMS
5.	Accident Investigation Reports	Available with OMS
6.	Accidents, Dangerous Occurrences and near miss incidents - statistics and analysis	Available with OMS
7.	Record of Tests & Examinations of Equipment & Structures as per Statues	Available with OMS
8.	Standard Operating Procedures (SOP) for various Operations	Available with OMS & OTPC operations
9.	Record of Work Permits	Available with OMS & OTPC operations
10.	Record of work environment monitoring (flammable, toxic and explosive	Available with OMS & OTPC operations

NO.	ITEMS	OBSERVATIONS
❖	❖	❖
	substances)	
11.	Maintenance, Testing and calibration Records of fire detection &fire fighting equipment	Available with OMS & OTPC operations
12.	Medical records of employees	Available with OMS & medical officer.
13.	Records of Industrial Hygiene surveys (noise, ventilation, illumination, Dust etc.)	Available
14.	Material Safety Data Sheet (MSDS)	Available & Displayed in various locations.
15.	On-site Emergency Plan & record of mock drills	Available
16.	Records of storage of hazardous solid waste and its disposal	Available
17.	Records of gaseous emissions and effluent discharges to the environment;	Available
18.	Housekeeping inspection records	Available
19.	Minutes of Safety Committee meetings	Available
20.	Statutory licenses and approvals	Available
21.	Records of any modifications carried out in plant or process.	MOC Copy available with Operations and TC
22.	Maintenance procedure and records	Available with MMD
23.	Instrumentation and equipment Calibration & testing records	Available with IMD
24.	Planned Shutdown maintenance	Available with OPN

NO.	ITEMS	OBSERVATIONS
❖	❖	❖
	procedures	
25.	In service inspection manuals, records including that of material handling	Available with MMD
26.	OH & S budget	Available
27.	Inspection books & other Statutory records	Available
28.	Records of previous Audits and safety analysis	Available
29.	Procedure for Safe transportation of hazardous substances	SOP Available
30.	Calibration records	Available with IMD
31.	Records for breakdown of plants during the process of manufacture	Available with MMD
32.	Records for waste material generated and their disposal	Available with Store and EHS&F
33.	SOP for disposal of waste materials	Not Available With EHS&F
34.	Records for issue of PPE items to the personnel working in process building.	Available

ANNEXURE – C (IS 14489: 2018)

(Clause 5.3.4)

General Points

NO.	ITEMS	OBSERVATIONS
OH & S MANAGEMENT		
OH & S POLICY		
1.	Does the organization have OH & S policy?	Available
2.	Who has signed the OH & S policy?	Signed by MD
3.	Whether the OH & S policy is per guidelines of the statutory provisions?	Yes-
4.	When was the OH & S policy declared and adopted?	2012
5.	Whether the OH & S policy reviewed periodically?	Yes
6.	Whether the OH & S policy is available in local language and made known to all?	Yes
7.	What was the last date of updation?	2019
8.	Does the policy find a place in the annual report?	Yes
OH & S ORGANIZATIONAL SET UP		
SAFETY DEPARTMENT		
9.	Does the factory have a safety department and what is strength of safety department?	Yes (3 Safety officer)
10.	Whether the strength and qualifications of Safety Officers are as per the statutes?	Yes 3 safety officers
11.	Does the head of safety department report to the Chief Executive?	Yes.
12.	How often are the safety officers retrained in the latest techniques of total safety	2 external training per year

	management? What is the frequency of retraining?	
13.	What additional duties the safety officer is required to do?	No
14.	What is the power of safety officer vis-a-vis unsafe condition or unsafe act?	To STOP work.
SAFETY COMMITTEE(S)		
15.	Does the factory have a safety committee(s)? What are the types, structures and terms of reference of the committees?	Yes, 2 types
16.	Is the constitution of the safety committee(s) as per the statute?	Yes
17.	How are the members of safety committee(s) selected? (elected / nominated)	Elected.
18.	How often are the meetings of safety committee(s) held?	Every quarter.
19.	Are the recommendations of the committees(s) implemented?	Yes.
20.	Are the minutes of the safety committee(s) meetings circulated among the members?	Yes
21.	Are the minutes forwarded to the trade union(s) and chief executive and occupier?	No, Union not registered.
22.	Whether the management and trade union play their active roles in supporting and accepting the committee(s) recommendations?	NA
23.	How are the safety committee(s) members	Emails and meetings.

	apprised of the latest development in safety, health and environment?	
SAFETY BUDGET		
24.	What is the annual safety budget?	11.87 Lakh for last year FY22-23
25.	How much percentage is this budget of the total turnover of the company?	-
26.	How much budget has been utilized till date?	10.87 lakhs budget utilized.
27.	Is the safety budget adequate?	Yes
28.	How is the safety budget arrived at?	Proper plan and execution and after have a meeting with Management.
29.	What is the pattern of expenditure for the last five years?	Increasing.
30.	What are the approved sanctions for the expenditure in this budget?	Purchasing of Fire equipment, PPE's, Signage's, Trainings, and Promotional Activities &Maintenance.
31.	Does this budget get reflected in the annual report of the company?	Yes.
SAFETY MANUAL		
32.	What is the periodicity of updation / review of safety manual?	Yes
33.	Does the safety manual adequately address all the hazards in the plant?	Yes
34.	Are the employee made aware of safety rules / instruction mentioned in the safety manual?	Yes
STANDARD OPERATING PROCEDURES (SOP)		
35.	Are written Standard / safe operating procedures available for all operations and processes?	Yes.

36.	Whether the written Standard / safe operating procedures are displayed or made available and explained in the local language to the workers?	Yes.
37.	Whether concerned section and safety department prepares standard / safe operating procedure jointly?	Yes.
38.	Are standard / safe operating procedures reviewed and updated?	Yes
39.	Have the workers been informed of the consequences of failure to observe the standard / safe operating procedures?	Yes.
PLANT MODIFICATION PROCEDURES		
40.	What is the system for effecting any change in the existing plant, equipment or process?	MOC
41.	Whether the P & I diagrams and other related documents are updated accordingly?	Yes
42.	Whether hazard assessment done before implementation of modification?	Yes wherever required.
WORK PERMIT SYSTEM		
43.	What types of work permits exist in the factory?	Limited work permit, Height work permit, Hot work, Confined space, Hazardous work activity, Electrical PTW, Excavation PTW
44.	Are the necessary forms detailing required safety precautions have been prepared and used for each type of work-permit?	Yes, its SAP based PTW Systems.
45.	Is the responsibility assigned to authorize	Yes, operation head

	person for issuing of safety work permit?	
46.	Is the copy of safe work permit sent to safety officer before execution of the job?	Yes.
47.	Is validity period specified in the safety work permit?	Yes.
48.	Are the records of work permit available and maintained in proper order?	Yes, also Internal audit for PTW is done.
CONTROL MEASURES FOR WORK AT HEIGHT		
49.	Is adequate safe access provided to all places where workers need to work?	Yes
50.	Are all such access in good condition?	Yes
51.	Are all scaffolds are properly designed and erected?	Yes
52.	Are scaffolds inspected every day before work begins?	yes
53.	Are ladders securely clamped or lashed in place?	yes
54.	Are planks in good condition?	yes
55.	Are scaffold walkways, platforms, runs or stairs free of debris, grease, any unnecessary obstruction and projecting nails?	yes
56.	Are the scaffolds higher than 20 m.? If yes, is a netting or intermediate railing provided between toe-boards and hand railings?	NA
57.	Are folding stepladders properly used?	Yes
58.	Are ladders set up at the proper slope of about 1:4?	Yes

59.	Do workers use hand lines to lift tools or materials?	Yes, Tool pouches are used
60.	Are proper ladders used around electrical hazards?	Fiber Glass Non-Conductive type.
61.	On sloping roofs, are crawling boards, lifelines, safety belts and edge protection provided where needed?	Yes.
62.	Whether the weak spots, skylights, or deteriorated asbestos-cement boards through which a worker might fall while working in the roof has been identified and safety net provided appropriately?	NA
63.	Are the workers being medically examined for their fitness to work at height?	Yes.
WORK IN CONFINED SPACE		
64.	Is work permit system followed for working in confined space?	Yes
65.	Whether monitoring of the atmosphere inside the confined space is carried out and ensured that there is no flammable or toxic gas in the area?	Yes
66.	Whether the person entering the confined space is using suitable personal protective equipment (PPE)?	Yes
67.	Is rescue team available in case of any emergency?	Yes (Fire Team and QRT Team)
CONTRACTORS' SAFETY SYSTEM		
68.	Is there any system for selection of contractors?	Yes.
69.	Are there any guidelines on contractor's	Yes

	safety and training?	
70.	Whether contract document includes necessary safety and welfare clauses as per statutes?	Yes.
71.	Is there any programme to ensure use of PPE by contractors personnel?	Yes.
72.	Do the contractors have their own safety organization?	Yes.
73.	Are the contractors reporting all accidents and injuries?	Yes
74.	Are contractor workers trained to observe safety at work place?	Yes.
75.	Whether contractor workers are engaged in process / operations? If yes, are they aware of safe operating procedures?	Yes.
PLANT DESIGN AND LAYOUT		
76.	Whether hazardous operations in the plant are segregated?	Yes
77.	Whether occupational health & safety aspects are considered during the design?	Yes
78.	Are all the equipment provided with adequate space for working, maintenance etc.?	Yes
79.	Are the storage tanks provided with enough space / clearance between them?	Yes
80.	Whether the plant layout has taken care of the movement of fire-fighting equipment and emergency exits?	Yes.
MEDICAL MANAGEMENT OF ACCIDENTS		

81.	Are medical facilities available with trained first aid staff and equipment in round the clock shift for all including contractors?	Yes with 3 Nurse and 1 Medical officers
82.	Is the ambulance van available for round the clock basis with the dedicated driver?	Yes
83.	Is there any mutual aid scheme available with the nearest hospitals to manage and treat injuries during emergency?	Yes, with Kakraban, hospital. Docs available with MO.
84.	Are the workers / contractor workers aware of emergency medical facilities?	Yes.
MANAGEMENT OF EMERGENCIES (NATURAL / MAN-MADE)		
85.	Does the system exist to detect and control these Emergencies?	Yes.
86.	Are the employees aware of the measures to be taken during emergencies?	Yes.
EMPLOYEES SELECTION AND PLACEMENT		
87.	Whether norms are available for selection of different category of employees?	Yes.
88.	Whether pre-employment medical examination is being conducted for employees?	Yes.
89.	Is there any procedure to evaluate safety awareness and record of the employees during their promotion?	Yes.
SAFETY CULTURE		
ATTITUDES OF MANAGERS		
90.	Do the managers follow the plant safety rules at all times?	Yes

91.	What are their attitudes towards safety reviews and audits?	Positive.
92.	What is the response of management to safety violation?	Yes
93.	Whether safety related decisions are taken in consultation with the workers?	Yes.
94.	What is the attitude of the managers towards non use of personal protective equipment?	Yes, STOP work & Given refresher training.
ATTITUDES OF WORKERS		
95.	Whether workers are aware of the consequences of their wrong actions?	Yes
96.	Are laid down safe working procedures followed strictly?	Yes
97.	What is the attitude of the workers towards their own mistake, which can prejudice safety?	Yes
98.	Do the workers report near miss incidents and suggest safety improvements?	Yes
99.	Are the workers aware of the system of rewards and sanctions relating to safety matters?	Yes
100.	What is the attitude of workers towards use of personal protective equipment?	Positive.
STATUTORY LICENSES, APPROVALS AND RECORDS		
101.	Whether all the safety related Acts / Rules (with latest amendments) applicable to your organization identified, informed to all employees and complied?	Yes
102.	Whether the licenses have been validated?	Yes

MOTIVATIONAL AND PROMOTIONAL MEASURES FOR OH & S		
103.	Does the factory have occupational health and safety suggestion scheme?	Yes
104.	Are occupational health and safety contests organized in the factory?	Yes
105.	Does the factory participate in National Awards?	Yes
106.	Has the factory been awarded during last five years?	Yes
107.	Does the organization publish safety bulletin / newsletters?	Yes
108.	Whether the safety bulletins are widely distributed?	Yes
109.	How is the occupational health and safety information including accident statistics disseminated in the factory? (Bulletin boards, Newsletter etc.)	Meetings and tool box talk,Emails.
110.	What are the activities conducted during National Safety day / week?	Safety drama, Slogan,Poster,Quiz,Mock Drill and prize distributions.
111.	What is the percentage of Workers participating in the various safety promotional activities?	100%
HAZARD IDENTIFICATION AND JOB SAFETY ANALYSIS		
112.	Was an initial process hazard analysis (PHA) completed?	Yes.
113.	What are the stages of PHA? Whether a dedicated group is identified for PHA?	Yes
114.	Was the PHA appropriate for the complexity of the process and identify, evaluate, and control the hazards involved	Yes

	in the process?	
115.	Does the hazard evaluation use one or more of the following PHA methodologies: What-If Analysis, Process Checklist, Hazard and Operability Study (HAZOP), Failure Mode and Effects Criticality Analysis (FMECA), Fault Tree Analysis (FTA) or any other appropriate equivalent methodology?	Yes
116.	Does PHA assure addressing issues of inherent safety features with respect to material and their properties?	Yes
117.	Does the PHA address the hazard identification, incidents history, consequences of failures (engineering and administrative controls), human factors, consequent analysis with respect to possible safety and health effects of failure of controls?	Yes
118.	What are the stages of PHA? Whether a dedicated group is identified for PHA?	Yes
119.	Does the system exists to promptly address findings and recommendations of PHA?	Yes
120.	Are the PHA's updated and revalidated at least every five years by a qualified team to assure that the PHA is consistent with the current process?	Yes.
121.	Whether the activities requiring Job Safety Analysis have been identified?	Yes

122.	Whether the identified jobs for Hazard Identification have been carried out by trained and experienced persons?	Yes
123.	Whether the checklists have been prepared on each Job Safety Analysis and are being used while carrying out the job?	Yes
PRODUCT SAFETY		
124.	Whether hazards arising from use of the products are identified?	NA
125.	Whether material safety data sheet prepared for the products?	NA
126.	Are all the products labelled and packed appropriately?	NA
127.	Whether safety instructions are given along with products?	NA
128.	Whether policy exists for recall of products?	NA
SAFETY TRAINING		
129.	Whether training needs have been identified?	Yes
130.	Is there any programme of induction training, its duration and topics covered?	Yes
131.	Whether the assessment of the trainees has been carried out?	Yes
132.	What are the infra-structural facilities available for training?	Training center with audio and visuals facility.
133.	Whether training is conducted by qualified person?	Yes
134.	Whether trainers are being re-trained from	Yes

	time to time?	
135.	Whether proper records of training program conducted are maintained?	Yes
136.	How training programs are evaluated?	Pre and post evaluation
137.	Whether schedule for training on occupational health and safety is available and maintained?	Yes
138.	Whether the training programmes are reviewed?	Yes
139.	Are all the employees periodically trained / retrained and what is the frequency of such training?	35 man hours per year.
140.	Are the retraining needs identified whenever a new process / products and change in existing process introduced?	Yes
141.	Whether training covers top management?	Yes
142.	How many hours of safety training is given to different employees?	35 Man hours per year
CHANGE MANAGEMENT		
MANAGEMENT OF CHANGE		
143.	Are there written procedures for managing change to process chemicals, technology, equipment and procedures and changes to facilities that affect the plant process / system operation?	Written procedures are made.
144.	Do the procedures assure that the technical basis for the proposed change addressed prior to any change?	Yes
145.	Do the procedures assure that the impact of the change on safety and health	Yes

	addressed prior to any change?	
146.	Do the procedures assure that modifications to operating procedures are addressed prior to any change?	Yes
147.	Do the procedures assure that the necessary time period for the change is addressed prior to any change?	Yes
148.	Do the procedures assure that the authorization requirements for the proposed change are addressed prior to any change?	Yes
149.	Are employees involved in operating a process, and maintenance and contract employees whose job tasks will be affected by change informed of, and trained in, the change prior to the start-up of process or affected part of process / operations?	Yes
150.	Is the safety information is reviewed and updated on changes?	Yes
151.	Are the operating procedures or practices updated?	Yes
MECHANICAL INTEGRITY		
152.	Does the mechanical integrity program include for all mechanical equipment including pressure vessels and storage tanks, piping and components, relief devices and vent systems, emergency shutdown systems, pumps, control systems?	Yes

153.	Are there written procedures to maintain the on-going integrity of process equipment?	Yes
154.	Whether training been provided to each employee involved in maintaining the on-going integrity of process equipment?	Yes
155.	Are inspections and tests performed on each item of process equipment included in the program?	Yes
156.	Does the inspection and test frequencymeet the manufacturer's recommendation and good engineering practice?	Yes
157.	Are inspections and tests performed more frequently if determined necessary by operating experience?	Yes
158.	Are deficiencies in equipment that are outside limits corrected before further use so as to assure safe operation?	Yes
159.	In the construction of new plants and equipment, whether quality assurance programme is implemented to ensure that equipment fabricated is suitable for the process?	Yes
160.	Are appropriate checks and inspections made during equipment installation stage?	Yes
161.	Are the suitability of maintenance materials, spareparts and equipment ensured during maintenance?	Yes
PHYSICAL HAZARD		

HOUSEKEEPING		
162.	Are all the passages, floors and the stairways in good condition?	Yes
163.	Is glass door taped or otherwise marked to make it visible to workers?	Yes
164.	Do you have the system to deal with the spillage?	Yes
165.	Do you have sufficient disposable bins clearly marked and whether these are suitably located? Are containers of refuse (waste) and trash emptied at the end of every day or soon after they are full? Are the containers or bins regularly cleaned?	Yes
166.	Are drip trays positioned wherever necessary?	Yes
167.	Do you have adequate localized extraction and scrubbing facilities for dust, fumes and gases? Please specify.	Yes
168.	Whether walkways are clearly marked and free from obstruction?	Yes
169.	Do you have any inter-departmental competition for good housekeeping?	Yes.
170.	Has your organization elaborated good housekeeping practices and standards and made them known to the employees?	Yes
171.	Are there any working conditions, which make the floors slippery? If so, what measures are taken to make them safe?	Yes
172.	Does the company have adequate	NA

	measures to suppress polluting dust arising out of materials stored on the roadside?	
MACHINE AND GENERAL AREA GUARDING		
173.	Whether machinery and equipment which can cause physical injuries to operator have been identified?	Yes
174.	Are all moving parts and point of operation of machinery adequately guarded?	Yes
175.	Are all fixed guards securely bolted in position and in good condition?	Yes
176.	Are all interlock guards for prevention of physical injury in good condition?	Yes
177.	Are all emergency stop buttons effective and clearly labelled?	Yes
178.	Are the operators for machines having moving parts aware of the danger of working with loose clothing?	Yes
179.	Are the openings where there is free fall hazard covered or fenced securely?	Yes
MATERIAL HANDLING		
180.	Are adequate equipment available for handling materials?	Yes
181.	Are the workers aware of the hazards associated with material being handled?	Yes
182.	Where manual handling is necessary, are the workers been trained? Do they practice this? Are workers warned for lifting of excessive weight? (Maximum weight of material for adult male and female are 55	Yes

	Kg and 30 Kg respectively)	
183.	Do workers follow safe procedures for storage of materials?	Yes
184.	Is the register maintained to record particulars of examination of all lifting machines, tools and tackles?	Yes
185.	Are all the statutory examinations and tests carried out and certified by competent person(s)?	Yes
186.	Are the operators of crane, lifts, hoists and other mechanized operations adequately qualified?	Yes
187.	Is the safe working load clearly marked?	Yes
188.	Has the person employed to operate crane, forklift, or to give signals to crane been medically examined for eyesight and colour vision?	Yes
189.	Is the frequency of eyesight and color vision examination as per the latest rules?	Yes
ELECTRICAL SAFE GUARDING		
190.	Are licensed electricians available for electrical work?	Yes
191.	Whether area classification for electrical equipment has been carried out?	In Process.
192.	Do the electrical fittings conform to area classification for electrical equipment?	Yes.
193.	Is a ground fault current interrupter system (ELCB) in use?	Yes
194.	Are all connections made by using	Yes

	appropriate plugs, receptacles or enclosures? Are fuses provided?	
195.	Are there any make shift connection bare wires or damaged cables?	No
196.	Is there a system of ensuring periodical inspection of hand tools, extension boards used for electrical work?	Yes
197.	Do the workers use proper types of PPE during the working on live line?	Yes
198.	Is the separate work permit issued for working on high voltage line?	Yes
199.	Whether the process(s) and equipment that generate and accumulate static charge have been identified?	Yes
200.	Whether all such equipment including pipelines for flammable materials are properly bonded and earthed?	Not present in Hydrogen plant area.
201.	Whether earth pit resistance is measured and the record maintained?	Yes
202.	Whether lightning arrestor has been installed and is adequate?	Yes
SAFETY IN STORAGE AND WAREHOUSING		
203.	Whether the Material Safety Data Sheet for all chemicals is available?	Yes
204.	Are the chemicals stored as per their hazardous properties including the incompatibility?	Yes
205.	Are all containers clearly, indelibly labelled? Are all chemicals stored as per	Yes

	safety regulations?	
206.	Whether all racks and steel cages have sufficient load bearing capacity?	Yes
207.	Is adequate natural ventilation provided to store room? Is there any emergency exit?	Yes
208.	Whether adequate fire-fighting arrangement existing in flammable chemical storage?	Yes
209.	Whether methodology for handling spillages of hazardous chemical available along with the equipment required handling the spillage?	Yes
210.	Whether aisles are marked and emergency exits displayed?	Yes
HAZARD ASSESSMENT FOR NEW EQUIPMENT		
211.	What is the system for effecting any change in the existing plant, equipment?	Yes
212.	Is there system for evaluating hazards from new equipment?	Yes
213.	Whether the P and I diagrams and other related documents are updated accordingly?	Yes
214.	Is any Job Hazard Analysis (JHA) carried out after installation of new equipment?	Yes
HAZARDS FROM RADIATION SOURCES		
215.	Whether licences have been obtained for storage / handling of radioactive material?	NA
216.	Whether approved Radiological Safety Officer appointed?	NA

217.	Whether appropriate PPEs are used against radiation hazards?	NA
218.	Is the flooring of the radioactive material handling area amenable for proper decontamination?	NA
219.	Is the storage room of radiation source as per the licence condition?	NA
220.	Are all persons working in the facility have radiation safety training?	NA
221.	Is the operator handling devices using radioactive materials qualified and possess the necessary certificate?	NA
222.	Is the periodical radiation monitoring carried out?	NA
223.	Are the records of inventory of radioactive material maintained in the standard format and submitted to the competent authority as per the period specified?	NA
224.	Are emergency handling tools available?	NA
225.	Are the personnel monitoring badges (TLD, Pocket dosimeter etc.) assigned and worn by each radiation worker?	NA
226.	Are the radiation symbol and red light displayed as required?	NA
CHEMICAL HAZARD		
TRANSPORTATION OF HAZARDOUS SUBSTANCES		
227.	What potentially hazardous materials are transported to or from the site (including wastes)	HCL,H2SO4,Chlorinetonner.Natural Gas,Hazardous waste.
228.	What modes of transport are used?	Road & Pipelines.

	1) Road, 2) Rail, and 3) Pipelines	
1) ROAD		
229.	Does the company employ licensed vehicle of its own / outside sources?	Yes.
230.	Are the loading / unloading procedures in place and safety precautions displayed?	Yes.
231.	Is there a provision to check the healthiness of road tanker with respect to explosives rules?	Yes.
232.	Are loaded tankers or trucks parked in a specific area on-site?	Yes.
233.	Do all truck and tanker drivers carry transport emergency (TREM) card or instruction booklet?	No
234.	Do all truck and tanker drivers get training in handling emergencies during transport?	No
235.	Are all the tankers marked for proper Hazchem code?	Yes.
2) RAIL		
236.	What hazardous materials are transported by rail?	NA
237.	Does the company have a direct siding on site?	NA
238.	Are tankers or other wagons used in transportation?	NA
3) PIPELINES		
239.	What materials are transported to and from	Natural Gas

	the site by pipelines?	
240.	Are the pipelines underground or over ground?	Over Ground &Underground.
241.	Are corrosion protection measures employed in pipelines?	Yes
242.	Whether intermediate booster pumps are used?	Yes
243.	What is the maximum, minimum and average transfer rate?	
244.	Are the pipelines extended in the public domain?	Yes.
245.	Are the pipelines dedicated for each type of chemicals?	Yes.
246.	Are the pipelines fitted with safety equipment such as leak detectors, automatic shut-off valves etc.?	Yes
247.	What is the frequency and method of testing of the pipeline?	In the scope of Supplier.
248.	Is there written procedure for tackling leakages in pipeline?	Yes.
HANDLING OF HAZARDOUS SUBSTANCES		
249.	What are the hazardous substances handled in the factory?	Natural Gas, Chlorine, Hydrogen,HCL, H2SO4, & Caustic flakes.
250.	Whether quantity of hazardous substances is above the threshold limit specified in the Manufacture, Storage and Handling of *Hazardous Substances Rule*, 1989? If yes, then required documentation is available as per the rule.	As per the table given in the report.

251.	Whether written procedure for handling the hazardous substance is available and operators are trained for handling such substances including actions required in case of leakages and spillages?	Yes
252.	Are the employees aware of the hazards arising from hazardous substances and safety precautions to be taken during handling of these?	Yes.
MATERIAL SAFETY DATA SHEETS (MSDS)		
253.	Are the material safety data sheets available for all the chemicals handled, used and manufactured in the factory?	Yes.
254.	Whether the latest MSDS are displayed at strategic locations?	Yes
255.	Is it available in local language?	Yes
SPILL CONTROL MEASURES		
256.	Whether spill control procedure is available?	Yes
257.	Whether spill collection pit / sump is available at the workplace?	Yes
258.	Whether methodology for recovery / disposal of collected material has been established?	Yes
STORAGE OF HAZARDOUS SUBSTANCES		
259.	Whether storage vessels are identified with the capacity as required under *MSIHC, Rules* 1989.	Yes
260.	What are the storage pressure and temperature?	As per the table given in the report.

261.	Whether vessels are above ground / underground?	Over Ground.
262.	If any of the tanks storing flammable material, whether electrical equipment and fittings are as per electrical area classification?	Yes Hydrogen
263.	Is the bunded area takes into account the total quantity of the largest tank?	Yes
264.	Whether the bund perimeter takes into consideration of trajectory of leak from tank?	Yes
265.	Are the vessels properly bonded and earthed and whether periodically checked and record maintained?	Yes
266.	Are the vessels fitted with remotely controlled isolation valves?	No
267.	Are vessels provided with emergency vent, relief valve, bursting disc, level indicator, pressuregaugeand overflow line?	Yes.
268.	Where do such vents discharge?	Atmosphere
269.	Are the vessels provided with alarms for high level, high temperature and high pressure?	Yes
270.	Are standby empty tanks or any other alternate systems provided for emptying / transfer in case of emergencies?	No
271.	What are the provisions made for fire-fighting / tackling emergency situations around the storage vessels?	Fire hydrant Systems, Fire extinguishers

272.	Has any consequence analysis for loss of containment been carried out?	Yes.
273.	Whether the vessels are tested as per statute?	Yes
274.	Whether log sheets are filled up on daily basis for recording the parameters of these vessels?	Yes
275.	Whether monitors for detection of leakage of flammable / toxic material installed?	Yes
276.	Whether the chemicals stored are as per their compatibility?	Yes
GAS CYLINDERS		
277.	What are the various gas cylinders used in the plant?	Chlorine, Hydrogen,Co2,Argon, Nitrogen, DA,Oxygen Cylinder, Calibration gasses. Refrigerant Gasses,SF-6 Gas.
278.	Are valid licenses available for storing all these cylinders?	Yes
279.	Are the cylinders stored and segregated as per their compatibility?	Yes
280.	What are the measures taken for combating any emergency in the cylinder storage area?	SCBA, Firefighting systems, Detection & PPE's
281.	Whether integrity test certificates are obtained from the suppliers of the cylinders?	Yes, partially available
282.	Are the cylinders chained and secured properly along with the valve caps and proper identification colour code?	Yes
283.	Are the cylinders protected from heat or	Yes

	sun and rain?	
284.	Whether monitors for detection of leakage of flammable / toxic gas installed?	Yes
LABELING AND COLOR CODING		
285.	Are all the containers, vessels and storage tanks labelled for its content and capacity?	Yes
286.	Whether the pipelines are colour coded as per IS 2379?	Yes
287.	Is any plant specific colour code followed?	As per IS 2379.
288.	Whether the color codes are displayed conspicuously in the working areas?	Yes.
HAZARDOUS WASTE MANAGEMENT		
289.	Is identification done for various types of hazardous wastes?	Yes
290.	Are these quantities less than those specified by the Hazardous Wastes (Management & Handling) Rules, 1989?	Yes
291.	What are their disposal modes?	By Road
292.	What are the systems / measures adopted for controlling air / water / land pollution?	Air- Stack monitoring,AAQM. Water- EPT. Land- Sample test of soil
293.	Whether the solid waste like combustibles, plastic, metals etc. segregated?	Yes
FIRE AND EXPLOSION HAZARD		
ORGANIZATIONAL SET-UP FOR FIRE FIGHTING		
294.	What is the total strength of fire station and fire crew?	20 Nos.
295.	How many fire crews are available in each shift?	5 Nos in each shift
296.	Is there fire squad identified in each shift?	Yes

297.	Standing fire order is available with latest revision?	Yes
298.	How is the communication with fire station?	By walkie talkie, Land phone, Dedicated Mobile phone.
299.	Does fire safety inspections carried out?	Yes.
300.	Does emergency procedure available for leakage or combustion of flammables?	Yes
301.	What measures are available to control the fire load in the plant area?	NA
302.	Whether technical knowledge and skills of the manager and staff responsible for overall fire safety of the plant is adequate?	Yes
303.	How many major and minor incidents / fires were there in the factory during the last five years? Give department / plant wise.	3 minor incidents took place 1. OTPC Plant area at Hydrogen. 2. Outside of the plant boundary. 3. Switch yard area
304.	Have all the fires / incidents been investigated and corrective actions taken? Give break-up.	Yes Report is prepared
305.	Resources: 1)Adequacy of protective clothing (coat, trouser, gloves, boots and helmets); 2) Availability of SCBA for fire-fighting operations and spare cylinders (at least 2 for each SCBA); 3) Adequacy of hose, nozzles, ladders, lighting equipment and pumps; and 4) Communication facility at fire station,	Fire suits, boots,helmets are available 4 SCBA & No Spare cylinders Adequate. walkie talkie, Land phone, Dedicated Mobile phone.

	walkie talkie sets during fire-fighting.	
BUILT IN SAFETY IN CIVIL DESIGN AND CONSTRUCTION		
306.	Whether the two safe means of escape available? Are they in separate directions?	Yes.
307.	Is emergency exits provided to the building handling flammables?	Yes
308.	Whether emergency lights are provided?	Yes.
309.	Whether fire / smoke detectors are installed in fire prone areas?	Yes.
310.	Whether fire call points are provided in different areas?	Yes.
311.	Whether Fire hydrants are provided near the buildings?	Yes.
312.	Is ventilation system in plant handling flammables is adequate to prevent formation of flammable mixtures?	Yes.
313.	Is adequate separation is provided between combustible / flammable materials and other material to restrict the fire growth?	Yes.
314.	Access routes for firefighting operations is available for areas having high fire load?	Yes.
315.	Whether building changes interferes with fire detection and / or fire suppression systems?	Particular fire safety measures are incorporated when plot plan is updated.
316.	Whether building changes cause unreasonable fire loading / openings in the fire rated walls?	No
BUILT IN SAFETY IN ELECTRIC CIRCUITS AND EQUIPMENT		
317.	Are the electrical equipment in areas	Yes.

	where flammables mixture is likely to be present of flame-proof type?	
318.	Are lightning arrestors are provided to the buildings / structures storing flammable materials?	Yes.
319.	Whether adequate bonding and grounding of electrical equipment / pipelines provided?	Yes.
EXPLOSIVE SUBSTANCES		
320.	Whether necessary license / approval taken from concerned statutory bodies?	Yes.
321.	Whether systems for explosion suppression, high speed fire detection with deluge, sprinklers, explosion venting etc. are provided?	Detectors are installed.
322.	Whether explosion resistant walls or barricades are provided around explosive storage?	Yes.
323.	Whether explosive substance storage areas are restricted for entry?	Yes.
324.	Whether only trained persons are handling explosive substances?	Yes.
325.	Whether explosive substances are stored and transported in approved containers only?	Yes.
326.	Whether electrical fixtures in areas handling explosives are explosion proof type?	Yes.
327.	Whether adequate measures are taken to	Yes.

	prevent any sources of ignition where explosive substances are handled?	
FIRE SAFETY IN HANDLING FLAMMABLE AND EXPLOSIVE MATERIALS		
328.	Whether emergency procedure is available for control of leakage?	Yes.
329.	Whether emergency measures are displayed locally in case of accidental spillage / leakage?	Yes.
330.	Whether facility is provided for safe drainage of combustible or flammable liquids in case of leakages?	No
331.	Whether highly flammable liquids are stored under inert atmosphere?	NA
332.	Whether flammable storage tanks are provided with flame arrestors?	Yes.
333.	Whether suitable PPE's are provided?	Yes.
FIRE DETECTION AND ALARM SYSTEM		
334.	What type of fire detection and alarm system provided?	Multi and Smoke
335.	Whether all fire prone areas of the plant are covered with fire detection system?	Yes.
336.	Whether fire detection equipment and smoke alarms in good operating condition?	Yes.
337.	Whether the numbers of fire call points are adequate and free from obstruction?	Yes.
338.	Whether regular inspection / maintenance / testing of fire detection and alarm system carried out and records maintained	Yes.

339.	Whether any atmospheric monitoring is carried out for explosive mixture of gases or vapours?	Yes.
340.	Whether emergency power supplies are provided to fire detection and fire alarm system?	Yes.
341.	Whether smoke detectors are located considering ventilation pattern?	Yes.
342.	Whether annunciation of fire is local or in the control room or in both places?	Yes.
343.	Whether fire panel is constantly attended?	Yes.
PASSIVE AND ACTIVE FIRE PROTECTION SYSTEM		
344.	What are the passive fire protection measures available? (Barriers, Doors, Dampers etc.)	Fire doors, Fire Wall.Dampers
345.	Are the areas requiring fire barriers identified?	Yes.
346.	Whether the fire barrier provided is of adequate ratings?	Yes.
347.	Whether ventilation ducts in flammable areas have been provided with isolation dampers of suitable fire rating?	Yes
348.	Whether sprinklers / deluge are installed wherever necessary?	Yes.
349.	Whether regular inspection / maintenance / testing of fire protection system carried out and records maintained?	Yes.
FIXED FIRE EXTINGUISHING SYSTEM		
350.	What are the sources of firewater and whether they are dedicated to the fire	Reservoir 25000 KL

	extinguishing system?	
351.	Whether the capacity of dedicated water reservoir is adequate to supply to hydrants for minimum 2 h?	Yes
352.	Whether un-interrupted power supply is provided to the firewater pumps?	Yes.
353.	Whether the extinguishing medium selected is appropriate to the class of fire (water, gaseous, foam, dry powder)?	Yes.
354.	Whether fire hydrants layout is available?	Yes.
355.	Whether additional (over minimum requirement) fire hoses, nozzles are available?	Yes.
356.	Whether the hydrants lines are kept pressurized?	Yes.
357.	Whether regular inspection / maintenance / testing of fixed fire extinguishing systems carried out and records maintained?	Yes.
PORTABLE FIRE EXTINGUISHING SYSTEM		
358.	Whether suitable type and numbers of fire extinguishers provided?	DCP,ABC,Co2, Water, Foam
359.	Whether the fire extinguishers are located at conspicuous position and easily accessible? Are they fully charged and tagged?	Yes.
360.	Whether fire extinguishers periodically inspected, tested, refilled and records maintained?	Yes
361.	Whether defective / unchecked fire	No

	extinguishers present at site?	
362.	Whether additional fire extinguishers are available?	Yes(10 % Extra)
FIRE FIGHTING EQUIPMENT AND FACILITIES		
363.	Whether fire tenders (water / foam) are available?	Water Fire tender
364.	Whether the fire-fighting system and equipment approved, tested and maintained as per relevant standard?	Yes
365.	Whether the SCBA / fire suit provided to firefighting team for immediate action?	Yes
366.	What is system for maintenance / recharge of SCBA?	Below 250 BAR, have to be refilled.
367.	Is proper access available for firefighting equipment?	Yes
368.	Whether fire hose cabinets are in good condition, easily visible, and accessible?	Yes
369.	Whether drill tower is available? Are fire personnel carrying out regular fire drill?	Yes
370.	What is the communication facility at fire station? Is it adequate?	Walkie-talkie, Land phone, Dedicated Mobile phone.
FIRE DRILL		
371.	Whether mock fire drills are conducted? What is the frequency of drills?	Yes (every 2 month)
372.	Whether fire drills are also performed in night shift?	Yes
373.	Whether feedback of fire drill is documented?	Yes
374.	What is the system of mutual-aid scheme?	No industries nearby
FIRE FIGHTING TRAINING		

375.	Whether there is a system of providing fire-fighting training to plant personnel?	Yes
376.	What is the frequency and duration of such training? Whether training records are maintained?	Internally- Monthly and External -2.
377.	Whether fire squads are identified for different areas for first-aid firefighting and rescue, and suitably trained?	Yes
378.	Are all personnel conversant with the fire prevention and protection measures?	Yes
379.	Whether the fire staff are sent for refresher / advanced training courses?	Yes
STATIC ELECTRICITY AND LIGHTNING		
380.	Whether all vessels and pipes are provided with suitable bonding and grounding?	In process
381.	Whether arrangement has been made for grounding the tanker containing flammable liquid during loading / unloading?	Yes
382.	Whether spark resistant tools are provided?	Yes
383.	Whether lightning protection is provided and is adequate?	Yes
384.	Whether antistatic clothing, hand gloves and footwear are provided?	No
PRESSURE RELIEF SYSTEM		
385.	Whether the listing of all ‘pressure plants’ [as defined under *Factories Act*] has been done?	Yes
INDUSTRIAL HYGIENE / OCCUPATIONAL HEALTH		

VENTILATION		
386.	Whether any ventilation study has been carried out?	No
387.	Whether natural ventilation is adequate or not?	Yes
388.	Whether dust / fumes / hot air is generated in the process?	Yes
389.	Is there any exhaust ventilation system in any section of the plant?	Yes
390.	Is periodic / preventive maintenance of ventilation system carried out and record is maintained?	Yes
391.	Does any ventilation system re-circulate the exhausted air in work areas?	Yes
392.	Is the work environment assessed and monitored for chemical and physical hazards?	Yes
393.	Whether PPE are provided to workers exposed to dust / fumes and gases?	Yes
ILLUMINATION		
394.	Whether illumination study has been carried out for the assessment of illumination level?	Yes
395.	Is there any system of periodical cleaning and replacing the light fittings / lamps in order to ensure that they give the intended illumination levels?	Yes
396.	Are the workers subject to periodic optometry tests and records maintained?	Yes
397.	Are emergency lighting available at first	Yes

	aid center?	
NOISE		
398.	Whether any noise study conducted?	Yes
399.	Are there any machines / processes generating high-noise?	Yes
400.	Whether engineering and administrative controls been implemented to reduce noise exposure below the permissible limits?	Yes
401.	Is there a system of subjecting all those employees to periodic audiometric test who work in high-level noise areas?	Yes
402.	Whether the workers are made aware of the ill effects of high noise?	Yes
403.	Whether ear muffs / plugs are provided and used?	Yes
VIBRATION		
404.	Are there equipment which contributes excess level of vibrations and whether they are identified?	Yes
405.	Whether any vibration study has been carried out?	Yes
406.	Are the measures taken to combat vibration to acceptable levels?	Yes
407.	What is the frequency for measurements of vibration?	Regular Intervals
408.	Are the records of measurements and maintenance of equipment / system maintained?	Yes
HEAT STRESS/ COLD STRESS (EXTREMES OF TEMPERATURE)		
409.	Are there sources from equipment	Boiler.

	increasing the heat load in work places?	
410.	Whether evaluation of heat stress is carried out?	NA
411.	Whether natural ventilation is adequate to minimize the heat stress in work environment?	Yes
412.	Are resources available to deal with very hot or very cold conditions (drinking water, lined gloves, insulated boots)?	Yes
413.	Do workers know the symptoms of heat cramps / heatstroke or frost bite / hypothermia?	Yes
414.	Are the personal protective equipment suitable for reducing the effects of heat stress available?	Yes
NON-IONIZING RADIATION		
415.	Does the work involve likely exposure to non-ionising radiations (ultraviolet, infrared, radiofrequency, microwaves, lasers, etc.)	NA
416.	Whether risk assessment has been done for all work areas involving presence of non-ionising radiations?	NA
417.	Are the work areas displayed with relevant safety signs?	NA
418.	Are the employees aware about the hazards of non-ionising radiations?	NA
419.	Does a written procedureexist for working in non-ionising radiations?	NA

420.	Is the work environment monitored periodically for physical hazards and control measures initiated whenever deviation from permissible values is observed?	NA
421.	Whether suitable personal protective equipment are provided to workers exposed to non-ionising radiations?	NA
WORK PLACE MONITORING FOR HAZARDOUS CHEMICALS		
422.	Whether the dust, fumes, smoke aerosols and mist are monitored as per statute and records maintained?	Yes
423.	What are the types of detectors used for monitoring concentration of hazardous chemicals?	Chlorine & hydrogen detectors
424.	Is any alarm system installed for any leakage of hazardous chemicals?	Yes
425.	Are antidotes available for toxic chemicals?	NA
426.	Are control measures initiated whenever deviation from permissible values is observed?	Yes
FIRST AID FACILITIES AND OCCUPATIONAL HEALTH CENTRE (OHC)		
427.	Are adequate numbers of first aid boxes provided? Give location details?	Yes Loc: Store,DM plant, Lab,CCR0 mtr, main control Room, H2 Plant,GBC,Riverintake,Maingate,Canteen, Admin Building, Workshop.FireStation,Training Centre, TSR Building.

428.	Are qualified / trained first aiders available in each shift?	Yes
429.	How many qualified / trained first-aiders are available at each plant / department?	44 Nos.
430.	How many persons are trained / given refreshers training in first aid in a year?	44Nos.
431.	Whether occupational health centre is provided?	Yes
432.	Does OHC conform to the provisions of the existing statutes?	Yes
433.	Are the Medical Attendants / Doctors available in each shift?	Yes
434.	What facilities are available for transportation of the injured to hospital?	Yes(Ambulance)
435.	Are the names of the trained first aiders displayed?	Yes
436.	Are the name of nearest hospitals and its telephone number available in OHC?	Yes
437.	Does the plant have any special preventive medicine program?	Covid Vaccination done.
438.	Is ambulance posted in proper place and is it available whenever required?	Yes
439.	Are sufficient numbers of anti-dotes available in case of any emergency?	No
440.	Are fire safety measures provided in first aid centre?	Yes
441.	Are emergency lighting arrangements available at first aid centre?	Yes
PERIODIC MEDICAL EXAMINATION		

442.	Whether the periodical medical examination of employees, required under relevant statute is carried out?	Yes
443.	Whether it is ensured that contractor employee are medically examined during pre-employment as well as during the course of employment?	Yes
444.	During the periodical medical examination of the workers, are they examined as per the hazardous process in which they work? (First schedule of *The Factories Act*, 1948)	Yes
445.	Are the records of all such examination maintained?	Yes
PERSONAL PROTECTIVE EQUIPMENT AND EMERGENCY EQUIPMENT		
446.	Whether list of required PPE for each hazardous activity is available?	Hand gloves, Safety Shoes, Helmets, Ear plug, Muff, Apron, Chemical Suit,Fire suits, BA set, Canister Mask,Arch Suit,Googles, Face shield, Heat Resistance gloves, Boiler suits etc.
447.	Whether feedback from workers obtained during selection of PPE?	Yes.
448.	Have the workers been trained in proper use ofPPE including BA sets?	Trained for PPE's For BA sets only firefighting crew is trained.
449.	What is the system of procurement, inspection, issue, maintenance and replacement of PPE?	The system is well defined for procurement, inspection, issue, maintenance and replacement of PPE's
450.	Whether qualitative and quantitative fit-check for respirators is ensured prior to use?	Yes

451.	What are the arrangements for safe custody and storage of PPE?	Lockers and PPE cupboards are available
452.	Are the contractor's workers provided with the required PPE?	Yes
453.	Do the PPE conform to any standard?	Yes, as per BIS Followed
454.	Are sufficient eye wash fountains and safety showers available?	Total 19 Installed
455.	Whether appropriate respiratory protective devices are available in accordance to the hazard potential?	Yes
456.	Are the staff members trained in the right uses of respiratory protective devices?	Yes
OCCUPATIONAL DISEASES		
457.	Whether pre-employment medical check-up data available?	Yes
458.	During the medical check-up, is any person found having occupational diseases mentioned in 3rd schedule of *The Factories Act*, 1948?	Yes.
459.	Whether the medical practitioner informed the Chief Inspector of Factories about the occurrence of the occupational disease?	Yes
ACCIDENT / INCIDENT REPORTING, INVESTIGATION AND ANALYSIS		
ACCIDENT REPORTING AND DATABASE MANAGEMENT		
460.	What is the procedure for accident / incident / dangerous occurrence reporting?	Form-18,Form-19, Form -24,Form-30
461.	Whether the accident data for the last *five* years for reportable and non-reportable accidents are available?	Data Available
ACCIDENT INVESTIGATION		

462.	Are all the accidents investigated?	Yes
463.	Whether accident investigation procedure is documented?	Yes
464.	Whether accident investigation reports are submitted to top management?	Yes
465.	How are the findings from accident investigation reports communicated to workers?	TBT, Meeting, Trainings, social media.
ANALYSIS OF ACCIDENTS		
466.	Whether accident analysis is done as per IS 3786?	Yes
467.	Whether root causes of accidents are analysed?	Yes
468.	Is the accident statistics effectively utilized? If yes, how?	Yes, CAPA prepared,Follow-up for closure&make it in process for continual improvement.
469.	What nature of injuries occurred during the last five years?	Cut injuries. Fractured.
IMPLEMENTATION OF RECOMMENDATIONS		
470.	How does the management ensure implementation of the recommendations to avoid recurrence of accidents and incidents?	ATR is available and its being monitored by top management
REPORTING AND INVESTIGATION OF NEAR-MISS INCIDENTS		
471.	Are all near-miss incidents reported and investigated?	Yes
472.	Is there any system of classifying and analyzing the near-miss incidents?	Yes
EMERGENCY PREPAREDNESS		
SITE SPECIFIC DETAILS		

473.	Are the site area maps (including layout, access roads and assembly points) available in control room / emergency control centre?	Yes
DUTIES AND RESPONSIBILITIES OF KEY PERSONNEL		
474.	Is the hierarchy of emergency response personnel right from site emergency controller downward and alternative officials identified?	Yes
475.	Are the duties and responsibilities assigned to the designated officials during emergency, both during and outside normal working hours clearly identified and understood by them?	Yes
IDENTIFICATION OF EMERGENCIES AND ACCIDENT SCENARIO		
476.	Are the possible accident scenarios leading to emergency identified and known to the operating personnel?	Yes
477.	Are approved emergency preparedness plans (on-site and off-site) in place?	Yes
DECLARATION AND TERMINATION OF EMERGENCY		
478.	Is the list of designated officials who are to be communicated about declaration and termination of emergency available in the control room / emergency control centre?	Yes
479.	Are the methods of communication (siren, public address system etc.) for declaration and termination of an emergency known to all the workers?	Siren & PA systems in place
RESOURCES-EVACUATION / TRANSPORT		

480.	Are the following resources (equipment, personnel and procedures) required to handle emergency available? 1. Communications, 2. Public announcement systems 3. Monitoring of hazardous releases into the environment, 4. Emergency shelters at the facility, 5.Emergency exits with proper illumination, with uninterrupted power supply, 6. Direction for emergency exit / escape route marked in haulage / Alleyways, 7. Transport for evacuation of plant personnel, 8. Medical care including administration of antidotes, 9. Security / maintenance of law and order.	Yes
COMMUNICATION FACILITIES		
481.	Does the emergency control centre have direct communication links with the fire station and the plant control room?	Yes
482.	Are there adequate alarm points from which an emergency alarm can be raised?	Yes
483.	Is there infrastructure available for ensuring backup electric power supply for communication links where required?	Yes
MEDICAL CARE		
484.	Is the procedure for emergency medical care available?	Yes

485.	Whether the system has been tested at regular frequency through mock drill / exercises for its adequacy?	Yes
486.	Does the system of periodic replacement of antidotes and medicines required in emergency exist?	NA
UPDATION OF EMERGENCY PLAN		
487.	Is the emergency plan updated based on the feedback from the periodic drills / exercises?	Yes
488.	Are the contact details of all concerned officials kept updated in the emergency plan?	Yes
PERIODIC DRILLS / EXERCISES		
489.	Are mock-exercises conducted at stipulated intervals?	Yes
490.	Are the scenarios varied in the mock-exercises to ensure that all possible factors including meteorological conditions, affected plant personnel covered?	Yes
491.	Whether emergency preparedness Plans have been tested and reviewed at regular frequency through mock drill for its adequacy	Yes
TRAINING OF PLANT PERSONNEL		
492.	Are the plant personnel trained in handling emergency equipment?	Yes
PUBLIC AWARENESS PROGRAMMES		
493.	Are public awareness programs conducted for the people around the site regarding the	Yes

	actions to be taken in case of off-site emergency?	
MUTUAL-AID PROGRAMME		
494.	Are the types of accidents where external organizations would be involved in remedial actions identified? Are their responsibilities defined?	NA
495.	Is the plant responsible for rendering mutual aid assistance to any other external organizations? Does this assistance affect the plant's emergency preparedness?	NA
496.	Whether the communication channels for mutual assistance identified and known with and between two organizations?	NA
EMERGENCY CONTROL CENTRE		
497.	Is the emergency control centre located beyond the effective distances of identified emergency scenarios?	Yes
498.	If the emergency control centre is located within the effect distance, is it suitably protected that it will be available in case of emergency?	NA
SAFETY INSPECTION		
INSPECTION PROGRAMME		
499.	Are checklists available for inspections? For example, availability of checklists like: a) Handling, Storage and Transportation of hazardous chemicals; b) Electrical hazards;	yes

	c) Fire safety; d) Hand and portable power tools; e) Machine hazards; f) Lifting equipment; g) Ladders and scaffolding; h) Environmental Monitoring; j) Civil structure; k) Housekeeping; m) Emergency equipment; and n) Gas cylinder and other pressure vessels used / available in the organization.	
SAFETY RELATED DEFICIENCY (SRD) REPORT		
500.	Are SRDs generated based on the area wise checklists?	Yes
501.	What is the procedure for resolving the SRDs?	Notification raised through SAP against observation raised
502.	Whether the procedure exists for notification and root cause analysis of non-conformities and action taken on them?	Yes
SAFETY INSPECTION RECORDS		
503.	Are the safety inspection records maintained?	Yes
METHODOLOGY AND INSPECTION TEAM		
504.	Is there written procedure for safety inspection?	Yes
505.	Whether safety inspection is carried out by a designated team?	Yes
506.	What is the frequency of safety inspections?	Monthly
507.	Whether an inspection report is generated?	Yes

COMPLIANCE OF RECOMMENDATIONS		
508.	To whom the recommendations are submitted	All concern HOD's
509.	Are recommendations of safety inspections complied in time?	Yes
510.	Is compliance of recommendations sent to top management?	Yes
511.	Is compliance of recommendations reviewed by safety committee?	Yes
512.	Does top management follows-up the compliance?	Yes

5.0 CLOSING MEETING

After preparing the Observations and Recommendations as mentioned in previous chapter, closing meeting was held and observations were discussed and agreed upon by Plant Management team. Each point was discussed, some missing information was obtained and the recommendations were finalized. The intention of the recommendations and their mode of compliance were explained to the plant management.

6.0 RECOMMENDATION RATIFICATION METHODOLOGY

After finalizing the Audit Observations and Recommendations in the closing meeting as mentioned in the previous chapter, the audit report is prepared by the Lead Auditor and it is ensured that the report is containing all the items required by IS 14489: 2018.

The Recommendations are given in Chapter 3.8and along with Annexure B & C in Chapter – 4and executive summary has been prepared for immediate review by the top management.

HSE department and the concern plant management are requested to convert these recommendations into actionoriented activities for implementation. The action plan should reflect responsible person and its pragmatic target dates. The action plan should be reviewed in respective plant performance meeting every month. If needed, we may be contacted for "**Compliance or Follow-up Audit**" to review implementation of recommendations of this audit.

7.0 CONCLUDING REMARKS

M/s. Prosafe Process Engineering Pvt. Ltd. – Surat Audit team had a privilege to enjoy the hospitality and cordial warm welcome by each and every plant.

Our experienced audit team strongly believes that the prevailing enthusiasm should be kept on track by developing system approached procedures. It is an industry wide experience that enthusiastic movement dies over a period of time, if corrective actions are not taken to cast these initiatives into procedural frame.

Now, it is a right time to take next Delta improvement by developinga framework encompassing people accountabilities, linkage with performance management and imbibing operating discipline.

Above said improvement avenues will yield excellent result if it is harnessed with safety culture. In view of the HSE commitment of top management, building a safety culture will take a minimal time if it is administered through behavior based safety approach. M/s.PROSAFE has a capability to design customized HSE architect to achieve zero incident work place.

Once again, we are thankful to **M/s. ONGC Tripura Power Company Ltd.**for giving opportunity to become your business partner. We shall be happy to retain our relationship.

Annexure 1

Health & Safety policy

OTPC

ONGC Tripura Power Company Limited

(JV Company of ONGC, IL&FS, IIF and Govt. of Tripura)

6th Floor, A Wing, IFCI Tower-61, Nehru Place, New Delhi-110019 Phone: +91-11-26402100 Fax: +91-11-26227532/26227533

ONGC Tripura Power Company Limited

Integrated Quality, Environment & Occupational health & Safety policy

ONGC Tripura Power Company Limited, engaged in generation of electrical energy is committed to enhance customer satisfaction, maintain workplace safety standards and minimize adverse impact on environment and health of all persons working for and on behalf of it.

Towards this end, it shall strive to:

- Achieve excellence by continual improvement of effectiveness of the management systems.
- Provide quality power by maintaining economy in generation.
- Protection of environment including prevent of pollution of environment and occupational illness by using sustainable technologies and work practices.
- Minimize waste generation through reduction at source, Recycling & Reusage
- Comply with applicable legal and other requirements.
- Establish and review objectives and targets to improve performance.
- Keep employees aware of their individual obligations in conservation of environment, health and workplace safety.

This policy has been communicated to all persons working under control of the organisation and shall be made available to the public and interested parties on request.

MD, OTPC

10.01.2019

Regd. Office: Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105 Phone: 0381-236-3714, Fax: 0381-236-3716
Head Office: Admin. Block, OTPC Power Plant, Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105
Phone: 0381- 2363711 (D), Fax: 0381-236-3715, CIN: U40101TR2004PLC007544, Website: www.otpcindia.in

PROJECT : OTPC GBC Revamp Project
CLIENT : M/s OTPC
SERVICE : Gas Booster Compressor – Revamp
LOCATION : Tripura

Existing Compressor details:

Compressor model : BCL 406
Driver : Motor thru Gearbox (Fixed speed)
No of units : 3 (2W+1S)
Year of supply : ~2011

Technical Adequacy study:

1. Technical Adequacy of existing Compressor, Gearbox along with all auxiliaries (supplied by BHEL) inlcuding lube oil system, seal gas system etc., will be studied for the revised operating conditions.
2. As per the preliminary discussion with customer, revamp study will be carried out considering new compressor internals & VFD (for variable speed operation).
3. Revised operating conditions are as per the attached Annexure-1.
4. Detailed Techincal Adequacy study report will be sumitted. List of components that are recommended for modification/ replacement to meet the revised process conditions will be specified in the report.
5. For the Technical adequacy study, it will be assumed that all items are in good working condition. Equipment Health check is not envisaged.
6. Detailed scope of supply/ works for modifications based on the Technical adequacy study and Offer for such modifications will be provided after submission of adequacy report .
7. Additional data / information of existing compressor package if required for conducting detailed adequacy check shall be arranged by customer.

Bhaskar Sen Choudhury

From:	Mukesh Kumar <mukesh.kumar@bhel.in>
Sent:	02 August 2024 15:43
To:	Bhaskar Sen Choudhury
Cc:	Prabhat Chandra; Biswajit Sarkar; Pradip Das; Jayanta Chakraborty; Sanjay Garhwal; Soubhik Choudhury; Narendra Kumar Gupta; vir@bhel.in; 'Ranjan(Addl GM/IPM/IS)'
Subject:	BHEL Budgetary Commercial offer for submission of Adequacy check report: GBC (BCL-406) at OTPC Tripura
Attachments:	Annexxure-1 (OTPC GBC revamp operating conditions - R02).xlsx; OTPC GBC revamp - Adequacy study writeup - R00.pdf

---

Dear Sir,

This has reference to the discussion with BHEL Hyderabad team and attached finalised operating condition for Adequacy check report for Gas Booster Compressor for OTPC, Tripura Plant.

We are pleased to offer the **best budgetary price offer of Basic Value of Rs. 82,00,000/-** (Rupees Eighty Two Lakhs) for submission of Adequacy check report as per the attached study write-up. No scope of supply is envisaged

Per Diem rate for site visit (If required) by BHEL official / BHEL sub vendor official will be **Rs. 2,00,000/-** (Rupees Two Lakhs).

GST will be Extra at the prevailing rate at the submission of report and site visit (If any). Presently GST rate is 18%.

The above quoted price will be based on BHEL following standard commercial terms and conditions for report submission:

1. Payment Terms:

    a. Advance of **50% of Basic order Value** along with the order and

    b. Balance **50% of Basic order value** along with 100% GST against BHEL Intimation of Readiness of report

2. Time Line for submission of report: **4 Months** from the receipt of the Advance payment. Quoted timeline will be subject to Force Majeure conditions.

3. Site visit, if required by BHEL personnel & India sub vendors will be carried out on quoted per diem rate basis.

    To & fro air fare for travel to site from supervisory personnel office shall be paid by Purchaser extra at actuals.

    Local conveyance and fully furnished AC accommodation shall be arranged by OTPC.

4. The quoted prices are subject to statutory variations in taxes & duties. Any increase in rate of existing taxes & duties or enactment of any new or additional taxes or duties will be borne by OTPC.

5. Order once placed shall not be suspended or cancelled at the convenience of Purchaser.

   In case, however if there is a compelling need of keeping the order under suspension, the Purchaser shall compensate the Supplier suitably for the cost incurred during such suspension and the cost to resume the contract in case of resumption.

   Further, in case Purchaser chooses to cancel the order, the supplier shall be compensated for the work already done and work in progress etc.

6. Our Budgetary offer is valid upto 02.09.2024.

Looking forward for receipt of the prestigious order at the earliest.

Thanking you and assuring our best services all the times.

Regards
Mukesh Kumar
Sr. Manager- Compressor Marketing
BHEL Delhi
PH: 01141793192
M: 9650199866

Project: **OTPC GBC Revamp study**	Item No:
Job No:	Description:
Client:	No. Required: **1**
Location:	

APPLICABLE TO: ● PROPOSAL PURCHASE AS BUILT

FOR ____ UNIT ____

SITE ____ SERIAL NO. ____

SERVICE ____ NO. REQUIRED ____

CONTINUOUS ~~INTERMITTENT~~ ~~STAND BY~~ DRIVER TYPE (3.1.1) **Motor (VFD) thru Gearbox**

MANUFACTURER **BHEL** MODEL **BCL 406** DRIVER ITEM NO. ____

NOTE: INFORMATION TO BE COMPLETED: BY PURCHASER BY MANUFACTURER

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)

	Max Flow_Min Mol Wt							
	Max inlet Temp				**Min inlet Temp**			
CONDITION	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Sm3/h	68560				68560			
GAS HANDLED (See also page 2)	Natural gas				Natural gas			
Nm³/h (1.013 BAR & 0 °C WET / DRY)	64865				64865			
WEIGHT FLOW, kg/hr (WET) / (DRY)								
INLET CONDITIONS (@ Comp. Flange)								
PRESSURE kg/cm2 (abs)	11.00	11.00	12.60	12.60	11.00	11.00	12.60	12.60
TEMPERATURE (°C)	50.0	50.0	50.0	50.0	9.0	9.0	9.0	9.0
RELATIVE HUMIDITY %								
MOLECULAR WEIGHT	16.47	16.47	16.47	16.47	16.47	16.47	16.47	16.47
Cp/Cv (K_1) ~~OR (K_{AVG})~~								
COMPRESSIBILITY (Z_1) ~~OR (Z_{AVG})~~								
INLET VOLUME, (m³/h) (ACTUAL) **(Rem 1)**	**7100**	**7100**	**6200**	**6200**	**6200**	**6200**	**5400**	**5400**
DISCHARGE CONDITIONS (@ Comp. Flange)								
PRESSURE kg/cm2 (abs)	33.00	34.50	33.00	34.50	33.00	34.50	33.00	34.50
TEMPERATURE (°C)								
Cp/Cv (K_2) ~~OR (K_{AVG})~~								
COMPRESSIBILITY (Z2) ~~OR (Z_{AVG})~~								
kW REQUIRED (BRG LOSSES INCLUDED)								
GEAR BOX LOSSES (KW)								
SPEED (RPM)								
ESTIMATED SURGE, m³/h (AT SPEED ABOVE)								
POLYTROPIC HEAD (KJ/KG)								
POLYTROPIC EFFICIENCY (%)								
CERTIFIED POINT								
PERFORMANCE CURVE NUMBER								

PROCESS CONTROL

METHOD ~~SUCTION THROTTLING~~ ~~VARIABLE INLET~~ SPEED VARIATION ~~DISCHARGE~~ ~~COOLED BYPASS~~

FROM ____ (BAR)(kPa abs) ~~GUIDE VANES~~ FROM ____ % ~~BLOWOFF~~ FROM

TO ____ (BAR)(kPa abs) (3.4.2.4) TO ____ % TO ____ TO ____

SIGNAL SOURCE (3.4.2.1) ____

TYPE ELECTRONIC ~~PNEUMATIC~~ ~~OTHER~~ ____

RANGE ____ mA ____ (BAR)(kPa abs) ____

ANTI-SURGE BYPASS MANUAL AUTOMATIC ~~NONE~~

REMARKS:

1. **Calculated actual inlet volume m3/h (approx.)**

0		Date of proposal			
Rev.	Date	Description	Prepared	Checked	App

बी एच ई एल BHEL	MECHANICAL DATA SHEET **API 617 CENTRIFUGAL COMPRESSOR** **SI UNITS**	Document No: Sheet 1A of 2	Rev. **0**

Project: **OTPC GBC Revamp study**	Item No:
Job No:	Description:
Client:	No. Required: **1**
Location:	

APPLICABLE TO: ● PROPOSAL PURCHASE AS BUILT

FOR UNIT

SITE SERIAL NO.

SERVICE NO. REQUIRED

CONTINUOUS ~~INTERMITTENT~~ ~~STAND BY~~ DRIVER TYPE (3.1.1) **Motor (VFD) thru Gearbox**

MANUFACTURER **BHEL** MODEL **BCL 406** DRIVER ITEM NO.

NOTE: INFORMATION TO BE COMPLETED: BY PURCHASER BY MANUFACTURER

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)

		Max Flow_Max Mol Wt							
		Max inlet Temp				Min inlet Temp			
CONDITION		Case 9	Case 10	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16
Sm3/h		68560				68560			
GAS HANDLED (See also page 2)		Natural gas				Natural gas			
Nm³/h (1.013 BAR & 0 °C WET / DRY)		64865				64865			
WEIGHT FLOW, kg/hr (WET) / (DRY)									
INLET CONDITIONS (@ Comp. Flange)									
PRESSURE kg/cm2 (abs)		11.00	11.00	12.60	12.60	11.00	11.00	12.60	12.60
TEMPERATURE (°C)		50.0	50.0	50.0	50.0	9.0	9.0	9.0	9.0
RELATIVE HUMIDITY %									
MOLECULAR WEIGHT		16.81	16.81	16.81	16.81	16.81	16.81	16.81	16.81
Cp/Cv (K_1) ~~OR (K_{AVG})~~									
COMPRESSIBILITY (Z_1) ~~OR (Z_{AVG})~~									
INLET VOLUME, (m³/h) (ACTUAL)	**(Rem 1)**	**7100**	**7100**	**6200**	**6200**	**6200**	**6200**	**5400**	**5400**
DISCHARGE CONDITIONS (@ Comp. Flange)									
PRESSURE kg/cm2 (abs)		33.00	34.50	33.00	34.50	33.00	34.50	33.00	34.50
TEMPERATURE (°C)									
Cp/Cv (K_2) ~~OR (K_{AVG})~~									
COMPRESSIBILITY (Z2) ~~OR (Z_{AVG})~~									
kW REQUIRED (BRG LOSSES INCLUDED)									
GEAR BOX LOSSES (KW)									
SPEED (RPM)									
ESTIMATED SURGE, m³/h (AT SPEED ABOVE)									
POLYTROPIC HEAD (KJ/KG)									
POLYTROPIC EFFICIENCY (%)									
CERTIFIED POINT									
PERFORMANCE CURVE NUMBER									

PROCESS CONTROL

METHOD ~~SUCTION THROTTLING~~ ~~VARIABLE INLET~~ SPEED VARIATION ~~DISCHARGE~~ ~~COOLED BYPASS~~

FROM (BAR)(kPa abs) ~~GUIDE VANES~~ FROM % ~~BLOWOFF~~ FROM

TO (BAR)(kPa abs) (3.4.2.4) TO % TO TO

SIGNAL SOURCE (3.4.2.1)

TYPE ELECTRONIC ~~PNEUMATIC~~ ~~OTHER~~

RANGE mA (BAR)(kPa abs)

ANTI-SURGE BYPASS MANUAL AUTOMATIC ~~NONE~~

REMARKS:

1. **Calculated actual inlet volume m3/h (approx.)**

0		Date of proposal			
Rev.	Date	Description	Prepared	Checked	App

बी एच ई एल BHEL	MECHANICAL DATA SHEET **API 617 CENTRIFUGAL COMPRESSOR** **SI UNITS**	Document No: Sheet 1B of 2	Rev. **0**

Project:	**OTPC GBC Revamp study**	Item No:	
Job No:		Description:	
Client:		No. Required:	**1**
Location:			

APPLICABLE TO: ● PROPOSAL PURCHASE AS BUILT

FOR UNIT

SITE SERIAL NO.

SERVICE NO. REQUIRED

CONTINUOUS ~~INTERMITTENT~~ ~~STAND BY~~ DRIVER TYPE (3.1.1) **Motor (VFD) thru Gearbox**

MANUFACTURER **BHEL** MODEL **BCL 406** DRIVER ITEM NO.

NOTE: INFORMATION TO BE COMPLETED: BY PURCHASER BY MANUFACTURER

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)		Min Flow_Min Mol Wt							
		Max inlet Temp				Min inlet Temp			
CONDITION		Case 17	Case 18	Case 19	Case 20	Case 21	Case 22	Case 23	Case 24
Sm3/h		46500				46500			
GAS HANDLED (See also page 2)		Natural gas				Natural gas			
Nm³/h (1.013 BAR & 0 °C WET / DRY)		43994				43994			
WEIGHT FLOW, kg/hr (WET) / (DRY)									
INLET CONDITIONS (@ Comp. Flange)									
PRESSURE kg/cm2 (abs)		11.00	11.00	12.60	12.60	11.00	11.00	12.60	12.60
TEMPERATURE (°C)		50.0	50.0	50.0	50.0	9.0	9.0	9.0	9.0
RELATIVE HUMIDITY %									
MOLECULAR WEIGHT		16.47	16.47	16.47	16.47	16.47	16.47	16.47	16.47
Cp/Cv (K_1) ~~OR (K_{AVG})~~									
COMPRESSIBILITY (Z_1) ~~OR (Z_{AVG})~~									
INLET VOLUME, (m³/h) (ACTUAL)	**(Rem 1)**	**4800**	**4800**	**4200**	**4200**	**4200**	**4200**	**3700**	**3700**
DISCHARGE CONDITIONS (@ Comp. Flange)									
PRESSURE kg/cm2 (abs)		33.00	34.50	33.00	34.50	33.00	34.50	33.00	34.50
TEMPERATURE (°C)									
Cp/Cv (K_2) ~~OR (K_{AVG})~~									
COMPRESSIBILITY (Z2) ~~OR (Z_{AVG})~~									
kW REQUIRED (BRG LOSSES INCLUDED)									
GEAR BOX LOSSES (KW)									
SPEED (RPM)									
ESTIMATED SURGE, m³/h (AT SPEED ABOVE)									
POLYTROPIC HEAD (KJ/KG)									
POLYTROPIC EFFICIENCY (%)									
CERTIFIED POINT									
PERFORMANCE CURVE NUMBER									

PROCESS CONTROL

METHOD ~~SUCTION THROTTLING~~ ~~VARIABLE INLET~~ SPEED VARIATION ~~DISCHARGE~~ ~~COOLED BYPASS~~

FROM ______ (BAR)(kPa abs) ~~GUIDE VANES~~ FROM ______ % ~~BLOWOFF~~ FROM

TO ______ (BAR)(kPa abs) (3.4.2.4) TO ______ % TO ______ TO

SIGNAL SOURCE (3.4.2.1)

TYPE ELECTRONIC ~~PNEUMATIC~~ ~~OTHER~~

RANGE ______ mA ______ (BAR)(kPa abs)

ANTI-SURGE BYPASS MANUAL AUTOMATIC ~~NONE~~

REMARKS:

1. **Calculated actual inlet volume m3/h (approx.)**

Rev.	Date	Description	Prepared	Checked	App
0		Date of proposal			

बी एच ई एल BHEL	MECHANICAL DATA SHEET **API 617 CENTRIFUGAL COMPRESSOR** **SI UNITS**	Document No: Sheet 1C of 2	Rev. **0**

Project: **OTPC GBC Revamp study**	Item No:
Job No:	Description:
Client:	No. Required: **1**
Location:	

APPLICABLE TO: ● PROPOSAL PURCHASE AS BUILT

FOR UNIT

SITE SERIAL NO.

SERVICE NO. REQUIRED

CONTINUOUS ~~INTERMITTENT~~ ~~STAND BY~~ DRIVER TYPE (3.1.1) **Motor (VFD) thru Gearbox**

MANUFACTURER **BHEL** MODEL **BCL 406** DRIVER ITEM NO.

NOTE: INFORMATION TO BE COMPLETED: BY PURCHASER BY MANUFACTURER

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)

		Min Flow_Max Mol Wt							
		Max inlet Temp				**Min inlet Temp**			
CONDITION		Case 25	Case 26	Case 27	Case 28	Case 29	Case 30	Case 31	Case 32
Sm3/h		46500				46500			
GAS HANDLED (See also page 2)		Natural gas				Natural gas			
Nm³/h (1.013 BAR & 0 °C WET / DRY)		43994				43994			
WEIGHT FLOW, kg/hr (WET) / (DRY)									
INLET CONDITIONS (@ Comp. Flange)									
PRESSURE kg/cm2 (abs)		11.00	11.00	12.60	12.60	11.00	11.00	12.60	12.60
TEMPERATURE (°C)		50.0	50.0	50.0	50.0	9.0	9.0	9.0	9.0
RELATIVE HUMIDITY %									
MOLECULAR WEIGHT		16.81	16.81	16.81	16.81	16.81	16.81	16.81	16.81
Cp/Cv (K_1) ~~OR (K_{AVG})~~									
COMPRESSIBILITY (Z_1) ~~OR (Z_{AVG})~~									
INLET VOLUME, (m³/h) (ACTUAL)	**(Rem 1)**	**4800**	**4800**	**4200**	**4200**	**4200**	**4200**	**3700**	**3700**
DISCHARGE CONDITIONS (@ Comp. Flange)									
PRESSURE kg/cm2 (abs)		33.00	34.50	33.00	34.50	33.00	34.50	33.00	34.50
TEMPERATURE (°C)									
Cp/Cv (K_2) ~~OR (K_{AVG})~~									
COMPRESSIBILITY (Z2) ~~OR (Z_{AVG})~~									
kW REQUIRED (BRG LOSSES INCLUDED)									
GEAR BOX LOSSES (KW)									
SPEED (RPM)									
ESTIMATED SURGE, m³/h (AT SPEED ABOVE)									
POLYTROPIC HEAD (KJ/KG)									
POLYTROPIC EFFICIENCY (%)									
CERTIFIED POINT									
PERFORMANCE CURVE NUMBER									

PROCESS CONTROL

METHOD ~~SUCTION THROTTLING~~ ~~VARIABLE INLET~~ SPEED VARIATION ~~DISCHARGE~~ ~~COOLED BYPASS~~

FROM ______ (BAR)(kPa abs) ~~GUIDE VANES~~ FROM ______ % ~~BLOWOFF~~ FROM

TO ______ (BAR)(kPa abs) (3.4.2.4) TO ______ % TO ______ TO

SIGNAL SOURCE (3.4.2.1)

TYPE ELECTRONIC ~~PNEUMATIC~~ ~~OTHER~~

RANGE ______ mA ______ (BAR)(kPa abs)

ANTI-SURGE BYPASS MANUAL AUTOMATIC ~~NONE~~

REMARKS:

1. **Calculated actual inlet volume m3/h (approx.)**

Rev.	Date	Description	Prepared	Checked	App
0		Date of proposal			

बी एच ई एल BHEL	MECHANICAL DATA SHEET **API 617 CENTRIFUGAL COMPRESSOR** **SI UNITS**	Document No: Sheet 1D of 2 — Rev. **0**

Project: **OTPC GBC Revamp study**		Item Number:	
Job No:		Description:	
Client:		No. Required: **1**	
Location:			

OPERATING CONDITIONS (Continued)

GAS ANALYSIS:

MOL %	MW	**Min Mol wt**	**Max Mol wt**
OXYGEN	31.99	As per original data sheet	
CARBONYL SULFIDE	60.07		
NITROGEN	28.016		
WATER	18.016		
CARBON MONOXIDE	28.010		
CARBON DIOXIDE	44.010		
HYDROGEN SULFIDE	34.076		
HYDROGEN	2.016		
METHANE	16.042		
ETHYLENE	28.052		
ETHANE	30.068		
PROPYLENE	42.078		
PROPANE	44.094		
I-BUTANE	58.120		
n-BUTANE	58.120		
I-PENTANE	72.146		
n-PENTANE	72.146		
HEXANE PLUS			
TOTAL		**100**	**100**
AVG. MOL. WT.		**16.47**	**16.81**

LOCATION: (2.1.9)

~~INDOOR~~ ● OUTDOOR GRADE

~~HEATED~~ ● UNDER ROOF ● MEZZANINE

● UNHEATED PARTIAL SIDES

WINTERIZATION REQ'D. (2.1.9) CL GR DIV

TROPICALIZATION REQ'D. (3.4.6.6)

SIT ELEVATION

RANGE OF AMB m BAROMETER

	DRY BULB	WET BULB
NORMAL	°C	°C
MAXIMUM	°C	°C
DESIGN	°C	°C

UNUSUAL CONDITIONS: DUST FUMES

OTHER (2.1.9)

NOISE SPECIFICATIONS: (2.1.10)

APPLICABLE TO MACHINE:

SEE SPECIFICATION

APPLICABLE TO NEIGHBORHOOD:

~~YES~~ NO

ACOUSTIC HOUSING:

APPLICABLE SPECIFICATIONS:

API 617, CENTRIFUGAL COMPR. FOR GEN. REFINERY SERV.

~~GOVERING SPECIFICATION (IF DIFFERENT)~~

PAINTING:

● MANUFACTURER'S STD.

OTHER

SHIPMENT: (4.4.1)

● DOMESTIC ~~EXPORT~~ ~~EXPORT BOXING REQ'D.~~

OUTDOOR STORAGE MORE THAN 6 MONTHS (4.4.1)

● SPARE ROTOR ASSEMBLY PACKAGED FOR (4.4.3.10)

~~HORIZONTAL STORAGE~~ VERTICAL STORAGE WITH N2 BLANKETTING

REMARKS:

Rev.	Date	Description	Prepared	Checked	Approved

बी एच ई एल BHEL	MECHANICAL DATA SHEET **API 617 CENTRIFUGAL COMPRESSOR** **SI UNITS**	Document No: Sheet 2 of 2	Rev. **0**

ONGC TRIPURA POWER COMPANY LIMITED

Palatana, Tripura

RCA# 113
Station Transformer-2 LV breaker tripped on under voltage on 21.10.2021 resulting in Unit-1&2 trip

O&M By:

O&M Solutions Private Limited

						13/12/2021
00	30.10.2021	IFI	Issued for Implementation	G. Tejeswar Rao HOD Operation OMS	Mohinder Singh Patel Plant Manager OMS	Prabhat Chandra DGM(O&M) OTPC
REV	DATE	STATUS	REVISION LIST	PREPARED BY	REVIEWED & APPROVED BY	VERIFIED BY

~~IR/21-22/21.10.2021/113~~

RCA COMMITTEE MEMBERS/CONCERNED DEPARTMENTS

OTPC			OMS		
DEPTT.	NAME	SIGNATURE	DEPTT.	NAME	SIGNATURE
OPERATION	J. Chakraborty	13/12/2021	OPERATION	G. T. Rao	
MECHANICAL	Bhaskar Sen Choudhury	10.12.2021	MECHANICAL	R. Bhadra	
ELECTRICAL	Alokesh Hazarika	11/12/21	ELECTRICAL	Ashok Kumar	
C & I	MD MUSA	11/12/21	C & I	D. DEBBARMA	
TECH. CELL	J. Chakraborty	13/12/2021	TECH. CELL		

INCIDENT NO	IR/21-22/21-10-2021/113
DATE OF INCIDENT	21-10-2021

INCIDENT:
At **11:15 hrs,** station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection & station 6.6KV section-B (OCA) bus got dead, resulting in tripping of Unit-1&2.

TIME OF OCCURRENCE	**11:15 hrs**
TIME OF RESTORATION	**GTG-1 sync at 18:01 hrs, STG-1 sync 20:03 hrs and GTG-2 sync at 21:16 hrs, STG-2 sync at 03:20 hrs (22.10.2021)**
GENERATION LOSS	**6.7093 MU**
GT COASTING DOWN TIME	GT-1 36 min and GT-2 29 min.
ST COASTING DOWN TIME	STG-1 49 min and STG-2 53 min.

Status of Unit-1&2 before Incident :
Station Load -655 MW, Total Gas Flow-128000 SM3/hr
Unit-1 Load –GT-1- 210 MW, STG-1- 114, Total- 324 MW
Unit-2 Load –GT-2- 215 MW, STG-2- 116 MW, Total- 331 MW
GBC-2 & 3 were in service
400KV lines-1&2, ICT-1&2, 132 KV lines-1&2 were in service and station transformer-1&2 in service.

DESCRIPTION OF INCIDENT:
At **11:15 hrs,** station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection & station 6.6KV section-B (OCA) bus got dead, resulting in tripping of 415V PMCC section-B of GBC switchgear, station switchgear, admin bldg switchgear, raw water switchgear, river water intake switchgear etc.

GBC-3 tripped due to loss of power and GBC-2 tripped due to both lube oil pumps power supply failure resulting in low lube oil header pressure. Due to low fuel gas pressure, both GT-1 and GT-2 run back started. During runback, at **11:16 hrs,** GT-1 tripped on purge valve fault protection and GT-2 tripped due to loss of flame protection. And both STG tripped due to GT trip.

After the tripping of both GTG, Unit 6.6 KV bus-B got dead as station 6.6KV bus was not available and resulted in tripping of auxiliaries drives like CW pumps, HPBFPs, DMCW pumps and IAC-B etc., those are connected with BUS-B.

EDG-1 and EDG-2 start in auto and emergency lube oil pumps came in service, both STG and GTG turning gear came into service. Later after getting EMD clearance, station 6.6 KV BUS-B charged at 11:37 hrs with bus coupler and normalized all above said 415V switchgear section-B and unit 6.6 KV switchgear section-B one by one.

SEQUENCE OF INCIDENT: As tabulated & attached

RELAY/ALARM EVENTS:

Max DNA HMI:

11:15:45 hrs: station transformer#2 tripped.
11:15:47 hrs: GBC-3 tripped.
11:15:51 hrs: GBC-2 tripped.
11:16:24 hrs: GT-1 tripped
11:16:24 hrs: ST-1 tripped due to GT-1 trip.
11:16:28 hrs: GT-2 tripped.
11:16:28 hrs: ST-2 tripped due to GT-2 trip

IMMEDIATE ACTION TAKEN:

- Ensure the auto cut-in of DC lube oil pumps and DC jacking oil pump of both GTG and STG.
- Ensure auto start of EDG-1 and EDG-2 and charging of both units 415V GTPMCC and STGPMCC emergency section.
- Informed to NERLDC for DC revision.
- Monitor the coasting down rate of STG-1 and STG-2.
- Charged Station 6.6 KV section-B switchgear from bus-coupler.
- Charged all 415V section-B switchgear with incomer-2, as bus-coupler not came in auto.
- Charged 6.6 KV section-B unit switchgear and started cooling water pumps, CEPs and HPBFPs etc.
- Bring Hot well level, deaerator level and drum level in normal working level for start-up.

ROOT CAUSE ANALYSIS :

RCA OF INCIDENT: Why –Why Analysis

1. Why Unit-1 & 2 tripped?
   - During run back, GT-1 tripped on purge valve fault during PM to PPM mode change over & GT-2 tripped on loss of flame due to no gas supply.
2. Why GT-1&2 run back happened?
   - Station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection. Station Bus-B became dead. All the down stream PMCC section -2 became dead. Hence, GBC-3 which was in Station Bus-B tripped. Gas fuel pressure dropped immediately & on fuel gas pressure low protection, both GT-1&2 run back started.
   - Within 6 secs, GBC-2 also tripped on lube oil header pressure low protection as running lube oil pump was from Gas fuel sec-B. Standby lube oil pump started in auto, but by that time GT-1 tripped on gas purge fault.
   - Control supply of GBC PMCC was supplied from GT PMCC-1 Section-B. As there is no supply to GT PMCC Sec-B , fuel gas PMCC control supply also got out resulting in no control power supply to any of the GBC. Both STG-1&2 tripped as GTs tripped.

3. Why Station transformer#2 LV side breaker tripped?

- Station transformer#2 LV side breaker (0CB 005) tripped on under voltage protection.

4. Why Under voltage acted in ST-2 Transformer breaker?

- ST-2 MW transducer was found faulty.
- Probable cause of failure of MW transducer are:

a) Although Work permit (LWC) on ECP for MW transducer checking was issued to EMD, it's out put is short circuit proof & output could not impact on entire transducer failure as it is in milliamps. Hence it is reasonably concluded that the LWC issued to check 4-20 mA output of MW transducer at ECP may not be the reason for the above disturbance.

b) Intermittent spike of power supply i.e 220V DC: Inbuilt surge protector with a range 2KV (peak) installed in the transducer. Since other breakers & instruments power feed through same 220V DC, the impact could have experienced. Hence this is ruled out.

c) Ageing of Transducer circuit: Since the transducer is manufactured in 2010: Internal circuit of ST-2 MW transducer was short circuited which grounded the R phase VT input in the transducer itself. This caused the blowing of R phase fuse. Hence the R-Phase voltage transformer input to relay was reduced to zero causing under voltage operation from relay.

- **In view of above, it is reasonably concluded that due to aging, the insulation of ST-2 MW transducer became weak resulting in internally developed fault & got short.**

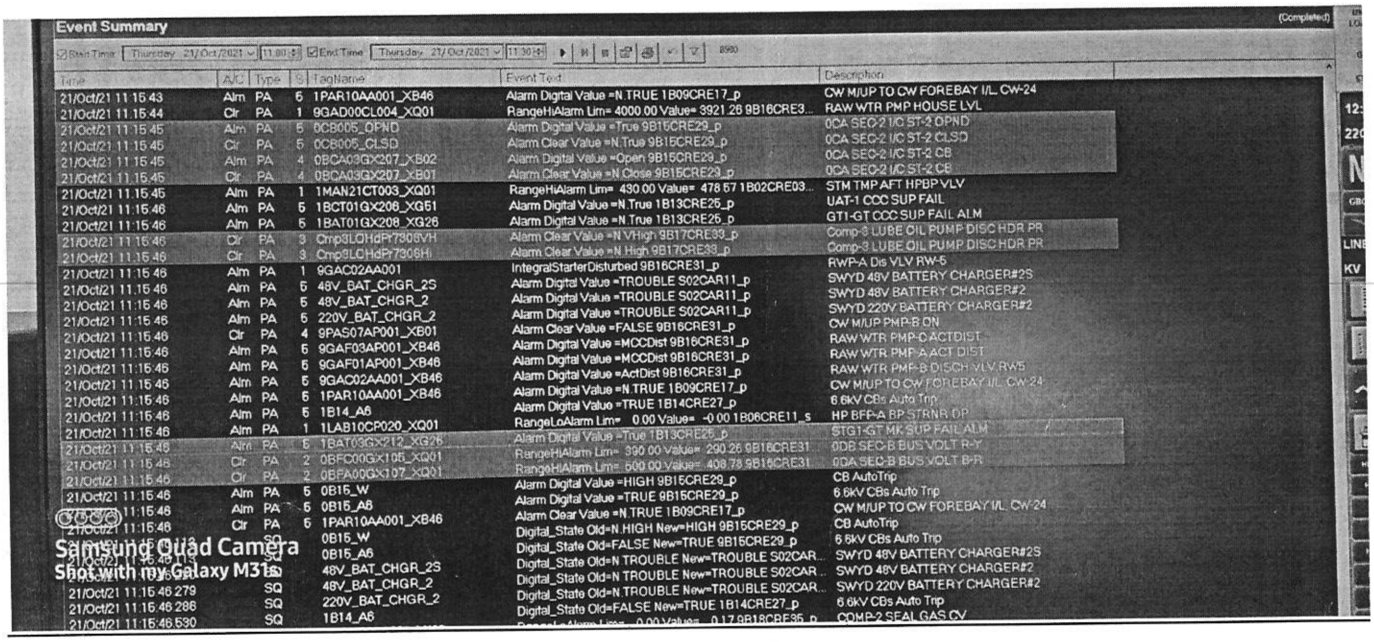
RCA RECOMMENDATIONS :

S.No	Recommendations	Responsibility	Target date
1	MW Transducer to be replaced.	OMS- EMD	Done immediately
2	Control supply of fuel PMCC to be changed over from GT-1 PMCC to Unit-2 UPS supply. As mentioned in RCA-104.	OMS-EMD	Done immediately
3	Fast bus transfer scheme to be implemented to 6.6KV station switchgears	OTPC- EMD	
4	Digital ~~Analog type~~ Transducer to be replaced with Digital type programmable Transducer in entire plant circuits.	OTPC- EMD	During Planned/opportunity shutdown
5	VT fuse fail blocking protection to be incorporated.	OTPC- EMD	May-2022

Reference to Incident & repetition if any	Nil

Annexure	DR of ST

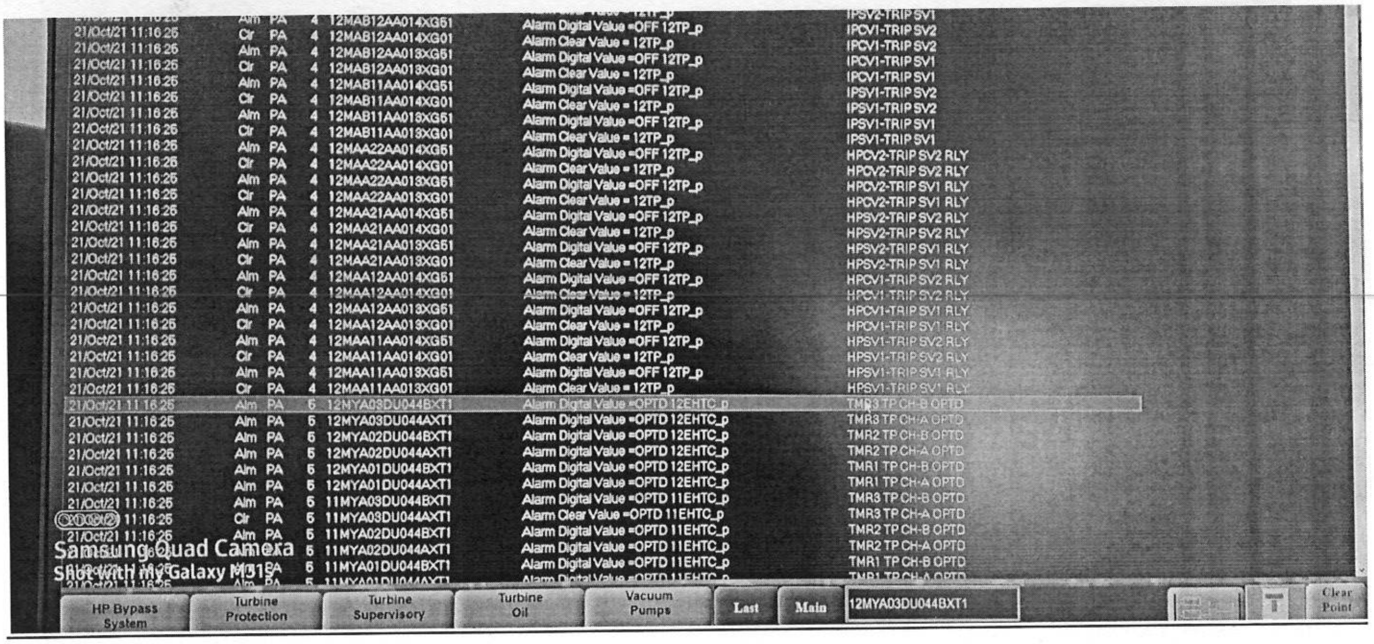
MAX DNA SOE



Time	A/C	Type	S	TagName	Event Text	Description
21/Oct/21 11:15:43	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:44	Clr	PA	1	9GAD00CL004_XQ01	RangeHiAlarm Lim= 4000.00 Value= 3921.26 9B16CRE3...	RAW WTR PMP HOUSE LVL
21/Oct/21 11:15:45	Alm	PA	5	0CB005_OPND	Alarm Digital Value =True 9B15CRE29_p	0CA SEC-2 I/C ST-2 OPND
21/Oct/21 11:15:45	Clr	PA	5	0CB005_CLSD	Alarm Clear Value =N.True 9B15CRE29_p	0CA SEC-2 I/C ST-2 CLSD
21/Oct/21 11:15:45	Alm	PA	4	0BCA03GX207_XB02	Alarm Digital Value =Open 9B15CRE29_p	0CA SEC-2 I/C ST-2 CB
21/Oct/21 11:15:45	Clr	PA	4	0BCA03GX207_XB01	Alarm Clear Value =N.Close 9B15CRE29_p	0CA SEC-2 I/C ST-2 CB
21/Oct/21 11:15:45	Alm	PA	1	1MAN21CT003_XQ01	RangeHiAlarm Lim= 430.00 Value= 478.57 1B02CRE03...	STM TMP AFT HPBP VLV
21/Oct/21 11:15:46	Alm	PA	5	1BCT01GX206_XG51	Alarm Digital Value =N.True 1B13CRE25_p	UAT-1 CCC SUP FAIL
21/Oct/21 11:15:46	Alm	PA	5	1BAT01GX208_XG26	Alarm Digital Value =N.True 1B13CRE25_p	GT1-GT CCC SUP FAIL ALM
21/Oct/21 11:15:46	Clr	PA	3	Cmp3LOHdPr7308VH	Alarm Clear Value =N.VHigh 9B17CRE33_p	Comp-3 LUBE OIL PUMP DISC HDR PR
21/Oct/21 11:15:46	Clr	PA	3	Cmp3LOHdPr7308Hi	Alarm Clear Value =N.High 9B17CRE33_p	Comp-3 LUBE OIL PUMP DISC HDR PR
21/Oct/21 11:15:46	Alm	PA	1	9GAC02AA001	IntegralStarterDisturbed 9B16CRE31_p	RWP-A Dis VLV RW-5
21/Oct/21 11:15:46	Alm	PA	5	48V_BAT_CHGR_2S	Alarm Digital Value =TROUBLE S02CAR11_p	SWYD 48V BATTERY CHARGER#2S
21/Oct/21 11:15:46	Alm	PA	5	48V_BAT_CHGR_2	Alarm Digital Value =TROUBLE S02CAR11_p	SWYD 48V BATTERY CHARGER#2
21/Oct/21 11:15:46	Alm	PA	5	220V_BAT_CHGR_2	Alarm Digital Value =TROUBLE S02CAR11_p	SWYD 220V BATTERY CHARGER#2
21/Oct/21 11:15:46	Clr	PA	4	9PAS07AP001_XB01	Alarm Clear Value =FALSE 9B16CRE31_p	CW M/UP PMP-B ON
21/Oct/21 11:15:46	Alm	PA	5	9GAF03AP001_XB46	Alarm Digital Value =MCCDist 9B16CRE31_p	RAW WTR PMP-C ACTDIST
21/Oct/21 11:15:46	Alm	PA	5	9GAF01AP001_XB46	Alarm Digital Value =MCCDist 9B16CRE31_p	RAW WTR PMP-A ACT DIST
21/Oct/21 11:15:46	Alm	PA	5	9GAC02AA001_XB46	Alarm Digital Value =ActDist 9B16CRE31_p	RAW WTR PMP-B DISCH VLV RW5
21/Oct/21 11:15:46	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:46	Alm	PA	5	1B14_A6	Alarm Digital Value =TRUE 1B14CRE27_p	6.6kV CBs Auto Trip
21/Oct/21 11:15:46	Alm	PA	1	1LAB10CP020_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.00 1B06CRE11_s	HP BFP-A BP STRNR DP
21/Oct/21 11:15:46	Alm	PA	5	1BAT03GX212_XG26	Alarm Digital Value =True 1B13CRE25_p	STG1-GT MK SUP FAIL ALM
21/Oct/21 11:15:46	Clr	PA	2	0BFC00GX105_XQ01	RangeHiAlarm Lim= 390.00 Value= 290.26 9B16CRE31	0DB SEC-B BUS VOLT R-Y
21/Oct/21 11:15:46	Clr	PA	2	0BFA00GX107_XQ01	RangeHiAlarm Lim= 500.00 Value= 408.78 9B16CRE31	0DA SEC-B BUS VOLT B-R
21/Oct/21 11:15:46	Alm	PA	5	0B15_W	Alarm Digital Value =HIGH 9B15CRE29_p	CB AutoTrip
21/Oct/21 11:15:46	Alm	PA	5	0B15_A6	Alarm Digital Value =TRUE 9B15CRE29_p	6.6kV CBs Auto Trip
21/Oct/21 11:15:46	Clr	PA	5	1PAR10AA001_XB46	Alarm Clear Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
[illegible]		SQ		0B15_W	Digital_State Old=N.HIGH New=HIGH 9B15CRE29_p	CB AutoTrip
[illegible]		SQ		0B15_A6	Digital_State Old=FALSE New=TRUE 9B15CRE29_p	6.6kV CBs Auto Trip
[illegible]		SQ		48V_BAT_CHGR_2S	Digital_State Old=N.TROUBLE New=TROUBLE S02CAR...	SWYD 48V BATTERY CHARGER#2S
[illegible]		SQ		48V_BAT_CHGR_2	Digital_State Old=N.TROUBLE New=TROUBLE S02CAR...	SWYD 48V BATTERY CHARGER#2
21/Oct/21 11:15:46.279		SQ		220V_BAT_CHGR_2	Digital_State Old=N.TROUBLE New=TROUBLE S02CAR...	SWYD 220V BATTERY CHARGER#2
21/Oct/21 11:15:46.286		SQ		1B14_A6	Digital_State Old=FALSE New=TRUE 1B14CRE27_p	6.6kV CBs Auto Trip
21/Oct/21 11:15:46.530		SQ				COMP-2 SEAL GAS CV

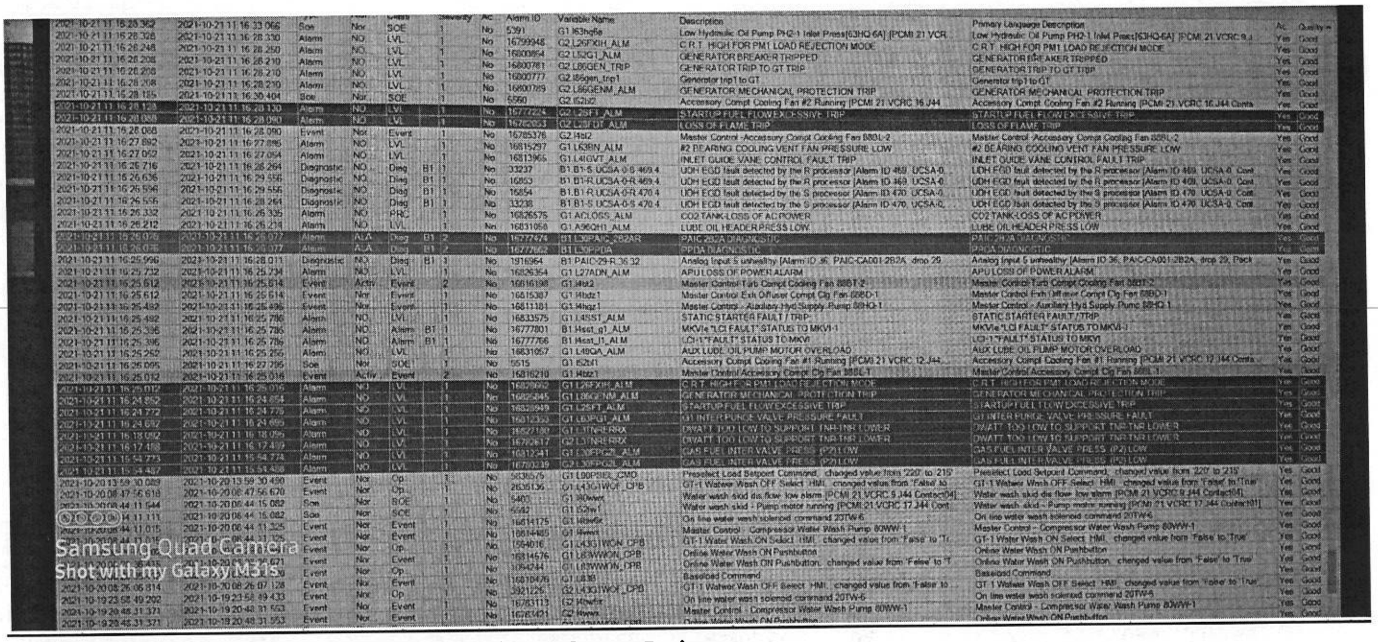
21/Oct/21 11:15:49	Clr	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= 195.94 9B17CRE33_p	CMP3 SUC FLTR DP2
21/Oct/21 11:15:49	Clr	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= 364.42 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:49	Alm	PA	2	0BFC00GX105_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.02 9B16CRE31_p	0DB SEC-B BUS VOLT R-Y
21/Oct/21 11:15:49	Alm	PA	2	0BFA03GX103_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.08 9B16CRE31_p	0DA I/C-0DAT02 CUR B PH
21/Oct/21 11:15:49	Alm	PA	1	2MMV42CP302_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B18CRE35_p	CMP2 LO DIFF PR PDT-7310
21/Oct/21 11:15:49	Alm	PA	5	1B14_A7	Alarm Digital Value =TRUE 1B14CRE27_p	415 V CBs Auto Trip
21/Oct/21 11:15:49.271		SQ		3QJN30AA_AUTO	Digital_State Old=AUTO New=MANUAL 9B17CRE33_p	GBC-3 ANTI SURGE VLV
21/Oct/21 11:15:49.853		SQ		3MMV21AP021_XB02	Digital_State Old=FdbkOff New=FALSE 9B17CRE33_p	GBC-3 LOP MAIN OFF
21/Oct/21 11:15:49.855		SQ		3MMV21AP021_XB01	Digital_State Old=FALSE New=FdbkOn 9B17CRE33_p	GBC-3 LOP MAIN ON
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOHdrPrVLo	Alarm Digital Value =High 9B17CRE33_p	Cmp-3 LO Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	2	0BFA00GX107_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.64 9B16CRE31_p	0DA SEC-B BUS VOLT B-R
21/Oct/21 11:15:50	Clr	PA	1	1LAB10CP020_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 1B06CRE11_s	HP BFP-A BP STRNR DP
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOPr7312CVLo	Alarm Digital Value =V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOPr7312BVLo	Alarm Digital Value =V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOPr7312AVLo	Alarm Digital Value =V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:50	Alm	PA	3	Cmp3LOHdrPrLow	Alarm Digital Value =High 9B17CRE33_p	Cmp-3 LO Hdr Pr Low
21/Oct/21 11:15:50	Clr	PA	5	3MMV21AP021_XB02	Alarm Clear Value =FALSE 9B17CRE33_p	GBC-3 LOP MAIN OFF
21/Oct/21 11:15:50	Alm	PA	5	3MMV21AP021_XB01	Alarm Digital Value =FdbkOn 9B17CRE33_p	GBC-3 LOP MAIN ON
21/Oct/21 11:15:50	Alm	PA	1	3MMV42CP310AXQ01	LowAlarm Limit = 1.00 Value = 0.92 9B17CRE33_p	CMP3 LO UPSTR PR PT-7312A
21/Oct/21 11:15:50	Alm	PA	2	0BFA03GX102_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.96 9B16CRE31_p	0DA I/C 0DAT02 CUR Y PH
21/Oct/21 11:15:50	Alm	PA	2	0BFA03GX101_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B16CRE31_p	0DA I/C-0DAT02 CUR R PH
21/Oct/21 11:15:50	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:50.311		SQ		Cmp3LOPr7312CVLo	Digital_State Old=N.VLow New=V.Low 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:51	Clr	PA	2	1LT4510	RangeLoAlarm Lim= 0.00 Value= 0.06 1B01CRE01_p	GT1 FSS FLT2 LVL1
21/Oct/21 11:15:51	Alm	PA	2	3QJN00CE001_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B17CRE33_p	COMP-3 MOTOR CURRENT
21/Oct/21 11:15:51	Alm	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= -38.46 9B17CRE33_p	CMP3 SUC FLTR DP2
21/Oct/21 11:15:51	Alm	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= -30.22 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:51	Clr	PA	3	Cmp2LOHdrPrLow	Alarm Clear Value =N.LOW 9B18CRE35_p	Cmp-2 LO Hdr Pr Low
21/Oct/21 11:15:51	Alm	PA	5	Cmp2LOPr7312CVLo	Alarm Digital Value =V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
[illegible]	Clr	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= 8.24 9B17CRE33_p	CMP3 SUC FLTR DP2
[illegible]	Clr	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= 111.25 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:51	Alm	PA	2	0BFA00GX105_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.11 9B16CRE31_p	0DA SEC-B BUS VOLT R-Y
21/Oct/21 11:15:51.681		SQ		Cmp2LOPr7312CVLo	Digital_State Old=N.VLow New=V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low

21/Oct/21 11:15:51	Alm	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= -30.22 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:51	Clr	PA	3	Cmp2LOHdrPrLow	Alarm Clear Value =N.LOW 9B18CRE35_p	Cmp-2 LO Hdr Pr Low
21/Oct/21 11:15:51	Alm	PA	5	Cmp2LOPr7312CVLo	Alarm Digital Value =V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:51	Clr	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= 8.24 9B17CRE33_p	CMP3 SUC FLTR DP2
21/Oct/21 11:15:51	Clr	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= 111.25 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:51	Alm	PA	2	0BFA00GX105_XQ01	RangeLoAlarm Lim= 0.00 Value= -0.11 9B16CRE31_p	0DA SEC-B BUS VOLT R-Y
21/Oct/21 11:15:51.681		SQ		Cmp2LOPr7312CVLo	Digital_State Old=N.VLow New=V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52	Clr	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= 14.19 9B17CRE33_p	CMP3 SUC FLTR DP2
21/Oct/21 11:15:52	Clr	PA	5	3QJN30CP201A	RangeLoAlarm Lim= 0.00 Value= 298.95 9B17CRE33_p	CMP3 SUC FLTR DP
21/Oct/21 11:15:52	Alm	PA	2	0BCB00GX103_XQ01	RangeLoAlarm Lim= 0.00 Value= 0.00 9B16CRE31_p	0CA BUS SEC-2 OLT B-R PH
21/Oct/21 11:15:52	Clr	PA	5	2QJN00AN001_XB11	Alarm Clear Value = 9B18CRE35_p	COMP-2 MOTOR
21/Oct/21 11:15:52	Alm	PA	5	1LAB82AA001_XB46	Alarm Digital Value =ActDist 1B04CRE07_p	LP FCS LO CAP CV-16 ISO, BFD-28
21/Oct/21 11:15:52	Alm	PA	3	Cmp2LOHdrPrVLo	Alarm Digital Value =V.LOW 9B18CRE35_p	Cmp-2 LO Hdr Pr V.Low
21/Oct/21 11:15:52	Alm	PA	5	Cmp2LOPr7312BVLo	Alarm Digital Value =V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52	Alm	PA	5	Cmp2LOPr7312AVLo	Alarm Digital Value =V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52	Alm	PA	3	Cmp2LOHdPr7308VL	Alarm Digital Value =V.Low 9B18CRE35_p	Comp-2 LUBE OIL PUMP DISC HDR PR
21/Oct/21 11:15:52	Clr	PA	1	1MAN21CT003_XQ01	RangeHiAlarm Lim= 430.00 Value= 288.81 1B02CRE03	STM TMP AFT HPBP VLV
21/Oct/21 11:15:52.181		SQ		Cmp2LOPr7312BVLo	Digital_State Old=N.VLow New=V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52.181		SQ		Cmp2LOPr7312AVLo	Digital_State Old=N.VLow New=V.Low 9B18CRE35_p	Comp-2 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:52.192		SQ		Cmp2LOHdrPrVLo	Digital_State Old=OK New=V.LOW 9B18CRE35_p	Cmp-2 LO Hdr Pr V.Low
21/Oct/21 11:15:52.202		SQ		2QJN00AN001_XB92	Digital_State Old= 0.00 New=CmdStop 9B18CRE35_p	COMP-2 MOTOR
21/Oct/21 11:15:52.285		SQ		2QJN00AN001_XB11	Digital_State Old=FdbkOn New= 0.00 9B18CRE35_p	COMP-2 MOTOR
21/Oct/21 11:15:52.287		SQ		2QJN00AN001_XB12	Digital_State Old= 0.00 New=FdbkOff 9B18CRE35_p	COMP-2 MOTOR
21/Oct/21 11:15:52.569		SQ		1MAL11AA011XB94	Digital_State Old= 0.00 New= 1.00 1ATRS1_p	DRN BEF HP CTRL VLV-1
21/Oct/21 11:15:53	Clr	PA	3	Cmp3LOPr7312CVLo	Alarm Clear Value =N.VLow 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:53	Clr	PA	3	Cmp3LOPr7312BVLo	Alarm Clear Value =N.VLow 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:53	Clr	PA	3	Cmp3LOPr7312AVLo	Alarm Clear Value =N.VLow 9B17CRE33_p	Comp-3 Lub Oil Hdr Pr V.Low
21/Oct/21 11:15:53	Clr	PA	1	3MMV42CP310AXQ01	LowAlarm Limit = 1.00 Value = 1.06 9B17CRE33_p	CMP3 LO UPSTR PR PT-7312A
21/Oct/21 11:15:53	Alm	PA	5	1PAR10AA001_XB46	Alarm Digital Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:53	Clr	PA	5	1LAB82AA001_XB46	Alarm Clear Value =FALSE 1B04CRE07_p	LP FCS LO CAP CV-16 ISO, BFD-28
21/Oct/21 11:15:53	Alm	PA	5	3QJN30CP201B	RangeLoAlarm Lim= 0.00 Value= -41.20 9B17CRE33_p	CMP3 SUC FLTR DP2
[illegible]	Alm	PA	5	2QJN00AN001Trip	Alarm Digital Value =Tripped 9B18CRE35_p	Comp-2 MOTOR
[illegible]	Clr	PA	5	1PAR10AA001_XB46	Alarm Clear Value =N.TRUE 1B09CRE17_p	CW M/UP TO CW FOREBAY I/L CW-24
21/Oct/21 11:15:53.172		SQ		2QJN30AA203_AO	Digital_State Old= 0.00 New= 1.00 9B18CRE35_p	
21/Oct/21 11:15:53.191		SQ		2QJN00AN001Trip	Digital_State Old=N.TRUE New=Tripped 9B18CRE35_p	Comp-2 MOTOR
21/Oct/21 11:15:53.201		SQ		2QJN00AN001_XB92	Digital_State Old=CmdStop New= 0.00 9B18CRE35_p	COMP-2 MOTOR

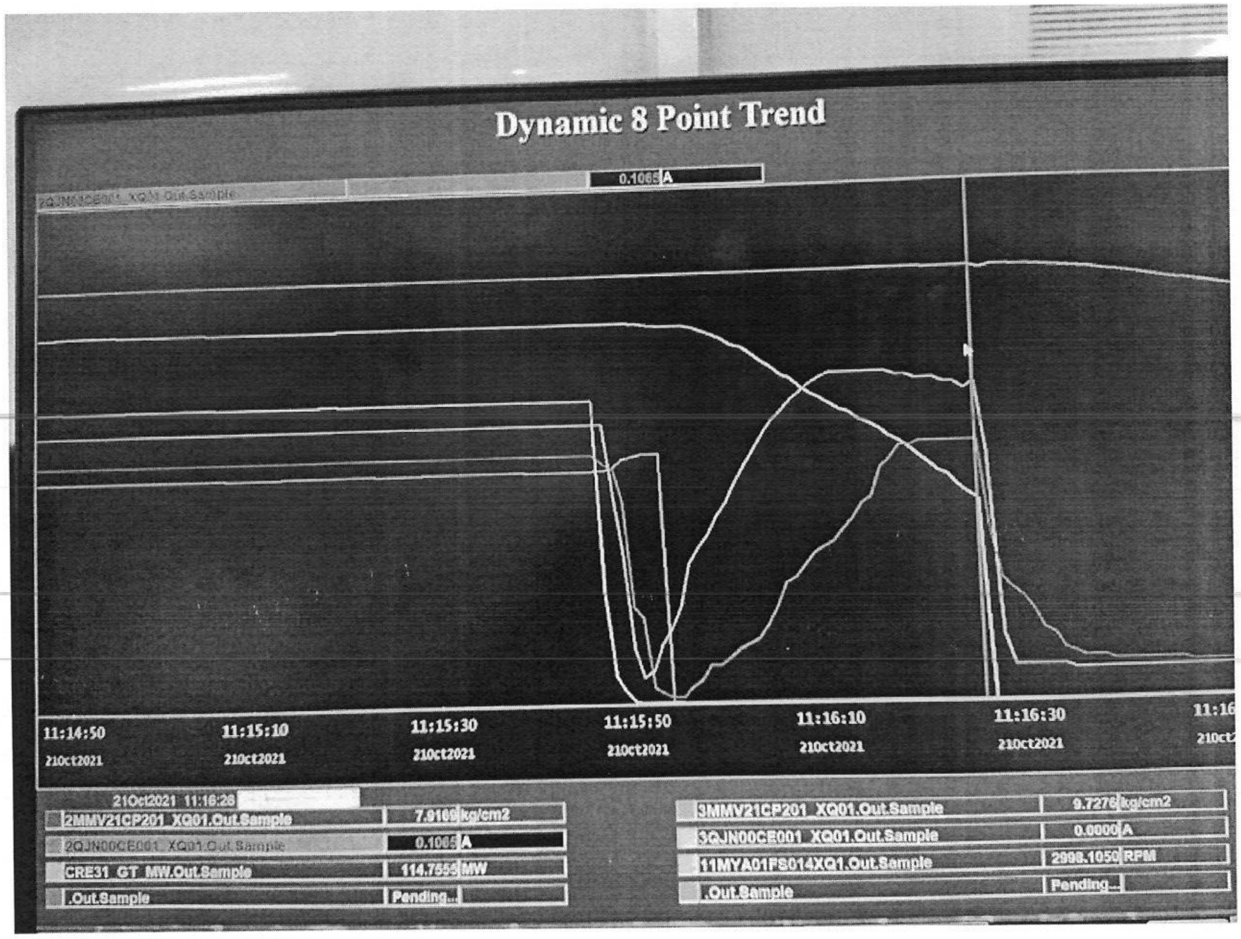


21/Oct/21 11:16:25	Alm	PA	4	12MAB12AA014XG51	Alarm Digital Value =OFF 12TP_p	IPCV1-TRIP SV2
21/Oct/21 11:16:25	Clr	PA	4	12MAB12AA014XG01	Alarm Clear Value = 12TP_p	IPCV1-TRIP SV2
21/Oct/21 11:16:25	Alm	PA	4	12MAB12AA013XG51	Alarm Digital Value =OFF 12TP_p	IPCV1-TRIP SV1
21/Oct/21 11:16:25	Clr	PA	4	12MAB12AA013XG01	Alarm Clear Value = 12TP_p	IPCV1-TRIP SV1
21/Oct/21 11:16:25	Alm	PA	4	12MAB11AA014XG51	Alarm Digital Value =OFF 12TP_p	IPSV1-TRIP SV2
21/Oct/21 11:16:25	Clr	PA	4	12MAB11AA014XG01	Alarm Clear Value = 12TP_p	IPSV1-TRIP SV2
21/Oct/21 11:16:25	Alm	PA	4	12MAB11AA013XG51	Alarm Digital Value =OFF 12TP_p	IPSV1-TRIP SV1
21/Oct/21 11:16:25	Clr	PA	4	12MAB11AA013XG01	Alarm Clear Value = 12TP_p	IPSV1-TRIP SV1
21/Oct/21 11:16:25	Alm	PA	4	12MAA22AA014XG51	Alarm Digital Value =OFF 12TP_p	HPCV2-TRIP SV2 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA22AA014XG01	Alarm Clear Value = 12TP_p	HPCV2-TRIP SV2 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA22AA013XG51	Alarm Digital Value =OFF 12TP_p	HPCV2-TRIP SV1 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA22AA013XG01	Alarm Clear Value = 12TP_p	HPCV2-TRIP SV1 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA21AA014XG51	Alarm Digital Value =OFF 12TP_p	HPSV2-TRIP SV2 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA21AA014XG01	Alarm Clear Value = 12TP_p	HPSV2-TRIP SV2 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA21AA013XG51	Alarm Digital Value =OFF 12TP_p	HPSV2-TRIP SV1 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA21AA013XG01	Alarm Clear Value = 12TP_p	HPSV2-TRIP SV1 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA12AA014XG51	Alarm Digital Value =OFF 12TP_p	HPCV1-TRIP SV2 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA12AA014XG01	Alarm Clear Value = 12TP_p	HPCV1-TRIP SV2 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA12AA013XG51	Alarm Digital Value =OFF 12TP_p	HPCV1-TRIP SV1 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA12AA013XG01	Alarm Clear Value = 12TP_p	HPCV1-TRIP SV1 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA11AA014XG51	Alarm Digital Value =OFF 12TP_p	HPSV1-TRIP SV2 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA11AA014XG01	Alarm Clear Value = 12TP_p	HPSV1-TRIP SV2 RLY
21/Oct/21 11:16:25	Alm	PA	4	12MAA11AA013XG51	Alarm Digital Value =OFF 12TP_p	HPSV1-TRIP SV1 RLY
21/Oct/21 11:16:25	Clr	PA	4	12MAA11AA013XG01	Alarm Clear Value = 12TP_p	HPSV1-TRIP SV1 RLY
21/Oct/21 11:16:25	Alm	PA	5	12MYA03DU044BXT1	Alarm Digital Value =OPTD 12EHTC_p	TMR3 TP CH-B OPTD
21/Oct/21 11:16:25	Alm	PA	5	12MYA03DU044AXT1	Alarm Digital Value =OPTD 12EHTC_p	TMR3 TP CH-A OPTD
21/Oct/21 11:16:25	Alm	PA	5	12MYA02DU044BXT1	Alarm Digital Value =OPTD 12EHTC_p	TMR2 TP CH-B OPTD
21/Oct/21 11:16:25	Alm	PA	5	12MYA02DU044AXT1	Alarm Digital Value =OPTD 12EHTC_p	TMR2 TP CH-A OPTD
21/Oct/21 11:16:25	Alm	PA	5	12MYA01DU044BXT1	Alarm Digital Value =OPTD 12EHTC_p	TMR1 TP CH-B OPTD
21/Oct/21 11:16:25	Alm	PA	5	12MYA01DU044AXT1	Alarm Digital Value =OPTD 12EHTC_p	TMR1 TP CH-A OPTD
21/Oct/21 11:16:25	Alm	PA	5	11MYA03DU044BXT1	Alarm Digital Value =OPTD 11EHTC_p	TMR3 TP CH-B OPTD
[illegible] 11:16:25	Clr	PA	5	11MYA03DU044AXT1	Alarm Clear Value =OPTD 11EHTC_p	TMR3 TP CH-A OPTD
21/Oct/21 11:16:25	Alm	PA	5	11MYA02DU044BXT1	Alarm Digital Value =OPTD 11EHTC_p	TMR2 TP CH-B OPTD
[illegible]	[illegible]	[illegible]	5	11MYA02DU044AXT1	Alarm Digital Value =OPTD 11EHTC_p	TMR2 TP CH-A OPTD
[illegible]	[illegible]	PA	5	11MYA01DU044BXT1	Alarm Digital Value =OPTD 11EHTC_p	TMR1 TP CH-B OPTD

MARK VIe SOE:



Trend showing GT-1 trip, GBC lube oil pr. shoot & drop



Dynamic 8 Point Trend
0.1065 A
11:14:50 21Oct2021
11:15:10 21Oct2021
11:15:30 21Oct2021
11:15:50 21Oct2021
11:16:10 21Oct2021
11:16:30 21Oct2021
21Oct2021 11:16:28
2MMV21CP201_XQ01.Out.Sample 7.9169 kg/cm2
2QJN00CE001_XQ01.Out.Sample 0.1065 A
CRE31_GT_MW.Out.Sample 114.7555 MW
.Out.Sample Pending...
3MMV21CP201_XQ01.Out.Sample 9.7276 kg/cm2
3QJN00CE001_XQ01.Out.Sample 0.0000 A
11MYA01FS014XQ1.Out.Sample 2998.1050 RPM
.Out.Sample Pending...

Cost Benefit Sheet

5.5KW, 7.5KW and 11KW VFD installation on AHU System at Control and Facility Building

AFE: 1300000558

Annual Energy Saving with 5.5KW VFD	7.9MWh
Annual Saving with 5.5KW VFD	25560/-
Annual Energy Saving with 7.5KW VFD	10.7MWh
Annual Saving with 7.5KW VFD	34440/-
Annual Energy Saving with 11KW VFD	15.4MWh
Annual Saving with 11KW VFD	49700/-
Total Annual Energy Saving	34MWh
Toal Annual Financial Saving	109700/-
VFD Installation Project Cost:	999448/-
Payback Period	9 Years (approx.)

FINAL REPORT

PLANT PERFORMANCE AUDIT-2

For 2 x 363.3 MW Combined Cycle Power Plant, India

BV PROJECT NO. 410764

PREPARED FOR

ONGC Tripura Power Company Limited (OTPC)

12 JULY 2023

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Acronym List

ACRONYM	DESCRIPTION
^{o}C	Degrees Centigrade
AC	Alternate Current
ACRT	Accelerated Creep Rupture Test
APS	Automatic Plant Start-up/Shutdown Control Scheme
ASME	American Society of Mechanical Engineers
AVR	Automatic Voltage Regulator
BHEL	Bharat Heavy Electrical Limited
BOP	Balance-of-Plant
BSI	Borescope Inspection
Btu	British Thermal Unit
Btu/kWh	British Thermal Unit per Kilowatt-Hour
CCPP	Combined Cycle Power Plant
CEMS	Continuous emission Monitoring System
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Commercial Operation Date
CRH	Cold Reheat
CT	Cooling Tower
CW	Circulating Water
DC	Direct Current
DCS	Distributed Control System
DGR	Daily Generation report
DLE	Dry Low Emission
DLN	Dry Low Nox
DM	Demineralized
EAF	Equivalent Availability Factor
EAF	Equivalent Availability Factor
EAF	Equivalent Availability Factor
ECR	Equipment Condition Report
ECT	Eddy Current Test

ACRONYM	DESCRIPTION
EFOR	Equivalent Forced Outage Rate
EHS	Environmental Health and Safety
ELCID	Electromagnetic Core Imperfection Detection
ESDV	Emergency Shutdown Valve
ETP	Effluent Treatment Plant
FFH	Factored Fired Hours
FOF	Forced Outage Factor
FOR	Forced Outage Rate
FSFL	Full Speed Full Load
FSNL	Full Speed No Load
GE	General Electric
GSU	Generator Step Up
GT	Gas Turbine
GTG	Gas Turbine Generator
HMBD	Heat and Mass Balance Diagram
HP	High Pressure
hp	Horsepower
HP	High-Pressure
HR	Heat Rate
HRSG	Heat Recovery Steam Generator
HSO	Hot Section Overhaul
HV	High Voltage
Hz	Hertz
I&C	Instrumentation and Control
I/O	Input/Output
IAF-II	India Alternative Fund- II
IL&FS	Infrastructure Leasing & Financial Services Limited
IP	Intermediate- Pressure
IR	Infrared
IRIS	Internal Rotary Inspection
Kcal	Kilocalories

ACRONYM	DESCRIPTION
kJ	Kilojoule
klb/h	Kilopounds per hour
kV	Kilovolt
kVA	Kilovolt-ampere
kVar	Kilovar
kW	Kilowatt
kWh	kilowatt-hour
LD	Liquidated Damage
LEAP	Life Expectancy Analysis Program
LED	Light Emitting Diode
LHV	Low Heating Value
LP	Low-Pressure
LTSA	Long Term Service Agreement
LV	Low Voltage
m/s	Meters per second
m^3/sec	Cubic meters per second
mA	Milliamperes
MO	Major Overhaul
MS	Main Steam
MT	Magnetic Particle Test
MTD	Month Till Date
MV	Medium Voltage
MW	Megawatts
MWh	Megawatt Hour
NCV	Net Calorific Value
NDT/ NDE	Non-Destructive Examination/ Non-Destructive Testing
NERC	North American Electric Reliability Corporation, USA
NOx	Nitrogen Oxides
O&M	Operations and Maintenance
O2	Oxygen
OAR	Operation Assessment Report

ACRONYM	DESCRIPTION
OEG	Operational Energy Group
OEM	Original Equipment Manufacturer
OMS	O&M Solutions Pvt. Ltd
ONGC	Oil and Natural Gas Corporation Limited
OTPC	ONGC Tripura Power Company Limited
P&ID	Process and Instrumentation Diagram
PCB	Pollution Control Board
PG Test	Performance Guarantee Test
PLC	Programmable Logic Controller
PM	Preventive Maintenance
PT	Dye Penetrant Test
PTC	Performance Test Codes
RCA	Root Cause Analysis
Rpm	Rotations per Minute
RT	Radiographic Test
RTD	Resistance Temperature Detector
RVI	Remote Visual Inspection
SMP	Standard Maintenance Procedure
SOP	Standard Operating Procedure
SOX	Sulphur Oxides
ST	Steam Turbine
STG	Steam Turbine Generator
TAT	Turn around time
TBC	Thermal Barrier Coating
TPH	Tons per hour
UTM	Ultrasonic Thickness Measurement
VGV	Variable Guide Vane
VI	Visual Inspection
VIGV	Variable Inlet Guide Vane
VMU	Vibration Monitoring Unit
YTD	Year Till Date

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1 Executive Summary

ONGC Tripura Power Company Limited (OTPC) is a joint venture of Oil and Natural Gas Corporation Limited (ONGC) and Govt. of Tripura. OTPC is operating a 726.6 MW (2X363.3 MW) Combined Cycle Power Plant (CCPP) at Palatana in the state of Tripura, India. The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015.

Black & Veatch has been contracted by OTPC to perform technical system audit, plant performance audit, and provide recommendations for improvement in plant performance, reliability, and safety of the plant. A list of **27** recommended performance improvement project is provided in ***Section 6.1.5.*** These recommendations are categorized based on “risk level”, “priority”, “CAPEX” and “On-line vs. Shutdown” planning. Few major upgrades specially for steam turbines such as steam seal upgrades, LP last stage modifications etc. are recommended to be analyzed in consultation with major retrofit package providers besides OEMs and planned during next capital overhauls at expected 100,000 Hrs.

1.1 Performance Analysis at Base Load

1.1.1 Heat Rate Analysis

Black & Veatch supported the conductance of site performance test with OTPC and OMS on 1st – 3rd of Feb-23 based on in-situ instrumentations. This assessment was part of 2nd audit cycle activity performed by Black & Veatch. The below table 0-1 compares the gross heat rate (Corrected) with PG test and [1]CERC norms.

Table 1-1 Gross Heat Rate Analysis

Unit	Perf. Test O/P (Uncorrected)	Perf. Test HR (Uncorrected)	PG Test		CERC	
			Output	HR	[1]HR	DIFF.
UOM	MW	kCal/kWh	MW	kCal/kWh	kCal/kWh	%
Block-1	335.70	1622.02	373.59	1504.9	1581	2.59
Block-2	339.19	1623.11	368.06	1505.5	1581	2.66

Both Block 1 and 2 were operated at base load. In Block-1, corrected heat rate for audit 2 was varying by 4.43% from OEM’s PG test value. In Block-2 performance test corrected heat rate was varying by 5.68% from OEM’s PG test results.

Overall, combined cycle heat rate (uncorrected) for Unit 1 and 2 are higher by 2.59% and 2.66% respectively from CERC’s permissible limit of 1581 kCal/kWh for base load operation.

[1] CERC tariff regulation 2019 specifies under u/s chapter 12; Norms of Operation to be 1.05 times of design gross heat rate for natural gas-fired combined cycle plant. The CERC value as applicable for OTPC is thereto derived by applying a 5% margin over the design heat rate of 1505.7 kCal/kWh.

1.1.2 Auxiliary Power Analysis

BLOCK	GROSS GENERATION (MW)	% OF RATED CAPACITY	AUX. ENERGY CONSUMPTION (%)	CERC NORMS (%)
Block-1 & 2	657.06	90.4	[2]3.446%	[3]3.30

APC is calculated at the station level based on EM data and deducting total hourly export (MWH) with hourly gross generation for the test period. The APC of station is around 4.4% higher than the CERC permissible limit for CCGT.

1.1.3 Performance Comparison with Other 9F Based Combined Cycle Units

S. NO	DESCRIPTION	UOM	BLOCK-1	BLOCK-2	[4]GLOBAL BENCHMARKS		
					Min	Max	Median
1	Gross Heat Rate (NCV basis)	kCal/kWh	1572.35	1591.27	1487	1766	1588
2	Plant Auxiliary Power Consumption	%	3.446		2.6	5.7	3.82

Black & Veatch compared OTPC heat rate and auxiliary power consumption with the industry standards. The data used for this assessment is referred using Black & Veatch's two decades of monitoring & diagnostic service of combined cycle plants. The performance of OTPC is shown graphically in the chart below. The chart shows that OTPC heat rate at 1581.82 (combined for block 1 and 2) is lower than the global median of 1584.81, however there are potential for average improvements inherent further up to 2-3% on the lower side duly accounting for machine's permanent degradation and its operating characteristics. Given Major Inspection (MI) for block 1 and block 2 are concluded in 2021 and 2022 respectively, the expected heat rate based on OEM supplied curve is reset at lower side to 1527.9 kCal/kWh and 1521.5 kCal/kWh respectively. The permanent degradation after 1 MI cycle is ~0.6-0.7% of design heat rate for both the blocks i.e., 10-12 kCal/KWh. With the considerations above, we expect that there is a potential for reduction of up to 2-3% in combined cycle heat rate by implementing the 27 recommendations outlined in section 6.1.5. ***Assuming overall reduction of 3%, a target heat rate of 1534 kCal/kWh or alternatively reduction of 45-50 kCal/kWh with respect to performance test heat rate can be targeted by OTPC in short to midterm.***

[2] Based on Energy Mater Data for the 2nd of February (15:00 -18:00 Hrs).

[3] Gas-based generating stations using electric motor driven Gas Booster Compressors, the Auxiliary Energy Consumption in case of Combined Cycle mode shall be 3.30%

[4] Following is the criterion used to ensure that comparison is justified in the context of OTPC.

- 10+ Combined cycle plants (9FA / 7FA) with block outputs in the range of approximately 300 to 1000 MW was considered.
- Operating history after COD for these plants are varying from 4 years to 12 years.
- Plants are in North America, China, Canada, and India.
- All plants are operated generally at either base load or sometimes at part load following grid dispatch instructions.

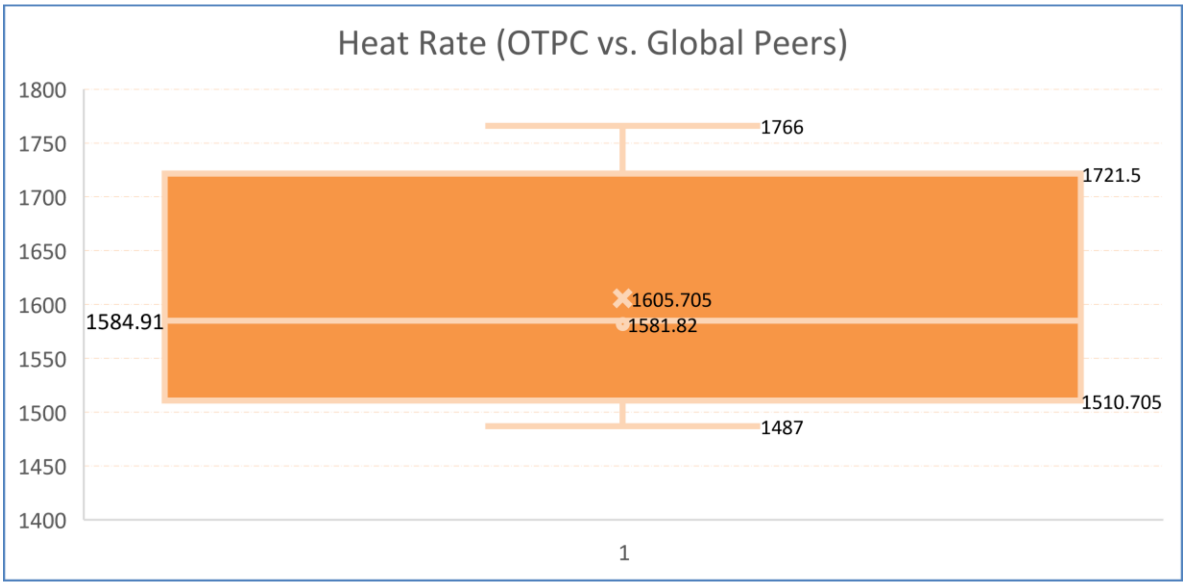
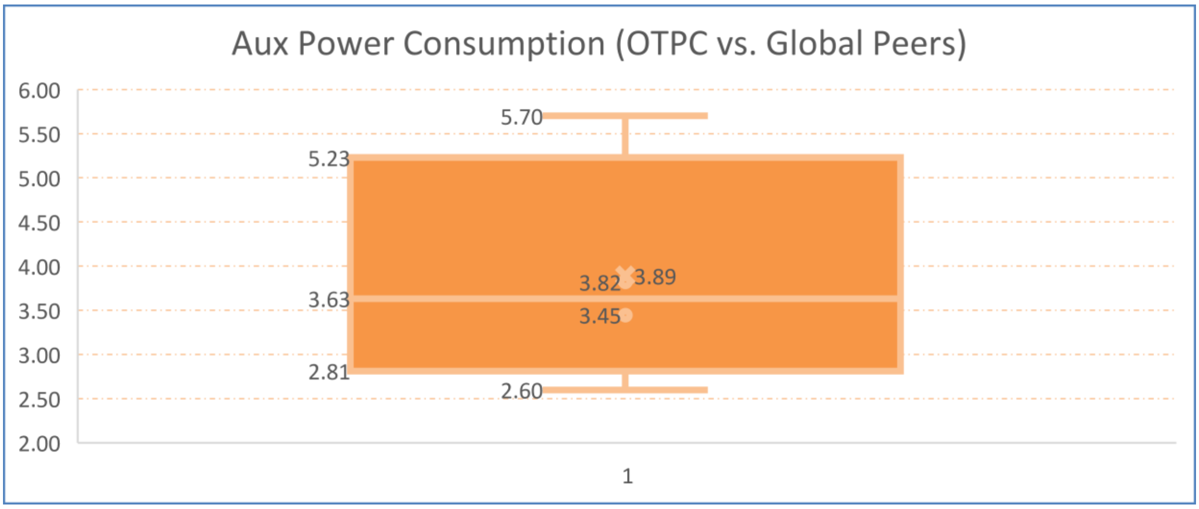


Figure 1 Box & Whisker Chart - OTPC vs. Global Peers

Figure 2 shows box and whisker plot of Aux power consumption. The OTPC auxiliary power consumption at 3.45% was lower than median of 3.82 and marginally higher than CERC norms of 3.30% respectively.



1.2 Recommended Improvement Actions

A list of 27 improvement project is provided in section 6.1.5 of the report and is reproduced below. These projects have each a potential of reducing heat rate and auxiliary power consumption varying with respect to severity of issues and measured adopted to rectify them including capital investment and technical support extended by OEMs and other equipment supplier. Please note that benefits of the projects are not additive and always complementary, hence heat rate improvement projects are required to be carefully evaluated to avoid double accounting or overstated expectations. We have classified these projects in two categories.

- Operational Adjustments
- System Modifications

Table 1-2 Heat Rate & APC Improvement Projects (1-5 Years)

Project ID	Project Description	Expected Heat Rate Reduction	Exp. APC Reduction	Type	CAPEX / Unit	Payback
1	HP/IP Section Internal Efficiency Improvement by Seal Upgrade	12-15 kCal/kWh	1.0-1.5 MW	System Modification (COH)	$1-1.5 million	<3 Years
2	Estimation of HP-IP Leakage by N2 Method (Services)	-	-	Operational Adjustment	$25-$35K	
3	LP Turbine efficiency Improvement by improving blade design and Increased annulus area (last stage blade replacement	10-30 kCal/kWh	Upto 1.0-2.0 MW	System Modification (COH)	$1.5-$2 million	3-5 Years
4	Addition of HP Exhaust pressure and temperature (Supply+ Service)	-	-	Operational Adjustment	$ 30-40K	
5a	Arrest Suspected Air Ingress in Condenser from Low Pressure Piping, LP turbine seals and diaphragm	5-10 kCal/kWh	-	Operational Adjustment	$ 30-40K	<1 Year
5b	Vacuum Pump “Under venting” Issue (Online Monitoring, Cleaning of Seal Water Cooler, Cavitation Avoidance)	5-10 kCal/kWh	-	System Modification (Minor)	$15-20K	<1 Year
5c	Condenser Cleaning (Online tube cleaning / Retubing with improved metallurgy	5-10 kCal/kWh	-	System Modification	$0.5-0.6 million	<2 Year
5d	Cooling Tower Projects (Fill pack replacements, CW flow equalization, Higher air flow using improved fan design, New Screen Design for CT basin)	10-15 kCal/kWh	Upto 0.5-1 MW, Condenser vacuum	System Modification	$0.8-1.2 million	<3 Year
6	Mitigate Inlet air filter choking and extend filter replacement cycle using Coalascer pads or Upgrade fine filter to EPA grade after cost benefit assessment with OEM	-	-	Operational Adjustment	$20-30K	<1 Year

Project ID	Project Description	Expected Heat Rate Reduction	Exp. APC Reduction	Type	CAPEX / Unit	Payback
7	Segregation of service air and instrument air usages (study)	-	Upto 100-150 KW	System Modification	$20-30K	<1 Year
8	Centralized controller for better loading / unloading frequency and average pressure band reduction	-	Upto 100 KW	System Modification	$80-100K	<1 Year
9	Arresting Leakages / Suspected Valve Passings CW Butterfly valve Plater Heat Exchanger BFP Recirculation IP Bypass Steam line	2-5 kCal/kWh	Upto 200 KW	Operational Adjustment	$50-80K	<1 Year
10	Real time monitoring of plant performance and continuous optimization	10-15kCal/kWh	Upto 0.5-1 MW	Operational Adjustment	$100-120K	<1 Year

A tabular and graphical representation for proposed recommendations and expected benefit is shown below.

Table 1-3 Heat Rate Improvement Strategy

Description	Units	Value[5]
Design Heat Rate	kCal/kWh	1505
Expected Heat Rate	kCal/kWh	1525
Target Heat Rate (Part Load, Gas Issues)	kCal/kWh	1534
Perf. Test Heat Rate	kCal/kWh	1582
Gap in Heat Rate (Target - Perf. Test)	kCal/kWh	48
Condenser Projects (5a,5b,5c)	kCal/kWh	-15
Cooling Tower Projects (5d)	kCal/kWh	-10
Steam Turbine Projects (1,2,3,5))	kCal/kWh	-20
Operational Adjustments (7,7,8,9)	kCal/kWh	-5
Predictive Analytics (10)	kCal/kWh	-10

[5] Values in negative indicates reduced gap between actual and target by project implementation. All improvement values are considered as median for representation purpose. Please refer 6.1.5 for range (minimum – maximum)

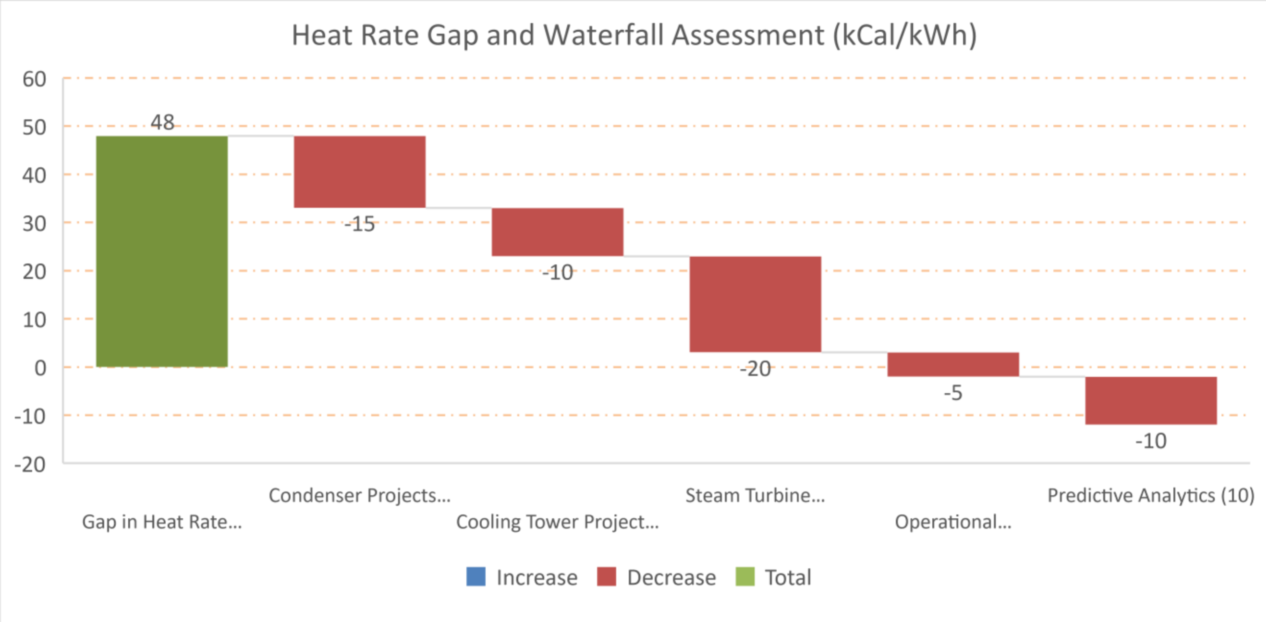


Figure 2 Heat Rate Gap and Waterfall Assessment

In conclusion, we have concluded two performance audits which were carefully organized between successive major inspections for Unit 2 and Unit 2 in 2021 and 2022 respectively. OTPC has implemented many upgrades and process improvements in the two units (ECP4 package upgrade for compressor, major retrofits in GT internals (nozzles, blades, shrouds, bearings replacement), IGV replacements, energy efficiency projects like CT fills replacements, new fan design, energy efficient lighting, insulation replacement etc. The focus for improvement is now required to be shifted towards bottoming cycle systems (HRSG, Steam turbine, Condenser and Auxiliaries) where we see considerable improvement potential through both system modification / upgrade strategy and operational adjustments. We are thankful to OTPC for giving opportunity to Black & Veatch to get associated in its decarbonization endeavor. Black & Veatch recommends systematic implementation of these projects in short-mid-term period for long-term efficient, reliable and safe plant operation achieving its environmental sustainability and decarbonization goals.

2 Facility Description

ONGC Tripura Power Company Limited (OTPC) is a joint venture of Oil and Natural Gas Corporation Limited (ONGC), and Government of Tripura. OTPC is operating a 726.6 MW (2X363.3 MW) Combined Cycle Power Plant (CCPP) at Palatana located about 60 (sixty) km from Agartala in the state of Tripura. The plant has 2 units each of 363. 3 MW on 1X1X1 configuration. Each unit consists of 1 GTG, 1 HRSG, and 1 STG along with associated plant auxiliaries supplied by BHEL.

The balance of plant system consists of Gas Booster Compressor house, river water intake system, fuel supply system, plant & fire water system, air supply system, hydrogen plant, nitrogen plant, 400 KV & 132 KV switchyard, etc.

The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015. The commissioning details of the station are shown below.

Table 2-1: Block-1 & 2 COD details

BLOCK NO	CAPACITY (MW)	TECHNOLOGY	DATE OF COMMISSIONING	DATE OF COMMERCIAL OPERATION
1	363.3	1X1 GE 9FA Combined Cycle	January 2013	4^{th} Jan 2014
2	363.3	1X1 GE 9FA Combined Cycle	November 2014	24^{th} Mar 2015

The plant receives gas from ONGC's gas fields located within 20-60 (twenty to sixty) km from the site. OTPC has entered into long term "Gas Sale and Purchase Agreement" (GSPA) with ONGC for purchase of fuel.

OTPC has entered into Operation and Maintenance Agreements with O&M Solutions Pvt. Ltd.(OMS) for providing operation and maintenance services including supply of consumables for the entire Plant. OTPC also has a maintenance services contract for services and supply of parts for Covered units of GT with General Electric International Inc and GE Energy Parts Inc respectively.

2.1 Equipment Design Information

Table 2-2: Equipment Design Information

DESCRIPTION	SPECIFICATION
Gas Turbine GT 2X363.3 MW	
Manufacturer	GE
Model ISO rated power Exhaust Temperature Speed Emission Control	9351FA Natural Gas Combustion turbine and Brush Generator 235400 KW 602.2 Deg. C 3000 RPM Dry Low NOx (DLN) 2.0
GT Turbine Generator (2 No)	

DESCRIPTION	SPECIFICATION
Manufacturer	BHEL, Haridwar
Terminal Voltage Stator Current Coolant Speed	15750 V 10022 A Hydrogen 3000 RPM
Heat Recovery Steam Generator (2 No)	
Manufacturer	BHEL
Features	Horizontal, natural circulation, water tube, top supported, fully drainable, modular design, Triple pressure with reheat type waste heat boiler
Maximum Capacity	289 TPH
Steam Turbine (2 No)	
Manufacturer	BHEL, Hyderabad
Type	Two Cylinder reheat Condensing turbine
Rated Speed	3000 RPM
Gas Booster Compressor [3 No]	
Manufacturer	BHEL
Model	BCL 406
Type	Centrifugal compressor
Drive Type	Electric Motor
Motor Power	3840 KW
Gas Heater	
Manufacturer	Not Availlable
Type Gas Flow	TEMA"AEL" 51520 kg/hr
GT Control System	
Type Model Make Control panel supply Monitor/Printer Supply	Electronic Speedtronic ™Mark VI/ Upgarded to Mark VIe M/S General Electric, USA 125 DC 240 AC
Plant Switchyard	400 kV and 132 kV switchyard with ICTs

3 Scope of Work and Audit Methodology

3.1 Scope of Performance Audit

The scope of Plant Performance Audit would be as follows

- Analyze the present key performance parameters of the plant and Identify reasons for variation/deviations of parameters, controllable losses, etc. and suggest ways to improve key performance indicators.
- Compare the plant performance parameters with design parameters.
- Compare the current plant performance parameters with performance targets.

3.2 Audit methodology

Black & Veatch team gathered available data to perform its assessment for this Report through the online data room. Black & Veatch conducted site visits to the OTPC site from 1st Feb – 4th Feb, 2023. The site visits involved meetings with representatives of OTPC and OMS. The purpose of the site was to assess the physical condition of the assets, to witness plant performance test and to gather additional information from operations personnel.

3.3 Performance Test Data Collection Guidelines

Black & Veatch has followed guidelines based on relevant ASME and PTC codes like PTC- 22, PTC -6, PTC -46, etc. for the performance evaluation. Some of the general guidelines are as below,

- Each unit shall be operated preferably in automatic mode and in a manner consistent with good utility practices.
- The total test duration comprises of the stabilization period, performance test period, and post-test period.
- The gas turbine shall be operating in baseload condition with IGV full open preferably.
- The test period will be preferably 120 minutes however, the test period shall not be less than 60 minutes if 120 minutes is not possible. ***Please refer table 3.1 for additional details***.

Table 3-1: Expected Minimum and Maximum Period for Performance Test

PERIOD	TIME	EXPECTED	MINIMUM
Stabilization period	Minutes	60	30
Test period	Minutes	120	60
Post-test period	Minutes	30	30
Total period	Minutes	210	120

- Before the start of the stabilization period, it shall be ensured that data is getting recorded at least for the parameters mentioned in the performance test data requirement section.

- The test shall not be carried out in conditions wherein there are expected major change in ambient parameters like ambient pressure, dry bulb temperature, and relative humidity.
- The test shall be repeated if there is starting/stopping of rain in between the test period.
- Following are critical stability conditions required per PTC 22. PTC 22 indicates sample standard deviation.

Table 3-2: Acceptable variations as per PTC 22

S.NO	VARIABLE	VARIATION ALLOWED PER PTC 22
1	Gross Power Output	0.65%
2	Air Temperature	1.3 DEGF (0.7 DEGC)
3	Fuel Flow	0.65%
4	Barometric Pressure	0.16%
5	Rated Speed	0.33%

- The test shall be restarted if there is a major disturbance or fluctuations during the performance test period.
- All drum blowdowns are to be kept closed.
- All drain /vent valves to be kept closed. Report if there are any water or steam leaks in the system.
- The electrical output from the combustion turbine shall be measured at the generator terminals with precision power meters.
- Fuel gas flow to the combustion turbine shall be measured using one or more calibrated orifice flow sections (designed in accordance with ASME MFC-3M), or other agreed-upon alternative meters (s) which meet the accuracy requirements of the test.
- Ambient conditions shall be measured with instrumentation that meets the accuracy requirements of the test.
- Upon completion of the test or during the test itself, the test data shall be reviewed to determine if any data should be rejected prior to the calculation of test results.
- All drain /vent valves to be kept closed. Report if there are any water or steam leaks in the system. All drum blowdowns were kept closed.
- The electrical output from the combustion turbine shall be measured at the generator terminals with precision power meters.

4 Principle Assumptions

In completing this assessment, Black & Veatch has used and relied upon certain information provided by OTPC and OMS. Black & Veatch believes the information provided is true and correct and reasonable for the purposes of this report. In preparing this report and the opinions presented herein, Black & Veatch has made certain assumptions with respect to conditions that may exist or events that may occur in the future. However, some events may occur, or circumstances change that cannot be foreseen or controlled by Black & Veatch and that may render these assumptions incorrect. To the extent that the actual future conditions differ from those assumed herein or provided to Black & Veatch by others, the actual results will differ from those that have been forecast in this report.

Throughout this report, Black & Veatch has stated assumptions and reported information provided by others, all of which were relied upon in the development of the conclusions of this report. Following is a summary of principal considerations and assumptions made in developing the opinions expressed herein:

- Natural gas and associated transportation will continue to be available in the quantities and qualities required by the plant throughout the remaining terms of agreements in place.
- The assets will be operated and maintained in accordance with good industry practices, with required renewals and replacements made in a timely manner.
- Equipment will not be operated in a manner to causes it to exceed the equipment manufacturer's ratings or recommendations.
- All contracts, agreements, rules, and regulations will be fully enforceable in accordance with their respective terms, and all parties will comply with the provisions of their respective agreements.
- All licenses, permits and approvals, and permit modifications (if necessary) will be obtained and/or renewed on a timely basis; and any such renewals will not contain conditions that adversely impact the operating and maintenance costs.

5 Plant Performance Test Result Analysis

Before the site visit, Black & Veatch has provided the formats and general guidelines for DCS data collection during stable operating conditions at baseload.

The baseload performance test data for Block-1 was recorded from 15:00 Hours to 17:00 Hours at 1 minute interval on 2nd of February. Similarly, Block-2 was kept at baseload operation from 15:00 Hours to 17:00 Hours on 3rd of February and performance test data was recorded for results evaluation.

5.1 Overall Plant Performance

5.1.1 Design Parameters

The plant's design parameters at base reference conditions provided by BHEL are shown in the below Table.

Table 5-1: Plant Parameters at Reference Design Condition

PARAMETERS	UNIT	VALUE
Block-1 & 2 Gross Output	MW	363.3
Block-1 &2 weighted average gross Heat Rate (NCV basis)	Kcal/kWh	1505.7
Auxiliary Power Consumption for the entire plant	%	3.41
NOx for each Block	PPM	50
Reference Condition		
Ambient Pressure	Bar (a)	1.0
Dry bulb Temperature	DEGC	27
Relative Humidity	%	77
LHV	KJ/KG	49328
CW inlet temperature	DEGC	32

5.1.2 Heat Rate Analysis

The table 5-2 describes the high-level results of the plant performance test conducted on 2nd and 3rd February.

Table 5-2 Gross Heat Rate Analysis

Unit	Perf. Test Output (Corrected)	Perf. Test HR (Corrected)	PG Test			CERC
			Output	HR	DIFF.	[6]HR
UOM	MW	kCal/kWh	MW	kCal/kWh	%	kCal/kWh
Block-1	344.62	1572.35	373.59	1504.9	4.43	1581
Block-2	344.7	1591.27	368.06	1505.5	5.68	1581

Table 5-3: Uncorrected & Corrected Heat Rate

DESCRIPTION	BASIS	UOM	DESIGN	BLOCK-1	BLOCK-2
Gross Load	Uncorrected	MW	363.3	335.70	339.19
	Corrected			344.05	344.70
Gross Heat Rate (NCV Basis)	Uncorrected	Kcal/kWh	1505.7	1622.02	1623.11
	Corrected			1572.35	1591.27

Table 5-4: Heat Rate Comparison between Expected (Degradation Curve) and Performance Test

UNIT	FIRED HOURS	EXPECTED HEAT RATE (KCAL/KWH)	TEST HEAT RATE (COR) (KCAL/KWH)	%DIFF. FROM EXPECT.	REMARKS
Block-1	70040.3	1527.9	1572.35	2.90	GT-1 Major inspection was done in 2021 at 56950 FFH
Block-2	60526.7	1521.5	1591.27	4.58	GT-2 Major Inspection is done in June 2022 at 55489 FFH.

Performance Analysis

The % difference from expected is higher in Block-2 due to following reasons.

- Lower bottoming cycle parameters in general specially pressure, temperature, flow rate at different sections of HRSG and ST cylinder
- Higher GT Inlet Filter DP i.e. 35 mm of H2O
- High back pressure

[6] CERC tariff regulation 2019; Gas plant having COD on or after 1.04.2009 - 1.05 X Design heat rate of unit/ block at 100% MCR and at site ambient conditions, zero percent make up, design cooling water temperature/back pressure

The expected heat rate derived from degradation curve supplied by OEM, are based on multiple assumptions i.e. operations within design conditions, Waterwash frequency (on-line and off-line), inspection intervals, steam turbine back pressure etc. The expected heat rate is placed in the table to support the benefits of MI in block 2 with degradation getting reset to new lower value trajectory after MI.

Table 1 Expected vs. Actual (% HR Degradation)

	Dec'21 (Block 1 - After MI)			Feb'23 (Block 2 -After MI)		
	Fired Hours	Expected Degradation	Actual Degradation	Fired Hours	Expected Degradation	Actual Degradation
Block 1	60619.5	1.03%	1.32%	70040.3	1.48%	2.90%
Block 2	51903.8	2.34%	4.55%	60526.7	1.05%	4.30%

Expected Degradation – Based on BHEL curve, Actual Degradation - Based on Performance Test Corrected Value

Black & Veatch has summarized the major equipment efficiencies calculated from the performance test results and compared the results with design.

Table 5-5: Performance Test Comparison with Design

Efficiency	UOM	Design	Performance Test Results	
			Block-1	Block-2
Overall Efficiency of CCPP	%	57.12	54.33	54.23
Compressor Efficiency	%	92.41	87.02	86.98
Gas Turbine Efficiency	%	35.14	34.98	35.49
HRSG Efficiency	%	83.3	89.18	88.20
STG Efficiency (Shaft O/P / Heat I/P)	%	33.91	29.69	30.08
HP Turbine Efficiency	%	89.1	**85.12**	**85.86**
IP Turbine Efficiency	%	95.8	**94.16**	**94.51**
LP Turbine Efficiency (UEEP)	%	89.1	**66.25**	**64.89**

- CCPP efficiency for blocks 1 and 2 are evaluated using PTC 46 standard and values are found to be around 54.33% and 54.23% respectively against the design value of 57.12%.
- Compressor polytropic efficiency is reported as 87.02% and 86.98% compared to design of 92.41%.
- HP turbine section internal efficiency is found to be 85.12% and 85.86% respectively.
- LP turbine efficiency (based on useful energy end point) is found to be 66.25% and 64.89% respectively.

5.2 Gas Turbine

The below table describes the performance output results of block 1 and 2 gas turbines compared against the design values.

Table 5-6: Block 1 &2 GT Performance against Design Values

Parameters	Unit	Index	Design	Performance Test	
				GT-1	GT-2
GT Load (Uncorrected)	MW	A	232.39	224.77	221.73
[7]GT Load (Corrected)	MW	Acor.	232.39	225.78	229.211
Fuel Flow	SM3/Hr	B	66738	65432.64	66157.85
LHV	Kcal/M3	C	8313.87	8321.773	8321.724
Ambient temperature	Deg C		27	27.67	27.44
GT Efficiency	%	860/[(BXC)/ AX1000]	35.14	36.09	35.94
GT Corrected Gross Heat Rate (LHV basis)	Kcal/kWh	D	2447.66	2382.76	2392.98
Specific Fuel Consumption	Kg/kWh	[BXRHO/AX1000]	0.21	0.211	0.209

[7] GT Load is corrected for ambient pressure, ambient temperature, RH, fired hours, frequency, LHV and power factor.

- GT efficiency is found to be 36.09% and 35.94% respectively and is within expected range. The calculation of efficiency is performed on GT corrected power output by direct method.
- Specific fuel consumption for blocks 1 and 2 at 0.211 and 0.235 kg/kWh respectively are noted to be higher than the design value of 0.21 kg/kWh.

5.3 Axial Compressor Performance

Parameters	Units	Index	Design	Block 1	Block 2
Compressor Inlet Pressure	kg/cm2	A	1.02	0.967	0.977
Compressor Discharge Pressure	kg/cm2	B	16.83	14.19	14.13
Compressor Inlet Air Temperature	Deg. C	C	27	27.67	27.44
Compressor Discharge Air Temperature	Deg. C	D	410	412.09	413.37
Air Flow	Kg/sec	E	602.59	596.42	586.71
IGV Angle	Deg	F		87.10	87.21
Combustion Turbine Gross Load (Site)	MW	G	232.39	224.77	221.73
Compressor Adiabatic Efficiency	%	F(PR,[8]Gc)	92.99	81.94	81.86
Polytropic Coefficient	-	K=[LN (PR)/LN(PR/TR)]	1.415	1.46	1.46
Polytropic Efficiency	%	F(K,Gc)	**95.13**	**87.02**	**86.98**
Compressor Pressure Ratio	-	PR=B/A	16.5	14.67	14.46
Compressor Temperature Ratio	-	TR=D/C	2.276	2.28	2.28

- GT compressor efficiency as per test data is found to be 87.02 % and 86.98% for block 1 and 2 respectively. During test, block 1 and 2 was operated at 224.77 MW and 221.73 MW respectively.
- The pressure ratio during test condition is calculated to be 14.67 and 14.46 respectively against design of 16.5. The air flow through compressor was calculated based on the difference in the flow of GT exhaust and natural gas mass flow rate.
- Overall, the performance of compressor is satisfactory.

During the site visit, Black & Veatch was informed about filter replacement cycle being twice in 1 year, generally 1 each in summer and winter cycle. This cycle of replacement is despite inlet air pulsation system being operational for the two units.

5.3.1 Recommendations:

5.3.1.1 Inlet Air Filter Replacement Cycle

Due to increase of fine dust in the ambient air, fine filters are getting exhausted within 4-6 months. This filter replacement requires shutdown of the unit. We recommend exploring the possibility of

[8] Gc – Gas Coefficient (Inlet and Outlet of Compressor)

installing Coalascer pad rolls before the prefilters. These Coalascer pads have good dust holding capacity. These pads can be changed online whenever these get choked.

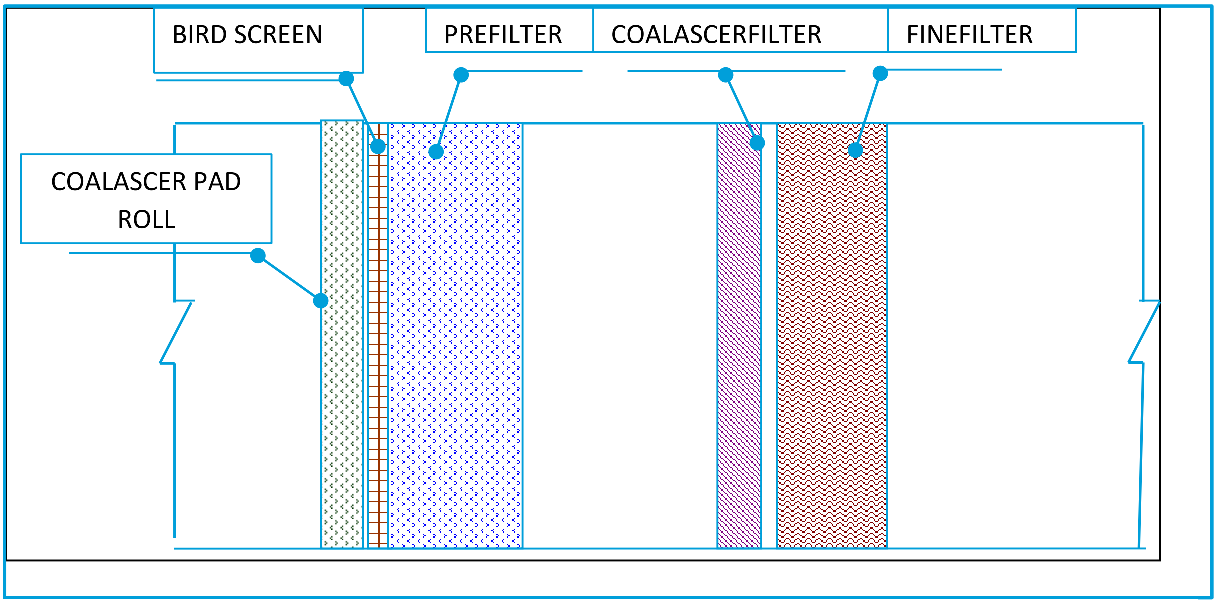


Figure 3 Coalascer Pad

The installation of coalescer pad rolls before bird screen will increase pressure drop (generally a pressure drops of 50 Pa impacts GT efficiency by 0.1%) but normally these pads are changeable on-line with ease and also extend filter replacement cycles. This modification is to be consulted with OEM and filter manufacturer before implementation for site specific environmental condition. The other possibility is upgrading / replacing fine filters to EPA grade (E10 or E11) without coalescer pad, but here also – there is a benefit-loss assessment with higher inlet air -dP (loss) and lower fouling in compressor (gain) as described above.

5.4 HRSG Performance

5.4.1 Design Parameters

The below table describes the design parameters of HRSG 1 & 2 as per the technical diary shared by OTPC.

Table 5-7: HRSG Design parameters

PARAMETERS	VALUES
HP Feed water Pressure, temperature, flow	158 kg/cm2, 152.1 DEGC, 289.6 TPH
HP Drum Pressure, temperature	145 kg/cm2, 339 DEGC
HP Main steam Pressure, temperature, flow	134 kg/cm22, 540 DEGC, 289.6 TPH
IP Feed water Pressure, temperature, flow	100 kg/cm2, 152.1 DEGC, 65 TPH
IP Drum Pressure, temperature	36.6 kg/cm2, 246 DEGC
IP SH outlet steam Pressure, temperature, flow	34.6 kg/cm22, 330 DEGC, 35.6 TPH
LP Feed water Pressure, temperature, flow	6.6 kg/cm2, 149.6 DEGC, 36.7 TPH
LP Drum Pressure, temperature	5.1 kg/cm2, 159 DEGC

PARAMETERS	VALUES
LP SH outlet steam Pressure, temperature, flow	4.4 kg/cm22, 230 DEGC, 36.7 TPH
CRH Inlet Pressure, temperature	34.8 kg/cm2, 345 DEGC
HRH outlet Pressure, temperature	33.2 kg/cm2, 540 DEGC
HRSG inlet pressure, Temperature, flow (flue gas)	266.71 mmWC, 700 DEGC, 2217.6 TPH

The below table describes the HRSG 1and 2 full load operating parameters compared against the design full load parameters and PG test DCS screenshot values (instantaneous).

Table 5-8: HRSG 1 and 2 full load parameters and comparison with design values

PARAMETERS	UOM	DESIGN	HRSG-1		HRSG-2	
			PG Test	Perf.Test	PG Test	Perf.Test
HP Main Steam Pressure,	Kg/cm2	134	129.09	126.0	126.80	122.84
HP Main Steam temperature	Deg C	540	536.05	530.6	541.00	534.6
HP Main Steam flow	TPH	289.6		292.3		286.9
IP Main Steam Pressure,	Kg/cm2	34.6	33.93	33.56	31.97	32.55
IP Main Steam Temperature	Deg C	330	312.76	312.2	326.27	327.06
IP Main Steam Flow	TPH	35.6		34.74		35.9
CRH Inlet Pressure,	Kg/cm2	34.8	33.61	35.98	30.97	34.22
CRH Inlet Temperature	Deg C	345	344.71	350.27	NA	353.22
HRH Outlet Pressure	Kg/cm2	33.2	32.71	35.02	31.90	33.30
HRH Outlet Temperature	Deg C	540	538.90	538.1	541.00	538.16
Feedwater outlet temperature	Deg C	152	147.45	149.73	149.44	149.12

5.4.2 HRSG Efficiency

The below table indicates the HRSG-1 & 2 main parameters and efficiency values from performance test output results at the GT baseload condition.

Table 5-9: HRSG Efficiency Results

PARAMETERS	UNIT	BLOCK-1	BLOCK-2
HP steam production / hr	TPH	290.9	286.9
HP steam Enthalpy	kcal/kg	818.3	821.7
IP steam production / hr	TPH	33.8	35.9
IP steam Enthalpy	kcal/kg	719.8	729.4
LP steam production / hr	TPH	36.9	36.5
LP steam Enthalpy	kcal/kg	699.7	699.0
HRSG inlet temp	Deg C	622.0	614.8

PARAMETERS	UNIT	BLOCK-1	BLOCK-2
HRSG outlet temp	Deg C	105.2	103.4
Air flow rate	TPH	2328.1	2366.6
HP Feedwater Enthalpy	kcal/kg	149.7	149.1
IP Feedwater Enthalpy	kcal/kg	147.7	146.6
LP Feedwater Enthalpy	kcal/kg	143.6	144.3
[9]HRSG (Eff)	%	89.18	88.20

- Black & Veatch has calculated the HRSG Efficiency by Input/Output method and noted that HRSG 1& 2 efficiencies are noted to be around 89.18% and 88.20% against the design value[10] of 83.35%.

5.4.3 LP Circuit Performance

The below table describes the performance of the LP circuit based on performance test results.

Table 5-10: LP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	TEST	
				HRSG-1	HRSG-2
LP Feed Water Pressure	Kg/cm2	10.4		13.4	13.6
LP Feed Water Temperature	Deg C	149.5	[A]	143.6	144.3
Enthalpy of LP Feed Water	Kcal/kg	150.7		144.6	145.3
Energy from LP FW	Kcal/sec	1536.43	[C]	1422.8	1455.0
LP Drum Pressure	Kg/cm2	5.1		4.8	4.8
LP Saturation Temperature	Deg C	158.92	[B]	157.4	157.5
LP Main Steam Flow	TPH	36.7	[E]	35.4	36.1
LP Main Steam Pressure	Kg/cm2	4.8		4.7	4.6
LP Main Steam Temperature	Deg C	229		235.5	234.5
LP Steam Enthalpy	Kcal/kg	696.9	[F]	699.5	699.0
Energy From LP Steam	Kcal/sec	7105.08	[D=E*F]	6881.8	7000.1
Energy Gain from LP Circuit	Kcal/sec	5568.65	[D-C]	5459.0	5545.1
Approach	Deg C	9.42	**[B-A]**	**13.7**	**13.2**

- The energy gain from the LP circuit is around 5459 and 5545 Kcal/sec for HRSG 1 & 2 respectively against the design values of 5568 Kcal/sec.

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[9] HRSG Efficiency is based on ratio of heat pick up in HP, IP, and LP circuit (output) and heat input from fuel gas across the control volume. [HP Steam flow X HP Steam Enthalpy Gain + IP Steam Flow X IP Steam Enthalpy Gain + RH Steam Flow X RH Steam Enthalpy Gain + LP Steam Flow X LP Steam Enthalpy Gain] / [Flue Gas Flow Rate X (HRSG Inlet Temp – HRSG Outlet Temperature) X Cp of Gas] *100

[10] Design details are calculated based on the design data available in technical diary and heat balance diagram.

- LP circuit approach is found to be around 13.7 and 13.2 Deg C respectively for HRSG 1 and 2 against the design value of 9.42 deg C.

5.4.4 IP Circuit Performance

The below table describes the performance of the IP circuit based on performance test results.

Table 5-11: IP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
IP Feed Water Flow	TPH	65.16		55.62	70.09
IP Feed Water Pressure	Kg/cm2	43.6		54.44	52.73
IP Feed Water Temperature	Deg C	150.2		147.73	146.64
Enthalpy of IP Feed Water	Kcal/kg	121.7		149.42	148.28
Energy from IP FW	Kcal/sec	2202.91	G	2308.52	2886.81
IP Drum Pressure	Kg/cm2	36.6		37.02	35.77
IP Saturation Temperature	Deg C	244.01	[B]	247.40	245.46
IP Main Steam Flow	TPH	35.8	[D]	33.82	35.90
IP Main Steam Pressure	Kg/cm2	36.6		33.56	32.55
IP Main Steam Temperature	Deg C	246		312.20	327.06
IP Steam Enthalpy	Kcal/kg	730.2	[E]	719.80	729.39
Energy From IP Steam	Kcal/sec	7262.01	F=D*E	6762.11	7272.68
Energy Gain from IP Circuit	Kcal/sec	5059.1	H=F-G	4453.59	4385.87
IP Economizer Outlet Temp.	Deg C	231	[B]	228.69	231.11
[11]Approach	Deg C	13.01	**[B-A]**	**18.71**	**14.35**

- Energy gain from the IP circuit is around 4453.59 and 4385.87 Kcal/sec for HRSG 1 & 2 respectively against the design values of 5059 Kcal/sec.
- IP circuit approach is found to be around 18.71 and 14.35 Deg C respectively for HRSG 1 and 2 against the design value of 13.01 deg C.
- Higher approach signifies reduced hear transfer in the economizer section either due to internal/ external fouling or surface area constraints. The assumption is that upstream parameters of HRSG like feedwater pressure, temperature is close to expected range. Please note that before inferring heat transfer issues, it is important that a trend of degradation is established over time with correct measuring points.

[11] Approach = IP economizer feed water outlet temperature – Saturation temperature corresponding to IP drum pressure

- Heat pick-up in the HRSG -1 IP circuit is observed to be below the design (~9-10%). The difference is attributable to lower IP steam flow rate and enthalpy and higher IP feed water inlet enthalpy with the addition of 6.48 TPH spray in bypass.
- Heat pick-up in the HRSG-2 IP circuit is lower due to higher IP feed water flow caused by IP bypass spray flow of 19.46 TPH. This has also impacted reheat circuit energy gain.

5.4.5 HP Circuit Performance

The below table describes the performance of the HP circuit based on performance test results.

Table 5-12 HP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
HP Feed Water Flow	TPH	289.6	[H]	290.12	284.64
HP Feed Water Pressure	Kg/cm2	158		147.69	144.98
HP Feed Water Temperature	Deg C	152.1		149.05	147.91
Enthalpy of HP Feed Water	Kcal/kg	155.5	[I]	152.15	150.95
Energy from HP FW	Kcal/sec	12510.11	[G=H*I]	12261.64	11935.58
HP Drum Pressure	Kg/cm2	145		137.08	134.31
HP Saturation Temperature	Deg C	338.46	[B]	335.59	329.4
HP Main Steam Flow	TPH	289.6	[E]	300.15	291.95
HP Main Steam Pressure	Kg/cm2	135		125.97	122.84
HP Main Steam Temperature	Deg C	540		530.57	534.62
HP Steam Enthalpy	Kcal/kg	821.8	[D]	818.32	821.67
Energy From HP Steam	Kcal/sec	66114.53	[F=D*E]	68227.21	66635.59
Energy Gain from HP Circuit	Kcal/sec	53604.42	[F-G]	55965.57	54700.02
HP Economizer Outlet Temp.	Deg C	334.19	[A]	331.20	**318.2**
[12]Approach	Deg C	4.27	[B-A]	4.40	**11.2**

- Energy gain from HP circuit is around 55965.57 and 54700 Kcal/sec for HRSG 1 & 2 respectively against the design values of 53604 Kcal/sec.
- HP circuit approach is found to be around 4.40 and 11.20 Deg C respectively for HRSG 1 and 2 against the design value of 4.27 deg C. In general, steam parameters (pressure and temperature) in HP sections are observed to slightly lower if compared to design or Unit 1. Unit specific variation in operating characteristic within range is normal, however this variation should be continuously checked.

[12] Approach = HP economizer feed water outlet temperature – Saturation temperature corresponding to HP drum pressure

- Approach signifies heat transfer gain in the superheater section of HRSG from the fuel gases. HRSG for HP Circuit 2 is high as we see lower HP economizer outlet temperature i.e. 318.9 Deg. C as compared to design of 334.19 Deg. C. Please note in general HP -2 pressure and temperature parameters are lower during the test. As noted above, a single point deviation is only a snapshot and a trend over time is to be analyzed with correct measurement to check any fouling in the tube section.

5.4.6 Reheater Circuit Performance

The below table describes the performance of the RH circuit based on performance test results.

Table 5-13: Re-heater circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
CRH Flow	TPH	269.45	[D]	270.67	266.72
CRH Pressure	Kg/cm2	35.85		35.98	34.22
CRH Temperature	Deg C	347.5		350.27	353.22
Enthalpy of CRH	Kcal/kg	740.3	[E]	741.03	743.67
Energy from CRH	Kcal/sec	55413.83	[F=D*E]	55714.37	55098.50
IP Feed water Flow	TPH	35.8		40.30	**55.36**
IP Feed Water Pressure	Kg/cm2	36.6		33.56	32.55
IP Feed Water Temperature	Deg C	246		312.20	327.06
IP Bypass Spray	TPH	0		6.48	19.46
Enthalpy of IP Feed Water	Kcal/kg	730.2		719.80	729.39
Energy from IP FW	Kcal/sec	7262.01	[G]	8057.75	11216.12
HRH Flow	TPH	305.045	[A]	307.70	306.43
HRH Pressure	Kg/cm2	33.3		35.98	34.22
HRH Temperature	Deg C	540		538.14	538.16
Enthalpy of HRH	Kcal/kg	846	[B]	844.73	845.15
Energy from HRH	Kcal/sec	71739.49	[C=A*B]	72200.10	71938.46
Total Energy into Re-Heater	Kcal/sec	62675.85	[H=F+G]	63772.12	66314.62
Energy Gain from Re-Heater	Kcal/sec	9063.64	[C-H]	8427.98	**5623.84**

- Energy gain from the reheater circuit is around 8427.98 and 5623.84 Kcal/sec for HRSG 1 & 2 respectively against the design values of 9063.6413Kcal/sec.

[13] Design heat pick up is calculated based on the design data available in the technical diary and heat balance diagram the design values

- Heat picks up in the HRSG-2 reheater circuit is lower due to higher IP feed water flow caused by IP bypass spray flow of 19.46 TPH. This has also impacted reheat circuit energy gain adversely if compared to design heat gain.

5.4.7 Recommendations

5.4.7.1 Suspected IP Bypass System Steam Passing & Steam Valve Upgrade

IP bypass controllers are also not able to effectively contain the steam and even hair line cracks in control valve may lead to significant flow of steam to condenser impacting condenser vacuum adversely. Our test data shows that IP bypass spray valve for Unit 1 and 2 was 6.48 TPH and 19.4 TPH respectively which suggest that there may be suspected steam flow in the downstream pipe, even though bypass valve position is shown as fully closed. It is necessary that suspected steam leakage in IP steam pipe is quickly arrested in available opportunity.

Unlike traditional control valves, there are designs which uses multi-stage, multi-turn technology divides the pressure reduction into many smaller stages. The number of turns, or stages, is selected to ensure a specific fluid discharge velocity is achieved at the exit of the control element. This reduces the potential for cavitation and erosion, that would otherwise compromise the valve's ability to effectively control leakage.

5.4.7.2 CBD Tank Vents Open to Atmosphere

As per the design, the Continuous Blow-Down Tank (CBD) vent is routed to Deaerator however, based on site-visit discussions, it is understood that for both units, CBD vent lines are kept open to atmosphere. CBD vent should be routed to the Deaerator for fluid recovery and improved energy utilization.

5.5 Steam Turbine

The below table indicates the performance output results of ST-1 and 2 at the GT baseload condition.

Table 5-14: Steam Turbine Performance

Parameters	Unit	Design	Performance Test	
			ST-1	ST-2
Unit Load	MW	130.91	112.81	113.64
MS Pressure	Kg/cm2	133.88	125.97	122.84
MS Temperature	Deg C	537.8	530.57	534.62
HP Exhaust Pressure	Kg/cm2	37.03	34.12	32.33
HP Exhaust Temperature	Deg C	347.3	348.76	347.95
HRH Pressure (IP Turbine Inlet)	Kg/cm2	34.4	33.56	32.55
HRH Temperature (IP Turbine Inlet)	Deg C	539.6	538.14	538.16
IP Turbine outlet pressure	Kg/cm2	5.04	4.71	4.21
IP Turbine outlet temperature	Deg C	264.5	282.17	274.45
LP Turbine inlet pressure	Kg/cm2	4.96	4.63	4.21
LP Turbine inlet temperature	Deg C	261.2	235.58	233.60
LP Turbine outlet pressure	Kg/cm2	0.088	0.200	0.173
LP Turbine outlet temperature	Deg C	NA	58.41	56.39

Parameters	Unit	Design	Performance Test	
			ST-1	ST-2
HP FW Flow	TPH	289.6	290.12	284.64
HP SH Attemperation Flow	TPH	0.00	10.03	7.31
IP FW Flow	TPH	65.15	55.62	70.09
IP SH Attemperation Flow	TPH	0.00	6.48	19.46
RH Attemperation Flow	TPH	0.00	3.76	3.16
STG Thermal Efficiency (Design 36.66)	%	36.66	32.32	29.93
HP Turbine Cylinder Efficiency(design-89.1%)	%	89.79%	**85.12**	**85.86**
IP Turbine Cylinder Efficiency(design-95.8%)	%	95.78%	**94.16**	**94.51**
LP Turbine Cylinder Efficiency(design-89.1%)	%	89.04%	**66.25**	**64.89**

5.5.1 Recommendations:

5.5.1.1 HP/IP Section Internal Efficiency Improvement by Seal Upgrade

Leakage losses represent the greatest portion of turbine stage losses. The losses are magnified as the turbine packing and turbine diaphragm spill strips wear out progressively. A large amount of these losses is recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization.

New turbine blade cover and nozzle spill strip designs are available which greatly reduce turbine blade tip leakage losses. New interstage and end packing will reduce packing leakage losses, resulting in more steam available to power the turbine blades. Retractable packing and brush seal packing designs are available from various manufacturers, which aim to reduce leakage losses even further from original designs. This upgrade can be performed at the HP/IP turbine major inspection and should be performed after engineering analysis and in consultation with OEMs.

The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP and IP turbine efficiencies. Typical efficiency improvements up to 0.7-1.2 % in heat rate is reported in the past. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.

The retrofit requires checking the actual clearances of the seals with respect to manufacturer's design clearances[14]. This task will help assess the extent of wear in the seals or help to find out the deviation of clearances from manufacturer's design clearances.

Replacement of existing seals with superior quality seals[15]. A generally guideline for replacement of seals is provided in the table below.

[14] Manufacturer's design clearances were not available.

[15] Option is feasible only when the slots provided by manufacturer fit with new type of seal

Table 5-15 General Guideline for Seal Replacement

Seal	Type
HIP Inter stage	Double stepped
HP turbine seals	Stepped
IP Turbine seal	Stepped
LP turbine seal	Plain seal

Actual clearances if found to be deviating from design clearances, it is recommended to explore the replacement and upgrade of the seals during the capital overhaul at 100,000 hours of steam turbine operation. Following are recommended seal types and arrangements based on industry best practices.

Vernier labyrinth seal: Seals provide better leakage resistance. The gland is independent of differential expansion. Both the shaft and seal ring are finned, the pitch of the fins being slightly different on the two seal components. This has the advantage that some of the fins will always be directly opposite, providing a greater restriction.

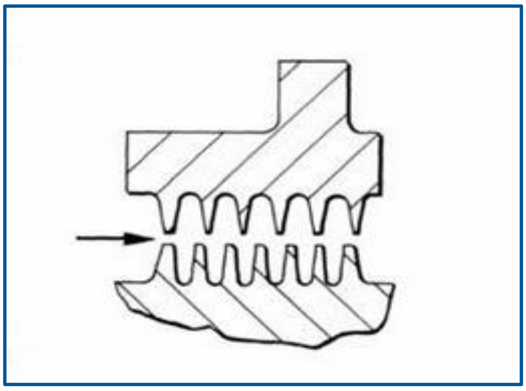


Figure 4 Vernier Labyrinth Seal

[16]**Spring backed labyrinth seal:** The radial clearance of the labyrinth gland is kept to minimum to minimize leakage across the gland (leakage is proportional to leakage area). The effects of rub are minimized in close clearance glands by making glands spring loaded.

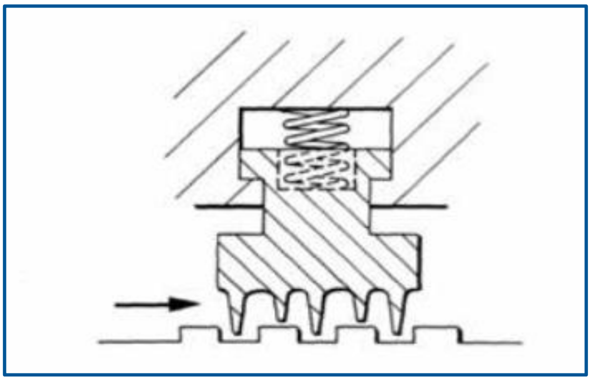


Figure 5 Spring Loaded Vernier Labyrinth Seal

[16]Power Plant Engineering, Black & Veatch

Labyrinth Glands with Fins in Radial & Axial Direction: The design increases the number of restrictions in a given gland length. The thickness of gland tip is kept minimum to avoid rubbing or if accidental rubbing happens, the heat generated is minimum.

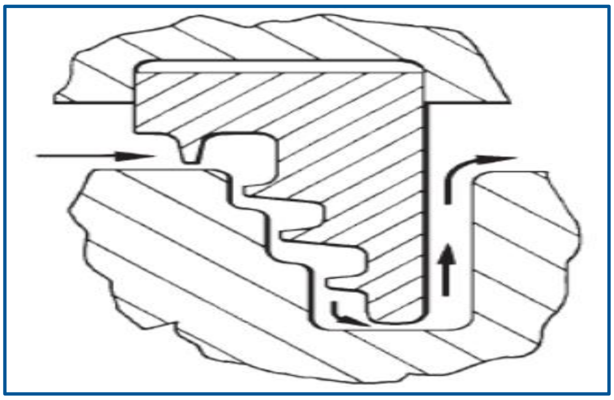


Figure 6 Labyrinth Glands with Axial and Radial Fins

5.5.1.2 Determination of HP to IP Leakage Flow (Temperature Inference Method)

The N2 packing leakage to IP turbine bowl is calculated using the temperature inference method. This method is an indirect method to determine the magnitude of leakage flow, since this leakage flow is inside the turbine, and it is impractical to directly measure it. Determination of the leakage flow shall also determine the true IP turbine efficiency. The leakage flow may be somewhat greater than or less than the actual design flows, depending upon the packing clearance and stage pressure.

A diagrammatic representation of available parameters for HP-IP turbine is shown below.

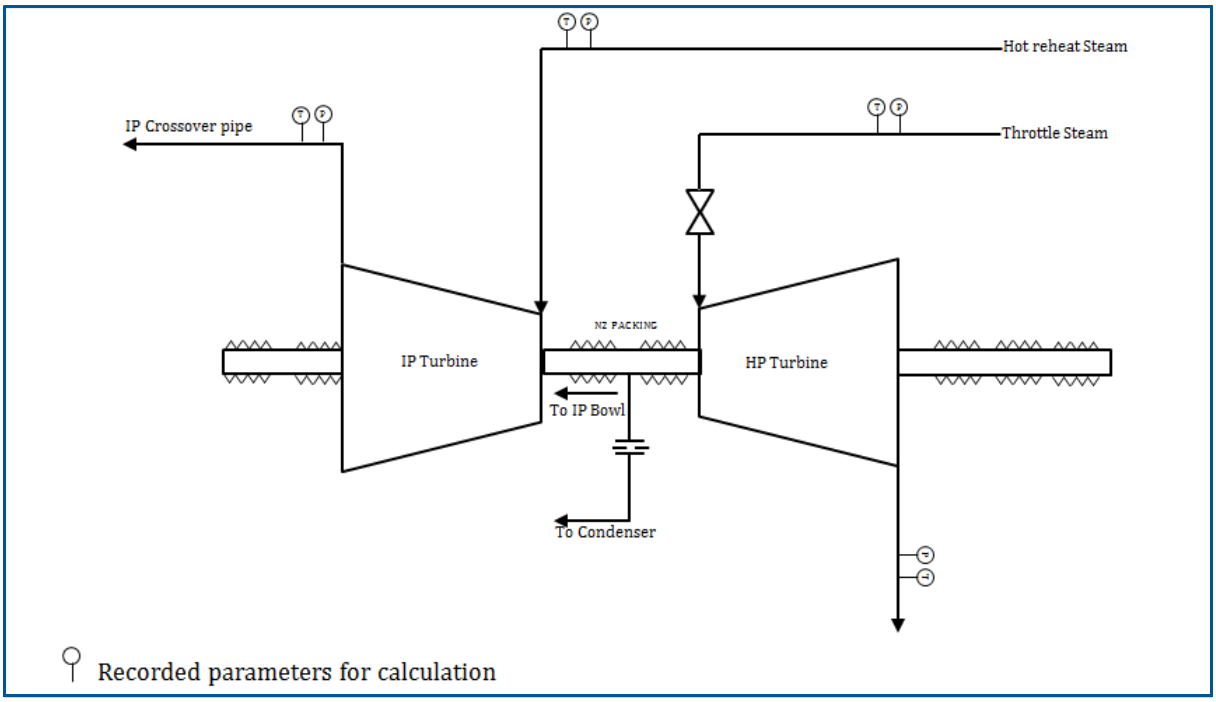


Figure 7 Determining HP-IP Leakage (Temperature Inference Method)

The basis of the temperature inference method is that IP section efficiency remains constant over the operating range. The method is based upon cooling effect that the internal HP to IP packing leakage on the apparent IP section efficiency.

The leakage from HP to IP section is generally cooler than the steam entering in the IP bowl, thereby yielding a reduced enthalpy condition at the IP exhaust and corresponding change in the "apparent" enthalpy efficiency drop.

The HP steam leaking to the IP cools the steam in the IP yielding an erroneously high value of measured IP efficiency, if not properly compensated. The amount of error in IP efficiency will vary according to the difference in enthalpy between the leakage steam and hot reheat steam. In this method, If initial temperature is raised and reheat temperature is decreased, this error will decrease and conversely it will increase if initial temperature is lowered and /or reheat temperature is increased.

In this method, at least three tests are run with variation in initial and reheat temperature. For each of the three tests, the measured IP efficiency for various assumed values of HP to IP leakage may be calculated. A curve of IP efficiency versus assumed leakage flow, as a percent of reheat flow is plotted. The lines for each test run will intersect at a point that indicates the actual HP to IP leakage and the actual IP turbine efficiency.

The temperature inference method is provided in **ASME PTC 6.2** code (***Please refer section C5 : Guiding Principle for Temperature Inference, IP Efficiency Plot and Ratio of Slopes Methods"***). In this method, at least three test runs are recommended with variation in main steam and reheat temperature.

For each of the three tests, the measured IP efficiency for various assumed values of HP to IP leakage may be calculated. A curve of IP efficiency versus assumed leakage flow as a percent of reheat flow is plotted. The lines for each test run will intersect at a point that indicates the actual HP to IP leakage and the actual IP turbine efficiency. An indicative methodology is provided, however please note that this is to be designed for individual units reviewing operational constraints and applicable temperature drop achievable without impacting the equipment adversely.

This test is to be carried out to estimate the N2 packing leakage between the HP and IP sections of the turbine. This is calculated by using the enthalpy drop test. Test procedure is as follows: -

- Maintain 100% load of the unit and main steam and hot reheat temperatures at base value. Once the parameters are stable test run will be carried out for 1 hour.
- Maintain MS temperature at base level and reduce the HRH temperature.
- Once the parameters are stable test run will be carried out for 1 hour.
- Bring the HRH temperature back to base value and then reduce MS temperature. Once the parameters are stable test run will be carried out for 1 hour.
- Retrieve the data for the steam parameters, estimate IP efficiency and perform the graphical analysis as described above for estimating HP-IP internal leakage.

5.5.1.3 Improving LP Turbine Efficiency by Improved Blade Design and Increased Annulus Area

The steam seal upgrade tends to decrease heat rate and increase LP turbine efficiency. The new gland seals also reduce the in-air leakage around the shaft. The improved gland seal reduces the amount of air that enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air in-leakage through improved seals can decrease (improve) back pressure by 4-12 KPa absolute with a corresponding heat rate improvement of nearly 1.0%.

Large OEMs globally also provide customized retrofit packages consisting of replacement of low-pressure turbine blades using improved blade design and increased exhaust annulus area to improve performance. The performance gain in the LP section based on industry experience is commendable with output increasing up to 1.00% and heat rate reduction up to 0.75% with only steam seal upgrades. The replacement is normally doable in capital overhaul, however the need for this retrofit to be carefully worked out evaluating turbine internal condition and aging of the machine.

The last stage buckets are responsible for approximately 10% of the turbine's total output. Redesign of the last stage buckets, including increasing length, reduces exhaust loss by increasing the amount of energy removed from the steam. This increases capacity and decreases heat rate. The project includes replacing the last stage LP turbine buckets or blades with new longer blades. Replacing the last stage diaphragm is also recommended to maximize efficiency gain. Longer last stage buckets reduce exhaust losses by maximizing the amount of energy extracted from the steam. This is done by increasing the area of the last stage to reduce exhaust velocity. Performance gains from replacing the last stage buckets is dependent on where the unit operates on the Exhaust Loss Curve. Combined with last stage bucket replacement, up to 3% improvement in output and 2.5% reduction in heat rate can be realized.

5.5.1.4 Performance Monitoring of HP Turbine Section & In-Situ Instrumentation for HP Exhaust Pressure and Temperature

One of the most critical measurements for analyzing HP turbine internal efficiency is HP turbine exhaust temperature. The ASME PTC test code 46 specifies this measurement to be close to HP turbine exhaust. Figure 5 below specifies the preferable location of measurement. Minimum 2 measurement of HPT exhaust temperature is recommended with instrument of 1 Deg. F or 0.56 Deg. C accuracy class for best results. HP exhaust pressure measurement is also recommended with an instrument of accuracy class 0.1%. The criterion for accuracy is stringent given the nature of calculations and its criticality to predict overall turbine internals condition.

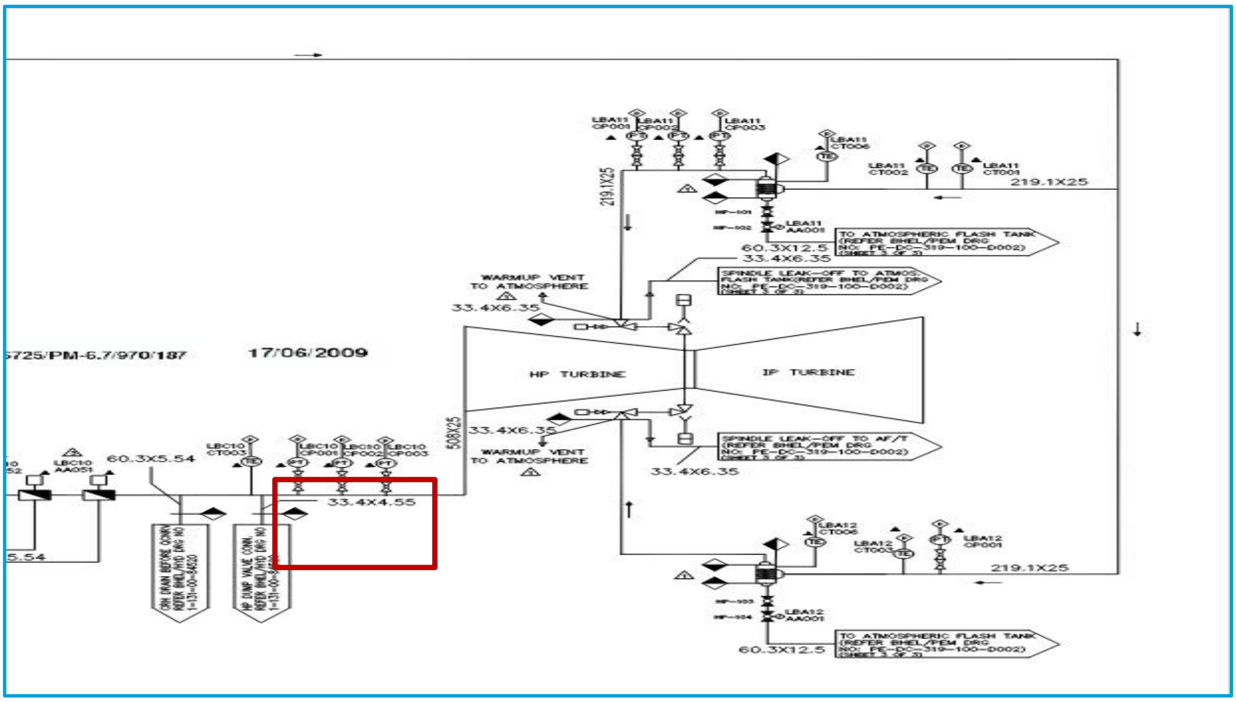


Figure 8 HP Exhaust Temperature Measurement

5.6 Condenser

The below table indicates the performance output results of Condenser-1 and 2 at the GT baseload condition against the design values.

Table 5-16:Condenser 1 & 2 Performance against Design performance

PARAMETERS	UNIT	DESIGN	INDEX	BLOCK -1	BLOCK-2
LP Exhaust Steam Flow	TPH	354.3		361.54	359.30
CW Inlet temperature	Deg C	32	[F]	34.33	31.18
CW outlet temperature	Deg C	41	[G]	44.30	40.57
Delta P (Difference) - LHS	mwc	**6**		**12.644**	
Delta P (Difference) - LHS	mwc	**6**		**12.972**	**12.380**
CW Flow	M3/hr	21000		23041	23044
Delta T (Difference)	Deg C	9	[H=G-F]	9.97	9.39
Vacuum	Kg/cm2(a)	0.095		0.200	0.1731
Saturation temperature	Deg C	44.43	[E]	59.64	56.56
Hot well temperature	Deg C	44.43		58.41	56.39
Sub-cooling	Deg. C	0		1.23	0.17
Dissolved O2 (Condensate)	ppb			17.86	3.13
TTD	Deg C	3.43	[E-G]	15.34	16.00

PARAMETERS	UNIT	DESIGN	INDEX	BLOCK -1	BLOCK-2
LMTD	Deg C	7.08	**H**	**19.9**	**20.3**
[17]Estimated Heat Duty	MW	**286.098**	**"U"*A*[H]**	**267.281**	**275.933**
Actual Heat Transfer Coefficient	kCal/hr-m2-C		[A]	1210.35	1154.12
Max. Possible Heat Transfer (100% Clean Tubes)	kCal/hr-m2-C		[B]	3718.91	3667.26
Cleanliness	-	0.8	**[A/B]**	**0.33**	**0.31**

- Condenser vacuum is reported as 0.200 kg/cm2 (a) and 0.173 kg/cm2 (a) at inlet CW temperature around 34.33 and 31.11 deg C in Unit 1 and 2 respectively.
- Condenser cleanliness is found to be around 0.33 and 0.31 respectively for condensers 1 and 2 against a design value of 0.80.

5.6.1 Back Pressure Deviation Check

Black & Veatch further analyzed the reasons for the higher back pressure in both units. The expected backpressure is calculated based on the design inlet parameters at clean condenser conditions.

Table 5-17: Unit 1 Condenser Spot back Pressure Check (Actual Vs Expected Analysis)

Back Pressure Check	UNIT	INDEX	Unit 1	Unit 2
Load	MW		112.81	113.64
Actual back pressure	bar	[F]	0.196	0.170
CW inlet temperature	Deg. C		34.33	31.18
CW outlet temperature	Deg. C		44.30	40.57
Hot Well Temperature	Deg. C		61.61	57.98
Barometric pressure	bar		1.006	1.005
Actual Back Pressure	kPa		**19.61**	**16.96**
Saturated Steam Temperature	Deg. C		59.64	56.54
Actual CW rise	Deg. C		9.969	9.39
Actual TTD	Deg. C		15.34	15.97
Expected back pressure	kPa	**[A]**	**10.24**	**9.00**
Optimum CW rise (From HBD @33 CW Inlet)	Deg. C		9.00	9.00
Optimum TTD (From HBD)	Deg. C		3.50	3.50
Back pressure due to CW inlet temp	kPa	[B]	15.71	14.25
Back pressure due to CW flow	kPa	[C]	16.17	14.42

[17] Condenser design heat duty – 246 mkCal/hr.
Estimated Heat Duty = Overall heat transfer coefficient*Surface Area of Condenser Tubes* LMTD

Back Pressure Check	UNIT	INDEX	Unit 1	Unit 2
Variation due to CW inlet temp. = Back Pressure due to CW inlet temp – Target Back Pressure	kPa	**[D=A-B]**	**5.47**	**5.25**
Variation due to CW flow = Back Pressure due to CW flow – Back Pressure due to CW inlet temp	kPa	**[E=C-B]**	**0.46**	**0.18**
Variation due to air/dirty tubes TTD = Actual Back Pressure – Back Pressure due to CW flow	kPa	**[F-C]**	**3.44**	**2.53**

Given the CW Inlet temperature of 34.33 Deg. C and 31.18 Deg. C for Condenser 1 and 2, If we consider design range of 9 deg. C (i.e. difference of CW inlet and outlet temperature) and [18]design TTD of 3.50 deg. C, we expect the back pressure to be 10.24 kPa and 9.00 kPa respectively. The back pressure measured at the test period was 19.61 kPa and 16.96 kPa respectively.

The deviation in back pressure due to CW inlet temperature is for Unit 1 is due to high CW inlet temperature (34.33Deg. C compared to design of 32 Deg. C) and high heat load. Please note that LP exhaust flow is higher by 7.24 TPH than design of 354.3 TPH with expected higher enthalpy steam entering condenser.

The gap in expected and actual vacuum is 9.37 kPa and 7.96 kPa respectively. The assessment shows that majority of back pressure deviation in Unit 1 (~37%) is attributable to impact of air ingress or dirty tubes. In Unit 2 (~32%) of back pressure deviation is attributable to air ingress / dirty tube.

Further evaluation of DP (delta pressure) across condenser suggests that delta P across both water boxes is much higher than design limits of 6 mwc. DO levels are also found to be higher in condensate water specially for Unit 1 which is 17.86 ppb.

Table 5-18 Condenser Parameters

PARAMETERS	UNIT	DESIGN	BLOCK-1	BLOCK-2
LP Exhaust Steam Flow	TPH	354.3	361.54	359.30
CW Inlet temperature	Deg C	32	34.33	31.18
CW outlet temperature	Deg C	41	44.30	40.57
Delta P (Difference) - LHS	mwc	**6**	**12.644**	**NA**
Delta P (Difference) - LHS	mwc	**6**	**12.972**	**12.380**
Dissolved O2 (In Condensate)	ppb	**-**	**17.86**	**3.13**
Condenser Cleanliness	-	**0.80**	**0.33**	**0.31**

5.6.2 Review of Condenser Cleanliness

The inspection was carried out on 21st June and 23rd June 2022 for Unit 2 during MI.

[18] Minor variation in TTD with CW inlet temperature is estimated based on HBDs. The HBD referred are PE-DC-319-100-D101, PE-DC-319-100-D106, PE-DC-319-100-D111 (100% CC load, 0% make up and 27 Deg. C, 9 Deg. C and 15 Deg. C ambient conditions respectively.

Observations After Opening of Condenser Water box :

- Tubes were choked from the slime and broken PVC fills.
- Tube sheet was not cleaned. Scales, depositions, slime and iron nodules were observed.
- Algae / organic growth was not concerning.
- No tube leakage observed while performing flood test.
- Issues found in water treatment (phosphate -zinc based compounds) for anti-scaling, bio-dispersion, corrosion inhibition, PH reduction and microbial control.

5.6.3 Condenser Instrumentation Adequacy

Plant operators and engineers require adequate instrumentation to continuously monitor plant operations, equipment health, and diagnostic of operation anomalies. As requested by OTPC, Black & Veatch has reviewed the instrumentation adequacy for calculating condenser performance.

5.6.3.1 Steam side Instrumentation:

Source: P&ID / 32-CONDENSATION SCHEME-21310084532-S00-R00

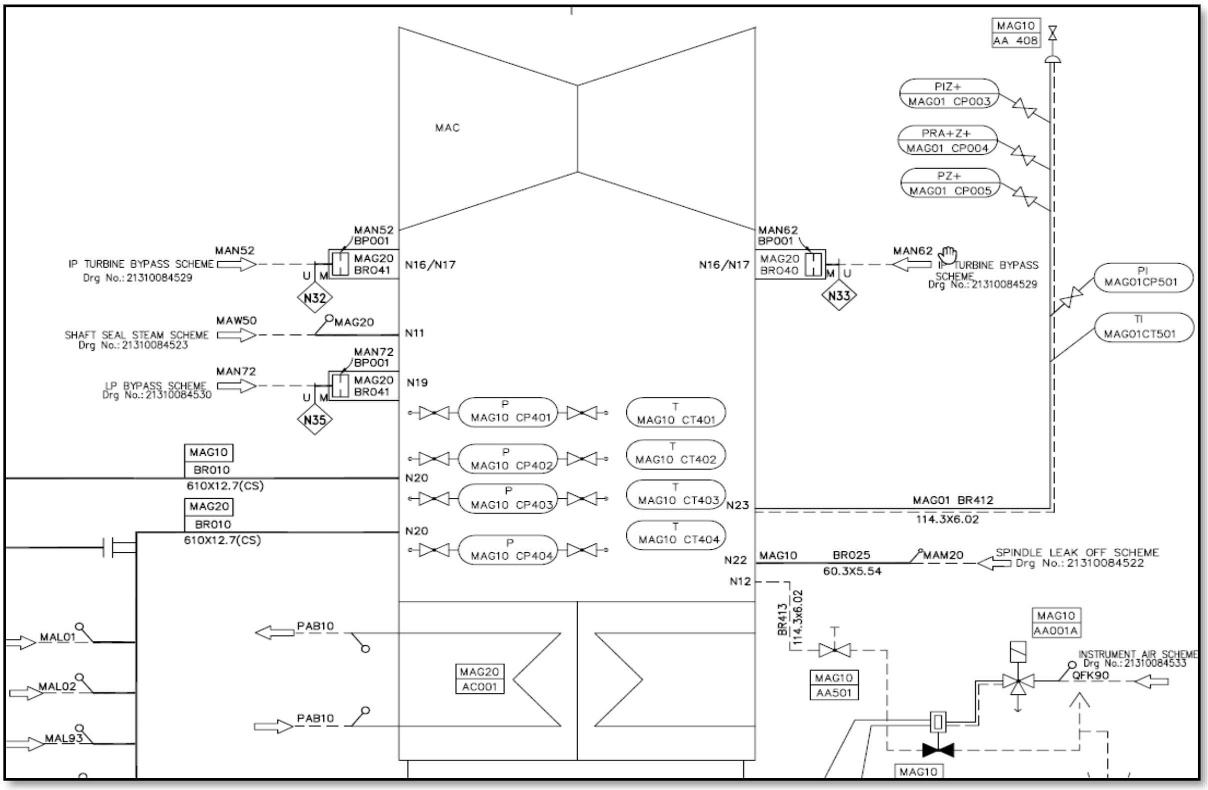


Figure 5-9: LP Turbine Steam Condensation System P&ID

As per the above P&ID and instrumentation schedule provided in the O&M manual (ONGC Steam Turbine/VOLUME-2 PART-2/Page no: 244), Black & Veatch understands that the following instrumentations are available for the condenser steam side measurements,

Table 5-19: Available Instruments for Condenser Steam Side Measurement

S.NO	MEASUREMENT	TAG NO
1	Condenser Pressure	MAG01 CP003

S.NO	MEASUREMENT	TAG NO
2	Condenser Pressure	MAG01 CP004
3	Condenser Pressure	MAG01 CP005
4	Condenser Pressure	MAG01 CP501
5	Condenser Pressure	MAG01 CP401
6	Condenser Pressure	MAG01 CP402
7	Condenser Pressure	MAG01 CP403
8	Condenser Pressure	MAG01 CP404
9	Condenser Temperature	MAG01 CT501
10	Condenser Temperature	MAG01 CT401
11	Condenser Temperature	MAG01 CT402
12	Condenser Temperature	MAG01 CT403
13	Condenser Temperature	MAG01 CT404
14	Vacuum Breaker Open	MAG10 CG051B
15	Vacuum Breaker Open	MAG10 CG051C

Black & Veatch opines that the instrumentation available for steam side measurements is adequate for calculating condenser performance. *The three condenser pressure instruments namely MAG01 CP003, CP004, and CP005 taken are used for the plant performance calculations.*

The below table describes the 2 hours average value of these three condenser pressure measurements taken during the performance test at full load conditions. ***Based on historian data made available to Black & Veatch, the sampling frequency of vacuum tags in DCS historian for Unit 1 are observed to be once every 60 minute which is very high. It is recommended to correct the tag sampling frequency in DCS to every minute interval.***

Table 5-20: Condenser Pressure Readings During Performance Test

BLOCK	TAG	AVERAGE VALUE IN
Block-1	11MAG01CP003XQ07.Out.Sample	0.2001
	11MAG01CP004XQ07.Out.Sample	0.1987
	11MAG01CP005XQ07.Out.Sample	0.2008
Block -2	21MAG01CP003XQ07.Out.Sample	0.1722
	21MAG01CP004XQ07.Out.Sample	0.1721
	21MAG01CP005XQ07.Out.Sample	0.1729

Black & Veatch recommend OTPC to ensure the calibration of all the instruments as recommended by OEM.

5.6.3.2 Waterside Instrumentation:

Source: P&ID/ PE-DG-319-165-N101 Rev 03 P&ID for CW-ACW SYSTEM

Black & Veatch has reviewed the instrumentation available in the CW waterside of the condenser for enabling condenser performance calculation as per the standards.

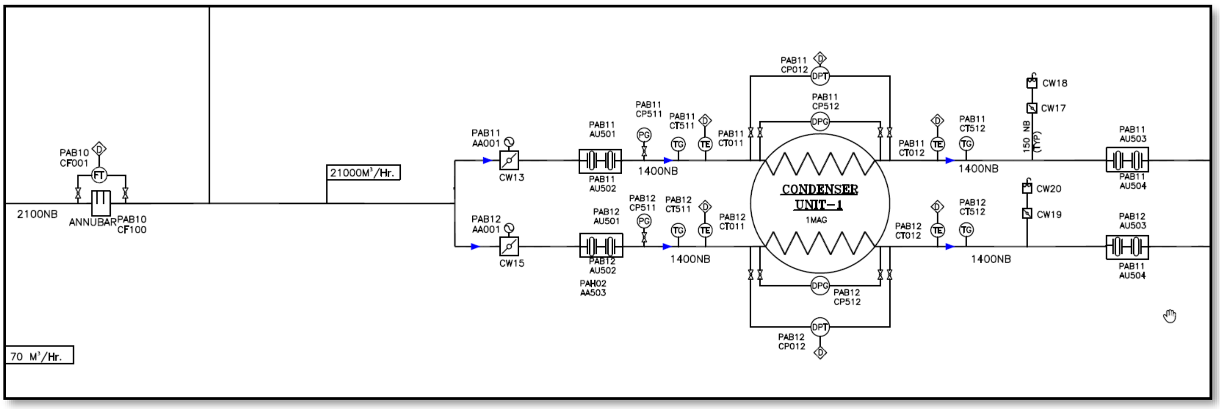


Figure 5-10: CW & ACW P&ID

As per the above P&ID, Black & Veatch understands that the following instrumentations are available at the condenser for waterside measurements.

Table 5-21: Available Instruments for Condenser Water Side Measurement

S.NO	MEASUREMENT	TAG NO
1	CW Flow (Annubar)	PAB10 CF001
2	CW Inlet Pressure Pass- 1	PAB11 CP511
3	CW Inlet Pressure Pass- 2	PAB12 CP511
4	CW Inlet Temperature Pass -1	PAB11 CT511
5	CW Inlet Temperature Pass -2	PAB12 CT511
6	CW Inlet Temperature Pass -1	PAB11 CT011
7	CW Inlet Temperature Pass -2	PAB12 CT011
8	DP Measurement Pass-1	PAB11 CP012
9	DP Measurement Pass-2	PAB12 CP012
10	DT Measurement Pass -1	PAB11 CP512
11	DT Measurement Pass -2	PAB12 CP512
12	CW Outlet Temperature Pass -1	PAB11 CT012
13	CW Outlet Temperature Pass -2	PAB12 CT012
14	CW Outlet Temperature Pass -1	PAB11 CT512
15	CW Outlet Temperature Pass -2	PAB12 CT512

It was observed that the CW (Annubar) (PAB10 CF001) flow measurement values of Unit-1 & 2 are around 23041.93 TPH and 33414.21 TPH. Black & Veatch validated the flow in Unit 2 using CW pump head and discharge characteristic and found the flow measurement to be erroneous. The calibration of this instrument is recommended in nearest opportunity.

CW Flow is the total flow measurement at the CW header which includes the CW flow to condenser circuit and ACW circuit. As per the P&ID (PE-DG-319-165-N101 Rev 03 P&ID for CW-ACW SYSTEM), there are separate flow meters to measure ACW flow to each PHE which also includes CW blowdown flow (flow meter is available to measure the blowdown) and HRSG blowdown tank flow.

Cross verification of the CW flow at the Cooling tower riser utilizing portable offline meter(like Ultrasonic flow meter) on a periodic basis is recommended once in every 6 months.

5.6.3.3 Air Extraction side Instrumentation:

Source: P&ID/ Vacuum Pump Manual/Chapter 5/ Drawings/Page no:2

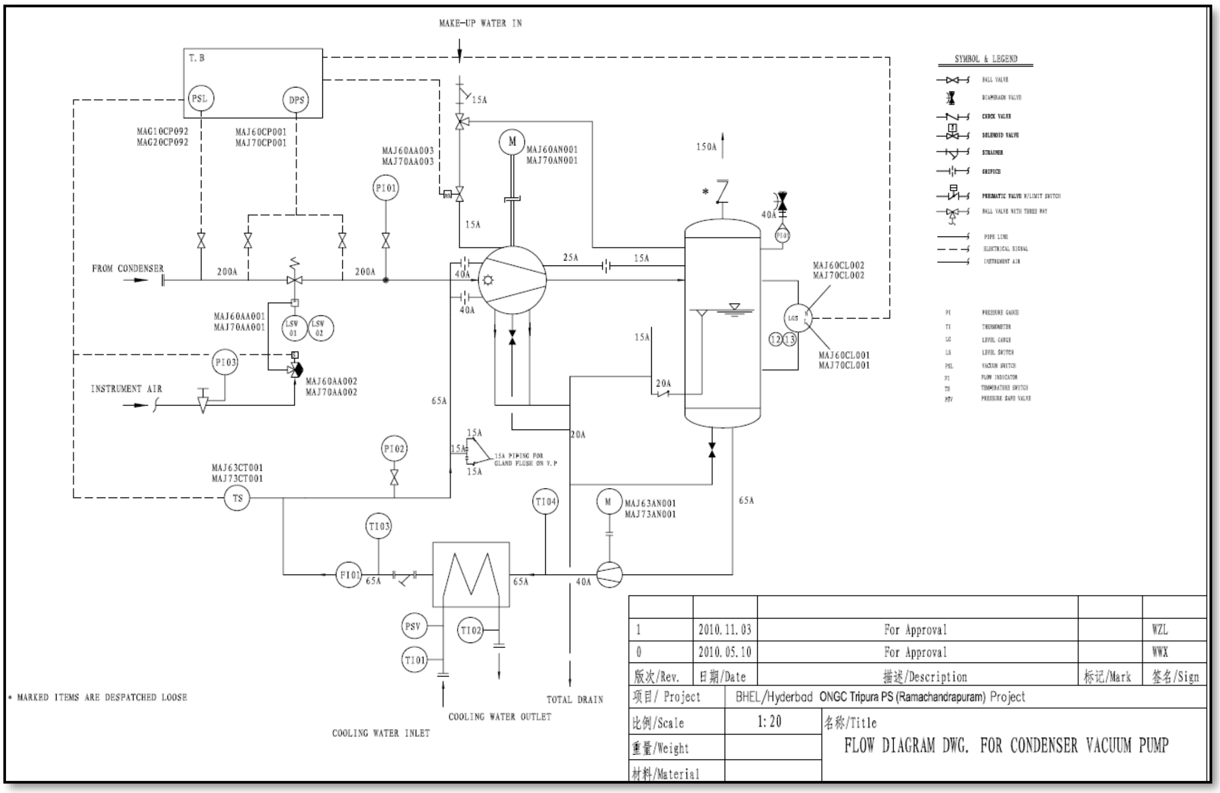


Figure 5-11: Air Extraction system P&ID

As per the above P&ID, Black & Veatch understands that Vacuum pumps are equipped with the following instruments,

- Inlet Air Pressure indicator at Inlet of main Vacuum Pump (PI01)
- Seal Water Pressure indicator at Inlet of main Vacuum Pump (PI02)
- Flow measurement Rota meter to measure Air outlet from Vacuum pump Separator (FI01)
- Seal Water Cooler Inlet Temperature Thermometer (T104)
- Seal Water Cooler Outlet Temperature Thermometer (T103)
- Cooling water inlet to seal cooler Temperature Thermometer (T102)
- Cooling Water Outlet from seal cooler Temperature Thermometer (T103)
- Separator Level Gauge and Level Switch

5.6.4 Recommendations:

5.6.4.1 On-Line Performance Monitoring of Vacuum Pump & Seal Water System

Black & Veatch opines that the instrumentation available at the air extraction system is adequate for calculating vacuum pump performance. However, as most of the readings are not readily available in DCS, Black & Veatch recommends following instruments for continuous monitoring of Vacuum pump and seal cooler performance in DCS.

Table 5-22 Vacuum Pump Performance and Recommended On-Line Measurements

PARAMETERS	STATUS	ON-LINE INDICATION	MONITORING
Seal Water Flow (Inlet to Seal Water Cooler)	Not Available	Not Available	Continuous
Seal Water Inlet and Outlet Temperature (Seal Water Cooler)	Gauge Available	Not Available	Continuous
Seal Water Inlet and Outlet Differential Pressure	Not Available	Not Available	Continuous
ACW Inlet and Outlet Temp. (Seal Water Cooler)	Gauge Available	Not Available	Continuous
Seal Water Temperature (Inlet to Vacuum Pump)	Gauge Available	Not Available	Continuous
Rota Meter Flow	Available	Not Available	Continuous

5.6.4.2 Investigate Suspected Air Ingress in Condenser Shell

Helium leak test is technology of choice due to availability, applicability (Can be done when unit is in operation) and detectability (Sensitivity of 10-6 mbar, fast (less than 20 seconds) , and ability to detect very fine leakages) of leakage points which are in condenser system but isn't useful for leakages which are under water up to condensate extraction pump (Downstream of hot well, flange joints, bellows, valves, suction strainer, and associated pipelines).

Infrared thermography has come to age as far as locating air ingress points are considered. Due to advancement of technology and drop in prices, good quality thermography cameras are available in reasonable rates in market today. But infrared thermography is best used when combined with other techniques like helium or acoustic technique to pinpoint areas of air ingress.

Ultrasonic acoustic leak detection system with high sensitivity is available which can be used for regular inspections to ensure near airtight condenser. In case of vacuum leak, air moves from a high-pressure side (outside condenser) to a low-pressure side (Inside condenser) and during its passage turbulent flow gets generated creating ultrasound frequencies (>20 KHz). This has strong ultrasonic components which are heard through noise attenuating headphones, the greater the leak, the greater would-be sound intensity. Ultrasonic acoustic leak detection when combined with Infrared thermography & Helium leak detection technique is proven to yield reliable and repeatable results with less false negatives. A typical helium leak set up is shown below.

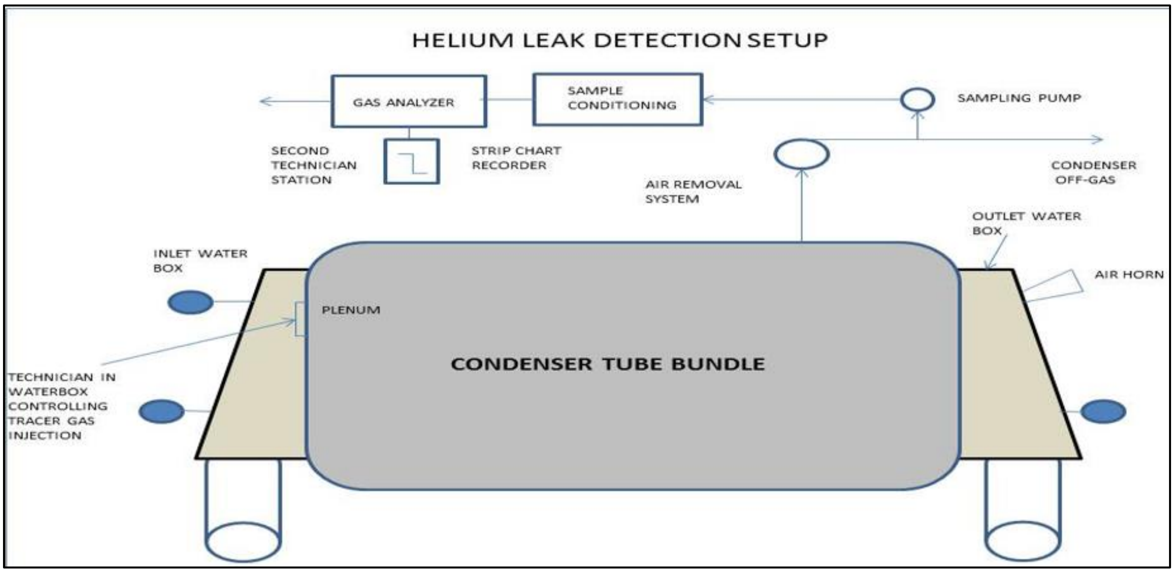
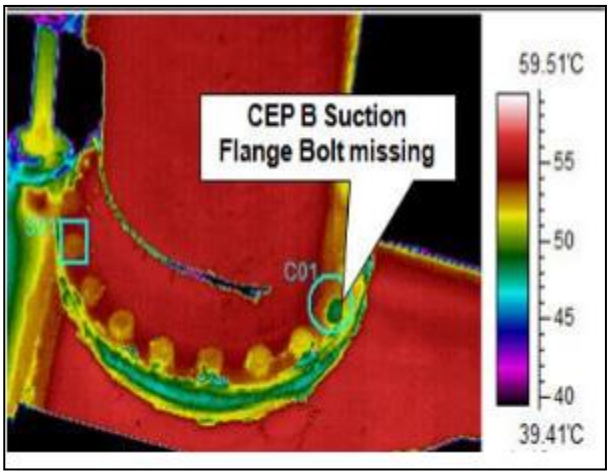


Figure 12 Helium Leak Set Up

Common primary source of leakages is generally listed as follows.

- Atmospheric relief valve or vacuum breakers
- Rupture disks
- Condenser Drains
- Turbine Seals
- Low Pressure Turbine Diaphragm / End Seals
- Turbine Instrumentation Lines
- Condenser Expansion Joint
- Tube sheet to Shell Joint
- Air removal suction component
- Condenser Instrumentations
- Low Pressure feed water heaters, associated piping, valves and instruments
- CEP strainers, vents, drains and seals
- Pipe flanges, Orifice flanges
- Valves
- Manholes

An assessment like infrared thermography often yields best results for wet sections after hot well. The two figures below suggest leakages observed which otherwise are difficult to detect by Helium leak test alone.



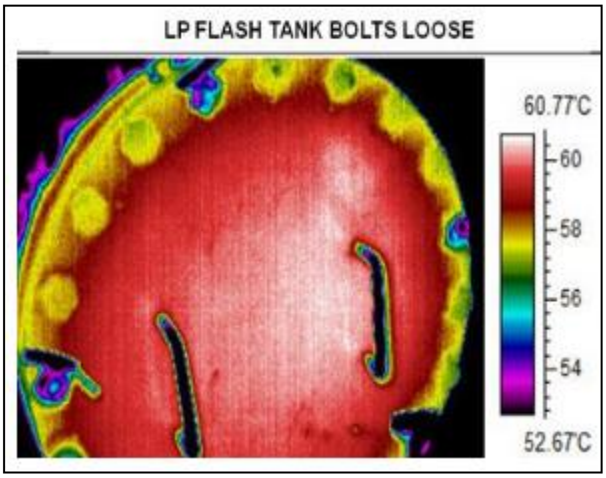


Figure 14 Infrared Thermography CEP Suction Flange **Figure 13 LP Flash Tank**

5.6.4.3 Online Tube Cleaning (OLTC) system

Black & Veatch recommends conducting a feasibility study for the installation of an Online Tube cleaning system for increasing heat-transfer effectiveness.

Online Tube Cleaning System facilitates continuous cleaning of the Condenser Tubes up with the Plant in operation. Cleaning is accomplished by passing slightly oversized Sponge Rubber Balls though the condenser tubes. Install a retrievable ball tube cleaning system to periodically remove bio fouling material from the inner surface of condenser tubes, keeping condenser tubes free of scale will maintain design heat transfer between the condensing steam and circulating water.

Major Components and Auxiliary Equipment of OLTC system are as follows.

- Ball Separator
- Ball Recirculating Skid
- Measuring and Control System
- Ball Monitoring System
- Ball Charger and Feeder

Ball charging is normally from the inlet to condenser and ball separator installed in the Condenser CW outlet pipe is ball catching equipment which separates the cleaning balls from cooling water for recirculation. The Ball Separator is fitted with single/double screens at a selected angle for the smooth collection of balls. The backwashing of the screens is initiated by DP measurement automatically. A ball recirculation system ensures these balls to be again routed to CW inlet pipe to condenser. The installation of ball cleaning system may be localized managed by a PLC or remotely using DCS. An HMI with audio/ visual alarms can also be provided.

5.6.4.4 Regular Replacement of Sacrificial Anodes

Black & Veatch recommends regular inspection of sacrificial anodes during every outage/condenser inspection if applicable. Sufficient stock of sacrificial anodes should be maintained for 100 percent replacement of damaged or worn-out anodes during every outage if Applicable For OTPC

5.7 Vacuum Pump

Table 5-23 Vacuum Pump Design Data

DESCRIPTION	PARTICULARS
Pump Design Point	1" of Hg (a)
Seal Water flow	13.6 m3
ACW Inlet (Design)	13 Deg. C
ACW Outlet	14.5 Deg. C
Seal Water Inlet (Cooler)	23.9 Deg. C
Seal Water Outlet (Cooler)	16.5 Deg. C
Condenser Design Pressure	2.84" of Hg(a)
Pump Capacity (HEI)	20 SCFM
Discharge Pressure	Atmospheric
Make Up Water	CEP Discharge
Design ITD	19 Deg. F

5.7.1 Condenser Performance and Vacuum System

Following section describes condenser performance in view of removal condensable and non-condensable gases in conjunction with vacuum pump operation. The analysis is based on data collected during the performance test.

Table 5-24 Condenser Performance and Vacuum System

Description	UOM	Expect.	Index	Unit 1		Unit 2	
				1A	1B	2A	2B
*Seal Liquid Temperature (Inlet to Cooler)	Deg. C	42.9	[A]	60.0	55.0	55.0	54.0
*Seal Liquid Temperature (Outlet to Cooler)	Deg. C	35.5	[B]	40.0	38.0	41.0	34.0
DT across Seal Cooler	Deg. C	**7.4**	**[A-B]**	**20.0**	**17.0**	**14.0**	**20.0**
Approach of Cooler	Deg. C	**3.5**	**[B-C]**	**4.0**	**5.0**	**7.0**	**4.0**
ACW Inlet Temperature	Deg. C	32	[C]	36.0	33.0	34.0	30.0
ACW Outlet Temperature	Deg. C	33.5	[D]	38.0	35.0	35.0	31.0

Description	UOM	Expect.	Index	Unit 1		Unit 2	
				1A	1B	2A	2B
Actual ITD (Tsat at Vac. Pump Suction Pres. - Seal Water Temp)	Deg. C	**10.6**	**Tsat(E)-B**	**15.0**	**17.0**	**10.3**	**17.3**
Vacuum Pump Air-Steam Inlet Temperature	Deg. C	-	-	53.0	54.0	51.0	51.0
Condenser Water Inlet Temperature	Deg. C	-	-	34.3	34.3	31.2	31.2
Condenser Water Outlet Temperature	Deg. C	-	-	44.3	44.3	40.6	40.6
Condenser Vacuum (Transmitter)	bar (a)	-	-	0.196	0.196	0.170	0.170
Vacuum Pump Inlet Pressure (Estimated)	bar (a)	[A]	[E]	0.158	0.158	0.131	0.131
Saturation Pressure Corresponding to Seal liquid Inlet Temperature	bar (a)	[B]	[F]	0.074	0.066	0.078	0.053
Cavitation Margin (Seal Liquid Inlet Temp.)	**bar (a)**	**[A-B]**	**[E-F]**	**0.084**	**0.091**	**0.054**	**0.078**

Note: Data marked in asterisk is measured locally by available gauge.

5.7.2 Review of Vacuum Pump & Seal Water Cooler Performance

Liquid Ring Vacuum Pump (LRVP) supports condenser operation by continually extracting the non-condensable gases (air) that enter the condenser to maximize the condensing capability and minimizes turbine exhaust back pressure. Surface condenser produces the vacuum while LRVP ensures sustenance of the condenser vacuum.

The LRVP should always operate in conjunction with the condenser. Under-venting of the condenser is caused when the LRVP cannot remove the non-condensable load entering the condenser. The condenser pressure will rise, and turbine operation is affected. This is caused when the high temperature of the seal water in the LRVP will not allow the pump to operate at the same pressure as the condenser. Based on local measurements performed during performance test, it is evident that the difference between seal water outlet temperature and ACW inlet temperature (also known as Seal water cooler approach) for pump 1A, 1B, 2A and 2B are 4-7 deg. C higher than expected.

Given the estimates for seal water cooler approach being based on temperature gauge readings which were not calibrated, we expect the seal water cooler approach to be much higher or possibly lower also in few cases than what is found during the test.

The seal cooler is used on LRVP systems where the service liquid is reused after it exits the LRVP. The service liquid is cooled to a lower temperature, so that desired vacuum and capacity of the LRVP can occur. The cooler is often overlooked when the LRVP system is maintained.

The proper heat transfer function of this heat exchanger is essential for trouble-free vacuum system operation. If the correct heat transfer between the two fluids is not taking place, the LRVP will operate in a different pressure range than the condenser. As stated previously, the condenser and the LRVP must operate in conjunction with one another using similar water temperatures.

Besides seal water cooler performance, there are two more suspect to vacuum pump underperformance.

- Increase in non-condensable heat load (Air -Ingress)
- Increase in condensable component of heat load (Higher steam loading likely caused due to inefficiency in LP turbine and last stage blades)
- Suspected Cavitation of Impeller & Cones
- Direction of Rotation (Check the pump Direction of Rotation (Normally clockwise if viewed from the drive end). Gas compression should be from the suction to the discharge port.

5.7.3 Recommendations

5.7.3.1 Develop and Implement Standard Maintenance Practice (SMP) for Cleaning of Seal Water Cooler

The seal water cooler may have to be cleaned to maintain its heat transfer capability. Ensure that the proper flow and temperature of cooling water is being supplied to the heat exchanger. If the temperature rise is low on the cooling water side and the seal water is not cold enough, fouling could be the problem. It is critical that the seal water cooler be cleaned at regular intervals and should be as closely scrutinized as the main condenser for proper operation. Proper system flushing after before any start up is also important to avoid fouling in tubes. Ensure that there is no place for air to accumulate inside the exchanger reducing its heat transfer surface. ***A SMP for Seal Water Cooler Cleaning is recommended to be adhered by maintenance personnel.***

Seal water flow and differential pressure measurements (On-line) are to be ensured for continuous monitoring of vacuum pump performance. Please refer table 4-14 for recommended on-line measurements of Vacuum pump. A cleaning cycle with frequency once every 6 month is preferable if feasible or as per recommendation of OEM whichever is earlier. A cooling with moderate chemical treatment is also feasible and is to be checked with OEM.

5.7.3.2 Cavitation Avoidance

High seal water inlet temp. may lead to pump cavitation. High seal water temperature in due course of two-stage compression may potentially exceed the corresponding saturation temp. (boiling point) causing cavitation. This problem can be mitigated if seal water flow and temperatures are made available for operators’ guidance and seal water cooler performance is regularly audited. Table 4-21 provides recommendations for online measurements of vacuum pump performance.

Cavitation related damage of Vacuum pump internals was reported by M/s Millennium Enterprise in its report and MOM dated 26th April 2022. The recommendations as per the report are also to procure SS rotor and installing flow meters for seal water.

Another method is using acceleration, true peak detection, frequency banded vibration sensor which is sensitive only to those frequencies normally excited during cavitation. This loop powered sensor provides a 4-mA to 20-mA output signal proportional to the sensed vibration level. A 4-mA to 20-mA output sensor may extend its signal to DCS and alarm limits can be set for alerting the operator. Even if it is not possible to shut the pump down once cavitation is detected, the knowledge that it is occurring can be used by plant personnel for troubleshooting and addressing the issue in a planned manner.

5.8 Cooling Tower

The cooling towers' performance was tested when both units were operating at baseload. The below tables describe the design details of the cooling tower performance parameters.

Table 5-25: Cooling Tower Design Details

DESCRIPTION	UNITS	PARTICULARS
CT basin capacity	m3	7000
No of Cooling Towers		2 (one for each unit)
No of cells in each CT		8 (7W+1S)
Capacity of each cell	m3/hr	3428.57
CT inlet temperature	Deg C	31
CT Outlet temperature	Deg C	42
Design Wet Bulb Temperature	Deg C	27.25
Evaporation Efficiency	%	85
No of fans in each CT		8
No of blades in each Fan/type		8 blades / Aerofoil
Fan motor capacity	kW	110

The below table describes the performance test output of cooling tower values against the design values.

Table 5-26: Cooling Tower- 1&2 Performance Test output against Design Values

DESCRIPTION	UNIT	DESIGN	INDEX	CT -1	CT-2
No of Cells in Service	Nos	8(7W+1S)		8W	8W
Dry Bulb Temp	Deg.C	NA	[M1]	26.68	26.42
Relative Humidity	%	NA	[M2]	37.62%	53.66%
Wet Bulb Temperature	Deg C	27.25	[M3]	17.76	19.90
CT inlet temperature	Deg C	32.00	[A]	34.33	31.18
CT Outlet temperature	Deg C	41.00	[B]	44.30	40.57
CT Range	Deg C	9.00	**C=[B-A]**	**9.97**	**9.39**
CT Approach	Deg C	4.75	**D=[A-M1]**	**16.57**	**11.28**
CT Effectiveness	%	65.5%	[C/C+D]%	37.6%	45.4%

Based on Performance calculation

- Effectiveness of cooling tower is calculated as 37.6 % and 45.4 % respectively for CT-1 &2 against the design effectiveness of 65.5%
- Cooling tower Approach is calculated as 16.57 Deg C and 11.28 Deg C respectively for CT-1 &2 against the design Approach of 4.75 DEGC.
- Cooling Tower Range is calculated as 9.97 DEGC and 9.39 Deg C respectively for CT-1 &2 against the design Range of 8 Deg C.

5.8.1 Recommendations:

5.8.1.1 Fill pack replacement in CT 1 and CT 2

Black & Veatch was informed that a program for fill pack replacement is already underway. In Unit 1, 2 fill packs in 2 cells and in Unit 2, fill packs in 5 cells are replaced till Feb-23. The plan is to be progressively replace all the fill packs in the two cooling towers. It is also recommended to upgrade the design from existing MC67 PVS fills design with other cross-corrugated Fills such as C.10.19 folded end fills.

Another upgrade is use multi-layer combinations of fill packs (rather than single later) such as 2 layers of 600 mm of 19 mm flute size with 1 layer of 300 mm of 12 mm flute size at the top can be checked for feasibility. This will help in doing the cleaning of fills and also can improve the thermal performance.

5.8.1.2 Measurement of CT flow in Risers and Equalization of flow across CT Cells

In multi-cell CT design, the inlet flow to each cells differs greatly due to long pipe length. Part of this issue is addressed by reducing the diameter of pipe as water traverses from the front most cell to the rear cell. The flow in riser pipes is often required to be adjusted to ensure that flow / cell is even across the cooling towers. ***A measurement of CT riser flow once in 6 month or after any major shutdown is recommended to ensure improved L/G (liquid to gas ratio) for each cell.***

5.8.1.3 Develop SMP for CT Fills Cleaning

Review the preventive maintenance schedule of cooling towers fills cleaning. Given the concentration of suspended solids found during visual inspection, fills cleaning may be undertaken 1 cell/month by drawing out the fill packs, weighing the fill packs in dry condition before cleaning, cleaning it by pressurized jet of water, observing the weight drop and then repacking it correctly without affecting/damaging the edges and flute profiles or honeycomb structure. ***A SMP for CT fills cleaning is recommended to be adhered by maintenance personnel.***

5.8.1.4 Provision for higher air flow by improved design of fans airfoil (Improved L/G ratio)

Replacement of GRP blades with high grade Epoxy coated blades in the fan of improved aerodynamic design. The primary objective is to ensure higher air flow through the fills for lowering the CT water outlet temperature. A well design retrofits can provide benefits up to 20% increased air flow / cell then conventional design for same power consumption.

5.8.1.5 Improvement in Air-Water Distribution of CT Cells

CTs often undergo deterioration over the period of operation and need sufficient and effective maintenance periodically. We recommend the following activities to be performed in pre-defined scheduled maintenance intervals.

- Inspection of water distribution system, fills, drift eliminators during each monthly PM.
- Installation of water nozzles in dry patches after internal inspection.
- Check for any damage to the PVC water distribution pipes, their end covers, leakage from the joints, damaged nozzles, missing distribution rings of the nozzles, blockage of nozzles below RCC ducts, etc. to ensure proper spraying of water evenly throughout the fill surface.
- In situ cleaning of fills and drift eliminator with clarified water once in a quarter to remove loose dirt or sludge.

- Check of fan blade tip clearance and maintain it as per the OEM recommendation, typically it is less than 50mm.
- Blade angle can be adjusted to the max allowable value to increase air flow as recommended by OEM, typically it is maintained around 12 to 14 degrees. However, this needs to be validated through OEM.
- While inspecting the fills and water distribution, use wooden ply or sheets for walking to avoid damage of fill edges.

5.8.1.6 CT Basin Screen Design

If the CT outlet channel has two slots to put the two separate screens, then we recommend keeping the upstream screen size opening to around 1.5" – 2" to restrict the large size debris and 1/2" (12 mm- 15 mm) opening for the downstream screen to restrict the smaller size fills or debris.

After doing this modification more frequent cleaning of the downstream screen may be required otherwise the CT basin will overflow in case of heavy blockage. This design typically has benefit of less pass through of broken fills, debris, and other external materials into condenser water box and tube sheet. Please refer figure 7 for a typical CT forebay screen designed for a utility in North India.

Figure 15 CT Basin Screen Design

5.9 Miscellaneous Pumps

Measurements of all major HT motors of HRSG, turbine & BOP area were taken using the Power Analyzer, which measures Voltage, Current, kW, and P.F., etc. The parameters were measured to measure the hydraulic efficiency of pumps. The measurements taken are tabulated and presented below Table.

Table 5-27: Block-1 & 2 Pump Parameters

HT PUMPS	DESIGN MOTOR RATING (KW)	VOLTAGE (KV)	CURRENT (AMPS)	POWER FACTOR	[19]HYDRAULIC POWER (KW)[A]	ELECTRICAL POWER (KW)[B]	EFFICIENCY [A/B*100] (%)
HP/IP BFP-1A	4000	6.77	232	0.862	1490.4	2344.9	63.60
HP/IP BFP-2A	4000	6.79	228	0.850	1443.4	2279.1	63.30
CEP 1B	600	6.77	46.9	0.834	275.9	458.6	60.20
CEP 2B	600	6.79	48.1	0.851	265.8	480.8	55.40
[20]DMCW 1B	300	6.75	26.0	0.851	157.6	257.5	61.20
DMCW 2B	300	6.79	26.2	0.850	184.3	261.9	70.40
CW Pump- 1A	1150	6.80	106.0	0.756	682.1	974.2	70.02
CW Pump- 1B	1150	6.80	109.9	0.760	681.2	957.8	71.12
CW Pump- 2A	1150	6.80	106.1	0.756	758.1	944.2	80.29
CW Pump- 2B	1150	6.80	109.9	0.760	734.2	983.2	74.66

[19] (Pump TDH X Flow X Density X g)/3600/1000

[20] DMCW Pump 1B was running at 1495 TPH and DMCW Pump 2B flow as 1840 TPH. Design flow rate is 1730 m3/hour and design pump efficiency is 84%.

The major pumps performance parameters do not indicate any major deviation except few cases where pumps operating point and design duty points are deviating large. There is a potential energy saving for pumps specially CEPs (continuous duty) if they are operated under VFD control.

OPTC has already implemented VFDs in low pressure BFP in Unit 2 and is under service.

5.10 Condensate Extraction Pump

Following tables provides performance assessment of CEP.

Table 5-28 CEP Performance

PARAMETERS	UNITS	DESIGN	INDEX	CEP 1B	CEP 2B
Discharge Pressure	Bar			24.66	24.37
Suction Pressure	Bar			0.196	0.170
Suction Temperature	Deg C	49.2		58.41	56.39
Discharge Temperature (Estimated)	Deg C			61.71	58.08
Discharge flow	m3/hr.	660.0		413.41	401.85
Speed	RPM	1484.0			
Voltage	KV	6.6	[A]	6.77	6.78
Current	A	65.0	[B]	46.9	48.1
Power Factor			[C]	0.83	0.85
Power	KW	600.0	[F=SQRT (3)*A*B*C]	458.6	480.1
Hydraulic Power	KW	466.0	[E]	275.9	265.8
Specific Weight	kg/m3	988.4		984.0	985.0
Pump TDH	mwc	210.0		**249.3**	**246.7**
Hydraulic Efficiency (TDH)	%	80.0	**[E/F]**	**60.20**	**55.40**

- The difference in pump design and operating efficiency is attributable due to operating point deviating from design considerably.
- Pump actual TDH is higher than design, suggesting higher power consumption as higher head increases the power consumption proportionately.
- Assessment of deaerator level control valve system shows potential for lowering the head by opening of the level control valve to full and operating pump at reduced speed using VFD.

5.10.1 Recommendations:

5.10.1.1 Retrofit of MV VFD for Power Saving in CEP

Under operating conditions, the deaerator level control valve remains throttled to maintain the deaerator inlet pressure of 4 kg/cm2. The power consumed by CEP at full load is about 460-480 kW (based on performance test data). The CEP discharge pressure is about 24Kg/cm2 which reduces to around 20 kg/cm2 at the inlet of deaerator level control valve (~ pressure drop of 20 kg/cm2 at valve throttling of 72%). Deaerator level control valve is throttling the condensate pressure from 20

kg/cm2 to around 4 kg/cm2 at the inlet of deaerator. Please refer snapshot of CEP operation during the performance test of Unit 1. Similar observation is reported for Unit 2 also.

Given the present operation of CEPs away from design efficiency point, it is recommended to retrofit the pump motor with a VFD to reduce the speed and thereby its discharge pressure adequately to avoid deaerator level controller valve throttling, while still meeting the pressure requirement of its duty points. A careful design review and performance analysis will result in the potential power saving is in the tune of minimum 100-120 KW at full load after adjusting for the increased HVAC auxiliary load of VFD. A detailed review of this retrofit is outside the scope, however industry experience suggests a pay back period typically of less than 3 years for such retrofit.

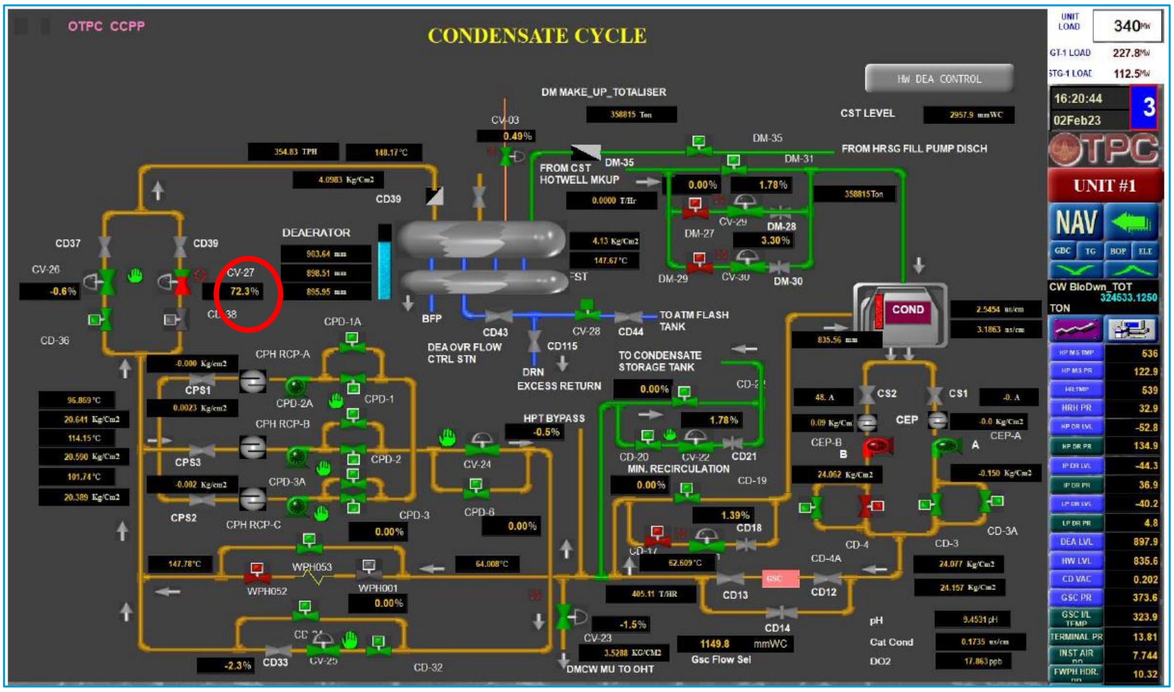


Figure 16 CEP Operation in Unit 1

- Deaerator at a pressure of 4.0 bar.
- HP/LP Bypass spray.
- LP Turbine Exhaust cooling sprays.
- Gland steam de-super heater
- Condenser drain flash box
- Condensate dozing (if applicable)

5.10.1.2 Retrofit of CEP Gland Packing to Mechanical Seals

Mechanical seal OEMs such as Eagle Burgmann, Borg Warner, etc. can be consulted for converting the gland packing to mechanical seal. This will help in increasing the life of shaft seal and reducing the dissolved oxygen content in the condensate. The performance data suggest significantly high DO level in Unit 1 (17.86 PPB).

5.11 Circulating Water Pump

Following tables provides performance assessment of CW Pumps.

Table 5-29 CW Pump Performance Evaluation

Parameters	Units	Design	INDEX	CW-1B	CW-1C	CW-2A	CW-2B
Discharge Pressure	Bar	NA		3.0303	3.0744	3.1235	3.0450
Suction Pressure (Estimated)	Bar	NA		0.9614	0.9614	0.9614	0.9614
Discharge Temperature	Deg C	NA		34.33	34.33	31.18	31.18
Suction flow	m3/hr.	12000	[G]	11648.0	11395.0	**12400.0**	**12450.0**
Voltage	KV	6.60	[A]	6.76	6.76	6.80	6.799
Current	A	108.6	[B]	110.0	107.6	106.0	109.9
Hydraulic Power	KW	865.0	[E=G*H]	682.1	681.2	758.1	734.2
Power Factor		0.8	[C]	0.7564	0.760	0.7564	0.76
Input Power	KW	1018.0	F=[SQRT(3)*A*B*C]	974.2	957.8	944.2	983.3
Pump Total Dynamic Head (Bowl)	mwc	22.0	[H]	21.59	22.04	22.54	21.74
Hydraulic Efficiency (Bowl)	%	85.0	**[E/F*100]**	**70.02**	**71.12**	**80.29**	**74.66**

5.11.1 Recommendations:

5.11.1.1 Measures for High CW Flow and for Arresting Suspected Passing in Butterfly Valve

In a parallel pump operation, passing of CW discharge valve of standby pump will lead to short circuiting of CW flow to the forebay. It is practically difficult to identify the short circuiting, but this issue leads to lower CW flow across the condenser, hence it is recommended to inspect all the valves internally and replace the elastomeric seals, seal retaining segments, metallic seals of valve disc, etc. Gearbox of the actuator should be adjusted to close the valves properly and should be crosschecked internally for its full closer.

5.11.1.2 Plate Heat Exchanger Isolation

Plate heat exchangers are often designed to operate as (1W + 1S) configuration, however many times, PHE are charged from ACW side for quick line up in case a changeover is warranted. This compromises standby PHE cleaning and effectiveness while adding to ACW power consumption. Standby PHE is recommended to be closed from both DMCW and ACW side as far as feasible to save unnecessary use of pumping power while keeping a close watch on in-service PHE differential pressure.

5.12 HP/IP Boiler FEED Pump

Table 5-30 HP/IP Boiler Feed Pump Performance Evaluation

Parameters	Units	Design	Index	HP BFP 1A	HP BFP 2A
Discharge Pressure	Bar	179.9		146.15	144.19
Suction Pressure	Bar	14.4		15.50	15.47
Suction Temperature	Deg C	149.5		146.66	146.40
Discharge Temperature	Deg C	149.5		149.73	149.12
Suction flow	m3/hr.	420	[G]	446.31	438.60
Voltage	KV	6.6	[A]	6.77	6.79
Current	A	405	[B]	232	228
Power Factor		0.89	[C]	0.862	0.85
Shaft Power	KW	3112.0	F=[SQRT(3)*A*B*C]	2344.9	2279.1
Hydraulic Power	KW	2490.0	[I=G*H]	1490.4	1443.4
Pump TDH	mwc	2000	[H]	1331.8	1312.2
Hydraulic Efficiency (TDH)	%	80.0	**[F/I*100]**	**63.60**	**63.30**

- The HPBFP efficiencies are observed to be within expected range. The deviation in efficiency can be explained based on pump design and operating duty point differences

5.13 DMCW Pump

Parameters	UOM	Design	Index	DMCW-1B	DMCW-2B
Discharge Pressure	Bar			7.08	6.91
Suction Pressure	Bar			3.25	3.27
Suction Temperature	Deg C	49.2		0.00	0.00
Discharge Temperature (Estd)	Deg C			40.35	41.15
Discharge flow	m3/hr.	1760.0	[G]	**1495.0**	**1840.1**
Speed	RPM	1486.0		NA	NA
Voltage	KV	6.6	[A]	6.75	6.79
Current	A	33.0	[B]	26.0	26.2
Power Factor			[C]	0.85	0.85
Power	KW	294.0	F=[SQRT(3)*A *B*C]	257.5	261.9
Hydraulic Power	KW	246.8	[I=G*H]	157.6	184.3
Pump TDH	mwc	44.0	[H]	39.0	37.1
Hydraulic Efficiency (TDH)	%	83.9	**[F/I*100]**	**61.20**	**70.40**

- The DMCW Pump efficiencies are observed to be within expected range. The deviation in efficiency can be explained based on pump design and operating duty point differences.
- DMCW Pump 1B was running at 1495 TPH and DMCW Pump 2B flow was 1840 TPH. Design flow rate is 1730 m3/hour and design pump efficiency are 84%. Given the pump 2B, being operated at higher than design flow (1840 TPH), a passing is suspected either via PHE (if standby PHE is isolated) or DMCW common recirculation line.

5.13.1 Recommendations:

5.13.1.1 Measures for Arresting Higher Flow Rate in DMCW 2B

A flow measurement using ultrasonic flow meter is required to adjust the pump operating points near the design duty point. Any suspected passing either in common recirculation valve or stand by PHE can be ascertained and arrested. Pump 1B and 2B are found to operate at different flow rate (difference by 345 TPH) which shall be corrected.

5.14 Compressed Air System

OTPC plant has two instrument air screw compressors with the capacity of 15 m3/min for the compressed air requirement. The operating pressure of the compressor is 8.5bar. The rated KW of drive motor is 132 KW. The input KW of compressor at rated condition is 119 KW and at unloaded condition, it is 27 KW. We have collected half hourly power consumption data for the compressor for 2.5 hours. Please refer below table for the details. The pressure at air drier outlet is 8.0 bar.

Description	Voltage (Volt)	Current (Load)	Current (Unload)	PF	Electrical Power (KW)
IAC -1A	435	185	56	NA	NA
IAC-1B	434	-	52	NA	NA
IAC-2A	438	184	55	NA	NA
IAC -2B	442	-	53	NA	NA

The power measurement for IAC was not available for Black & Veatch to conclude, however analyzing historical data suggest that power consumption of compressor at unload and load conditions are typically in the range of 22-25 KW and 100-110 KW respectively. The loading/ unloading cycle of IAC suggested few optimizations as evident in the table below.

Description	15:00	15:30	16:00	16:30	17:00	Instrument Air Pressure (bar)
IAC-1A	Unload	Unload	Load	Load	Unload	7.78
IAC-1B	**Unload**	**Unload**	**Unload**	**Unload**	**Unload**	
IAC-2A	Unload	Unload	Unload	Load	Load	7.72
IAC-2B	**Unload**	**Unload**	**Unload**	**Unload**	**Unload**	

IAC -1B and 2B are found to be completely unloaded for the period of performance test, while IAC 1A and 2A operated cyclically to maintain instrument air header pressure. Load/unload compressors

have two pressure setpoints: an upper setpoint and a lower setpoint. The compressor regulates the pressure between these two setpoint. When the lower pressure is reached, the compressor starts 'pumping air'. This setpoint is called the 'loading setpoint'. To avoid an ever-last uncontrolled rise in pressure, the compressor has an upper setpoint, called the 'unload setpoint' - where the compressor stops pumping air. There is various microprocessor-based control for Improved Loading / Unloading of Compressor which also reduces overall power consumption of the compressed air system.

5.14.1.1 Service Air and Instrument Air Segregation

Segregating the plant service and operating air and instrument air system can result in energy savings. In past assessments, Black & Veatch has seen plants that combine their service, operating, and instrument air system into a single system. In OTPC also, compressors are operated to meet both service air and instrument air requirements. Utilizing instrument air for service and controls together will result in higher energy demands specially for air-drying application.

5.14.1.2 Centralized Controller for Equalizing the Run-Hours of Two Parallel Compressors & Energy Saving

Normally, the load/unload pressure of each unit are set to react to changes in air demand. If the system pressure drops, an additional compressor will switch to loaded running. However, the sequence will always be the same, and this leads to a higher pressure than required. Central controllers can be set to prevent unequal wear of compressors, equalizing the running hours on multiple machines for more efficient service scheduling and reduced cost. Another advantage of centralized controller is that they reduce the average pressure band (load and unload set points). It also reduces the operating pressure of machines. By reducing the pressure by 1 bar (or 14.5 psi), energy usage gets lowered by 5-10%, while reducing the pressure by 1 bar (or 14.5 psi) decreases air leakages by average 10-15%.

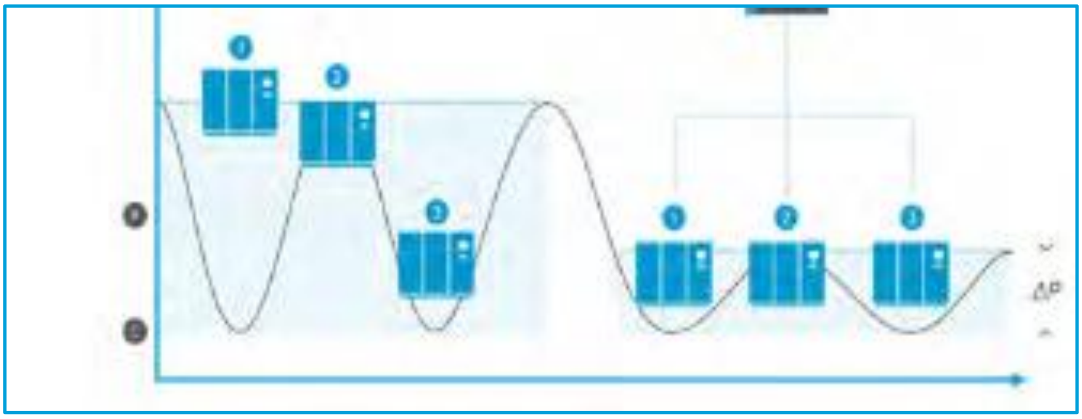


Figure 17 Average Pressure Band Trend for Parallel Compressor Operation

6 Recommendations

6.1 Based on Plant Performance Audit

The recommendations related to performance impact are categorized based on Risk, Priority, Capex requirement, and shutdown requirement. The assumed criteria and basis for these categorizations are provided below.

6.1.1 Risk Categorization:

The identified recommendations are further categorized into different risk levels based on the threats and hazards involved with the recommendations in the system. The different risk categorizations are as below

- Low
- Minor
- Moderate
- Major
- Critical

6.1.2 Priority Categorization:

The identified recommendations are further categorized into different priority levels based on the period the recommendation is expected to be planned for the reliable operation of the plant. The different priority categorizations and their criteria are as below

Table 6-1: Priority Categorization

PRIORITY	CRITERIA
Immediate	Important and urgent
Short term	Important and urgent but can be delayed
Long term	Important, not urgent
Good to have	Not important, not urgent

6.1.3 Capex Requirement Categorization:

The identified recommendations are categorized into different CAPEX requirements based on the high-level Capex estimate required to implement the recommendations. The different CAPEX requirements and their range considered are as below,

Table 6-2: Priority Categorization

CAPEX REQUIREMENT	RANGE (INR LAKHS)
High	> 100 lakh
Medium	25 to 100 lakh

CAPEX REQUIREMENT	RANGE (INR LAKHS)
Low	< 25 lakh
Not Applicable	

6.1.4 Shutdown Requirement Categorization:

The recommendations are further analyzed and shutdown requirements to implement the recommendations are identified. The shutdown requirement is based on the time period expected to implement the recommendations. The different shutdown requirements considered are as below,

Table 6-3: Priority Categorization

SHUTDOWN REQUIREMENT	RANGE (DAYS)
No	0
Minor Outage	15-30 days
Major Outage	30-45 days

6.1.5 Recommendation Summary

Black & Veatch has utilized information gathered at various stages during the execution of this Performance system Audit and assessments carried out in the above sections as a basis for identifying recommendations. Black & Veatch has identified around 10 recommendations for plant performance improvement and reliable plant operation. The below table describes the number of identified recommendations with respect to each categorization explained above.

Table 6-4: Recommendations Under Different Categories

PRIORITY	RISK CATEGORY	CAPEX REQUIREMENT	SHUTDOWN REQUIREMENT
Immediate - 4 no's	Low - 1 no	High -4 no's	No -4 no's
Short term - 21 no's	Minor - 1 no	Medium - 4 no	Minor Outage -14 no's
Long term - 1 no's	Moderate - 14 no's	Low - 15 no’s	Major Outage -2 no's
Good to have -1 no	Major -1 no	NA - 4 no's	No Outage -11 no’s
	Critical - 10 no's		

The recommendations to improve the plant performance are provided in the below table.

Table 6-5: Plant Performance Improvement Recommendations

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
1	Compressor	5.3.1.1	Inlet Air Filter Choking	Due to increase of fine dust in the ambient air, fine filters are getting exhausted within 4-6 months. This filter replacement requires shutdown of the unit. We recommend exploring the possibility of installing Coalascer pad rolls before the prefilters. These Coalascer pads have good dust holding capacity. These pads can be changed online whenever these get choked. Alternatively OTPC may also explore upgrading / replacing fine filters to EPA grade (E10 or E11) without coalescer pad after cost benefit assessment.	Moderate	Good to have	Low	Minor Outage	-	-
2	IP Turbine Bypass System	5.4.7.1	Suspected IP Bypass System Steam Passing & Steam Valve Upgrade	Test data shows that IP bypass spray valve for Unit 1 and 2 was 6.48 TPH and 19.4 TPH respectively which suggest that there may be suspected steam flow in the downstream pipe. It is necessary that suspected steam leakage in IP steam pipe is quickly arrested in available opportunity.	Minor	Short term	Low	Minor Outage	1-3	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				Unlike traditional control valves, there are designs which uses multi-stage, multi-turn technology divides the pressure reduction into many smaller stages. The number of turns, or stages, is selected to ensure a specific fluid discharge velocity is achieved at the exit of the control element. This reduces the potential for cavitation and erosion, that would otherwise compromise the valve's ability to effectively control leakage.						
3	HRSG	5.4.7.2	CBD Tank Vents Open to Atmosphere	As per the design, the Continuous Blow-Down Tank (CBD) vent is routed to Deaerator however, based on site-visit discussions, it is understood that for both units, CBD vent lines are kept open to atmosphere. CBD vent should be routed to the Deaerator for fluid recovery and improved energy utilization.	Moderate	Short term	Low	Minor Outage	-	-
4	Steam Turbine	5.5.1.1	HP/IP Section Internal Efficiency Improvement by Seal Upgrade	Leakage losses represent the greatest portion of turbine stage losses. The losses are magnified as the turbine packing and turbine diaphragm spill strips	Critical	Immediate	High	Major Outage		

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				wear out progressively. A large amount of these losses is recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization. The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP and IP turbine efficiencies. Typical efficiency improvements up to 0.7-1.2 % in heat rate is reported in the past. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.						
5	Steam Turbine (HP/IP Section)	5.5.1.2	Suspected high HP to IP Leakage Flow (Temperature Inference Method)	The N2 packing leakage to IP turbine bowl is calculated using the temperature inference method. This method is an indirect method to determine the magnitude of leakage flow,	Critical	Short Term	Medium	No	12-15	1.0-1.5

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				since this leakage flow is inside the turbine, and it is impractical to directly measure it. Determination of the leakage flow shall also determine the true IP turbine efficiency.						
6	Steam Turbine (LP)	5.5.1.3	Improving LP Turbine Efficiency by Improved Blade Design and Increased Annulus Area	The steam seal upgrade tends to decrease heat rate and increase LP turbine efficiency. The new gland seals also reduce the in-air leakage around the shaft. The improved gland seal reduces the amount of air that enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air in-leakage through improved seals can decrease (improve) back pressure by 4-12 KPa absolute with a corresponding heat rate improvement of nearly 1.0%.	Moderate	Long Term	High	Major Outage	10-30	1.0-2.0
7	Steam Turbine (HP Section)	5.5.1.4	Performance Monitoring of HP Turbine Section & In-Situ Instrumentation for HP Exhaust Pressure and Temperature	One of the most critical measurements for analyzing HP turbine internal efficiency is HP turbine exhaust temperature. The ASME PTC test code 46 specifies this measurement to be	Moderate	Short Term	Low	Minor Outage	-	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				close to HP turbine exhaust. A minimum 2 measurements of HPT exhaust temperature is recommended with the instrument of 1 Deg. F or 0.56 Deg. C accuracy class for best results. HP exhaust pressure measurement is also recommended with an instrument of accuracy class 0.1%.						
8	Vacuum Pump	5.6.4.1	On-Line Performance Monitoring of Vacuum Pump & Seal Water System	Black & Veatch opines that the instrumentation available at the air extraction system is adequate for calculating vacuum pump performance. However, as most of the readings are not readily available in DCS, Black & Veatch recommends the following instruments for continuous monitoring of Vacuum pump and seal cooler performance in DCS. •Seal Water Flow (Inlet to Seal Water Cooler) •Seal Water Inlet and Outlet Temperature (Seal Water Cooler) •Seal Water Inlet and Outlet Differential Pressure	Critical	Immediate	Low	Minor Outage	5-10	

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				•ACW Inlet and Outlet Temp. (Seal Water Cooler) •Seal Water Temperature (Inlet to Vacuum Pump) •Rota Meter Flow						
9	Condenser	5.6.4.2	Investigate Suspected Air Ingress in Condenser Shell	Helium leak test is technology of choice due to availability, applicability (Can be done when unit is in operation) and detectability (Sensitivity of 10-6 mbar, fast (less than 20 seconds) , and ability to detect very fine leakages) of leakage points which are in condenser system but isn't useful for leakages which are under water up to condensate extraction pump (Downstream of hot well, flange joints, bellows, valves, suction strainer, and associated pipelines).	Critical	Immediate	Low	No	5-10	
10	Condenser	5.6.4.3	Online Tube Cleaning (OLTC) system	Black & Veatch recommends conducting a feasibility study for the installation of an Online Tube cleaning system for increasing heat-transfer effectiveness.	Major	Short Term	Medium	Minor	5-6	
11	Condenser	5.6.4.4	Regular Replacement of Sacrificial Anodes	Black & Veatch recommends regular inspection of sacrificial anodes during every	Low	Short term	Low	Minor	-	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				outage/condenser inspection if applicable. Sufficient stock of sacrificial anodes should be maintained for 100 percent replacement of damaged or worn-out anodes during every outage if Applicable For OTPC						
12	Vacuum Pump	5.7.3.1	Develop and Implement Standard Maintenance Practice (SMP) for Cleaning of Seal Water Cooler	The seal water cooler may have to be cleaned to maintain its heat transfer capability. Ensure that the proper flow and temperature of cooling water is being supplied to the heat exchanger.	Critical	Immediate	NA	No	Included in ID 8	-
13	Vacuum Pump	5.7.3.2	Cavitation Avoidance	High seal water inlet temp. may lead to pump cavitation. High seal water temperature in due course of two-stage compression may potentially exceed the corresponding saturation temp. (boiling point) causing cavitation. This problem can be mitigated if seal water flow and temperatures are made available for operators' guidance and seal water cooler performance is regularly audited.	Critical	Short Term	Low	Minor Outage	Included in ID 8	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				Another method is using acceleration, true peak detection, frequency banded vibration sensor which is sensitive only to those frequencies normally excited during cavitation. This loop-powered sensor provides a 4-mA to 20-mA output signal proportional to the sensed vibration level. A 4-mA to 20-mA output sensor may extend its signal to DCS and alarm limits can be set for alerting the operator.						
14	Cooling Tower	5.8.1.1	Fill pack replacement in CT 1 and CT 2	Black & Veatch was informed that a program for fill pack replacement is already underway. In Unit 1, 2 fill packs in 2 cells and in Unit 2, fill packs in 5 cells are replaced till Feb-23. The plan is to be progressively replace all the fill packs in the two cooling towers. It is also recommended to upgrade the design from existing MC67 PVS fills design with other cross-corrugated Fills such as C.10.19 folded end fills.	Critical	Short Term	High	No	15-20	0.5-1

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
15	Cooling Tower	5.8.1.2	Measurement of CT flow in Risers and Equalization of flow across CT Cells	In multi-cell CT design, the inlet flow to each cells differs greatly due to long pipe length. Part of this issue is addressed by reducing the diameter of pipe as water traverses from the front most cell to the rear cell. The flow in riser pipes is often required to be adjusted to ensure that flow / cell is even across the cooling towers. A measurement of CT riser flow once in 6 month or after any major shutdown is recommended to ensure improved L/G (liquid to gas ratio) for each cell.	Critical	Short Term	Low	No	Included in ID 14	-
16	Cooling Tower	5.8.1.3	Develop SMP for CT Fills Cleaning	Review the preventive maintenance schedule of cooling towers fills cleaning. Given the concentration of suspended solids found during visual inspection, fills cleaning may be undertaken 1 cell/month by drawing out the fill packs, weighing the fill packs in dry condition before cleaning, cleaning it by pressurized jet of	Critical	Short Term	NA	No	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				water, observing the weight drop and then repacking it correctly without affecting/damaging the edges and flute profiles or honeycomb structure. A SMP for CT fills cleaning is recommended to be adhered by maintenance personnel.						
17	Cooling Tower	5.8.1.4	Provision for higher air flow by improved design of fans airfoil (Improved L/G ratio)	Replacement of GRP blades with high grade Epoxy coated blades in the fan of improved aerodynamic design. The primary objective is to ensure higher air flow through the fills for lowering the CT water outlet temperature. A well design retrofits can provide benefits up to 20% increased air flow / cell then conventional design for same power consumption.	Moderate	Short Term	Low	No	Included in ID 14	-
18	Cooling Towers	5.8.1.5	Improvement in Air-Water Distribution of CT Cells	CTs often undergo deterioration over the period of operation and need sufficient and effective maintenance periodically. •Inspection of water distribution system, fills, drift eliminators during each monthly PM.	Critical	Short Term	Low	No	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				•Installation of water nozzles in dry patches after internal inspection. •Check for any damage to the PVC water distribution pipes, their end covers, leakage from the joints, damaged nozzles, missing distribution rings of the nozzles, blockage of nozzles below RCC ducts, etc. •In situ cleaning of fills and drift eliminator with clarified water once in a quarter to remove loose dirt or sludge. •Check of fan blade tip clearance •Blade angle adjustment						
19	Cooling Towers	5.8.1.6	CT Basin Screen Design	If the CT outlet channel has two slots to put the two separate screens, then we recommend keeping the upstream screen size opening to around 1.5" – 2" to restrict the large size debris and 1/2" (12 mm- 15 mm) opening for the downstream screen to restrict the smaller size fills or debris.	Moderate	Short Term	Low	Minor Outage	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
20	Condensate Extraction Pump	5.10.1.1	Retrofit of MV VFD for Power Saving in CEP	Given the present operation of CEPs away from design efficiency point, it is recommended to retrofit the pump motor with a VFD to reduce the speed and thereby its discharge pressure adequately to avoid deaerator level controller valve throttling, while still meeting the pressure requirement of its duty points. A careful design review and performance analysis will result in the potential power saving is in the tune of minimum 100-120 KW at full load after adjusting for the increased HVAC auxiliary load of VFD.	Moderate	Short Term	High	Minor Outage	-	120-150 KW
21	Condensate Extraction Pump	5.10.1.2	Retrofit of CEP Gland Packing to Mechanical Seals	Mechanical seal OEMs such as Eagle Burgmann, Borg Warner, etc. can be consulted for converting the gland packing to mechanical seal. This will help in increasing the life of shaft seal and reducing the dissolved oxygen content in the condensate. The performance data suggest significantly high DO level in Unit 1 (17.86 PPB).	Moderate	Short Term	Medium	Minor Outage	-	10-150 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
22	CW Pump	5.11.1.1	Measures for High CW Flow and for Arresting Suspected Passing in Butterfly Valve	In a parallel pump operation, passing of CW discharge valve of standby pump will lead to short circuiting of CW flow to the forebay. It is practically difficult to identify the short circuiting, but this issue leads to lower CW flow across the condenser, hence it is recommended to inspect all the valves internally and replace the elastomeric seals, seal retaining segments, metallic seals of valve disc, etc. Gearbox of the actuator should be adjusted to close the valves properly and should be crosschecked internally for its full closer.	Moderate	Short Term	Low	Minor Outage	-	100-150 KW
23	Plate Heat Exchanger	5.11.1.2	Plate Heat Exchanger Isolation	Plate heat exchangers are often designed to operate as (1W + 1S) configuration, however many times, PHE are charged from ACW side for quick line up in case a changeover is warranted. This compromises standby PHE cleaning and effectiveness while adding to ACW power consumption. Standby PHE is	Moderate	Short Term	NA	No	-	15-25 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				recommended to be closed from both DMCW and ACW side as far as feasible to save unnecessary use of pumping power while keeping a close watch on in-service PHE differential pressure.						
24	DMCW	5.13.1.1	Measures for Arresting Higher Flow Rate in DMCW 2B	A flow measurement using ultrasonic flow meter is required to adjust the pump operating points near the design duty point. Any suspected passing either in common recirculation valve or stand by PHE can be ascertained and arrested. Pump 1B and 2B are found to operate at different flow rate (difference by 345 TPH) which shall be corrected.	Moderate	Short Term	NA	No	-	Included in ID 23
25	Instrument / Service Air Compressor	5.14.1.1	Service Air and Instrument Air Segregation	Segregating the plant service and operating air and instrument air system can result in energy savings. In past assessments, Black & Veatch has seen plants that combine their service, operating, and instrument air system into a single system. In OTPC also, compressors are operated to meet both service	Moderate	Short Term	Low	Minor Outage	-	Upto 50-100 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				air and instrument air requirements. Utilizing instrument air for service and controls together will result in higher energy demands specially for the air-drying applications.						
26	Instrument/ Service Air Compressor	5.14.1.2	Centralized Controller for Equalizing the Run-Hours of Two Parallel Compressors & Energy Saving	Normally, the load/unload pressure of each unit are set to react to changes in air demand. If the system pressure drops, an additional compressor will switch to loaded running. However, the sequence will always be the same, and this leads to a higher pressure than required. Central controllers can be set to prevent unequal wear of compressors, equalizing the running hours on multiple machines for more efficient service scheduling and reduced cost. Another advantage of centralized controller is that they reduce the average pressure band (load and unload set points). It also reduces the operating pressure of machines. By reducing the pressure by 1 bar (or 14.5 psi), energy usage gets lowered by 5-10%, while	Moderate	Short Term	Low	Minor Outage	-	Upto 50-100 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				reducing the pressure by 1 bar (or 14.5 psi) decreases air leakages by average 10-15%.						
27	Real Time Performance Monitoring	-	Performance Monitoring Using Real Time Data and Predictive Analytics Approach	Machine learning-based predictive maintenance plan detects any failure event significantly quicker, compared to the traditional approaches. The strategy utilizes the following sequential steps: • Real-time data fetching, organizing, stacking, and classifying. • Process data may be temperature, current, flow, pressure, vibration, level or calculated variables. • Using engineering knowledge and the machine learning approach, develop a predictive model of the variable and save as the operating baseline • Detect process anomalies and diagnose / mitigate the issue before its occurrence	Moderate	Short Term	Low	No	10-15	0.5-1

7 Conclusion

Black & Veatch is thankful to OTPC for providing the opportunity to perform the Plant Performance Audit of its Combined Cycle Plant.

In this report, we have provided our observations and recommendations on –

- Major performance audit observations of individual equipment and system
- Comparative assessment with similar peer units.
- Performance improvement recommendations for sustainable operation.

Black & Veatch has reviewed the past reports and provided recommendations in ***section 6.1.5*** along with expected heat rate and aux power consumption benefits.

A summary of these recommended improvement project is tabulated as follows.

Table 7-1 List of Performance Improvement Projects Including Key Decision Metrics

PRIORITY	RISK CATEGORY	CAPEX REQUIREMENT	SHUTDOWN REQUIREMENT
Immediate - 4 no's	Low - 1 no	High -4 no's	No -4 no's
Short term - 21 no's	Minor - 1 no	Medium - 4 no	Minor Outage -14 no's
Long term - 1 no's	Moderate - 14 no's	Low - 15 no's	Major Outage -2 no's
Good to have -1 no	Major -1 no	NA - 4 no's	No Outage -11 no's
	Critical - 10 no's		

Black & Veatch recommends systematic implementation of these projects in short-mid-term period for long-term efficient, reliable, and safe plant operation achieving its environmental sustainability and decarbonization goals.

CENTRAL ELECTRICITY REGULATORY COMMISSION
NEW DELHI

No. L-1/265/2022/CERC Dated: 29.5.2023

PREAMBLE

The term “Grid” has been defined in sub-section 32 of Section 2 of the Electricity Act, 2003 (the Act) to mean the high voltage backbone system of inter-connected transmission lines, sub-stations and generating plants. The Central Commission has been vested with the functions under clause (h) of sub-section (1) of Section 79 of the Act to specify the Grid Code having regard to the Grid Standards. Clause (d) of Section 73 of the Act mandates the Central Electricity Authority to specify the Grid Standards for operation and maintenance of the transmission lines. Further, clause (i) of sub-section (1) of Section 79 of the Act enjoins upon the Central Commission to specify and enforce the standards with respect to the quality, continuity and reliability of services by the licensees. Sub-Section 2 of Section 28 of the Act provides that the Regional Load Despatch Centre shall comply with such principles, guidelines and methodologies in respect of wheeling and optimum scheduling and despatch of electricity as the Central Commission may specify in the Grid Code. Clause (e) of sub-section (3) of Section 28 of the Act provides that the Regional Load Despatch Centre shall be responsible for carrying out real time operations for grid control and despatch of electricity within the region through secure and economic operation of the regional grid in accordance with the Grid Standards and the Grid Code. Sub-Section (1) of Section 26 of the Act provides that National Load Despatch Centre shall be established at the national level for optimum scheduling and despatch of electricity among the Regional Load Despatch Centres. Sub-Section (1) of Section 29 of the Act provides that the Regional Load Despatch Centre shall give such directions and exercise such supervision and control as may be required for ensuring the stability of the grid operation and for achieving the maximum economy and efficiency in the operation of the power system in the region under its control. Sub-section (2) of Section 29 of the Act mandates that every licensee, generating company, generating station, sub-station and any other person connected with the operation of the power system shall comply with the directions issued by the Regional Load Despatch Centre under sub-section (1). Sub-Section (3) of Section 29 provides that all directions issued by the Regional Load Despatch Centres to the transmission licensee of State transmission lines or any other licensee of the State or generating company (other than those connected with inter-State transmission System) or sub-station in the State shall be issued through the State Load Despatch Centre which shall ensure compliance with such directions by the concerned generating company or the licensee or sub-station. Sub-Section (3) of Section 33 of the Act provides that the State Load Despatch Centre shall comply with the directions of the Regional Load Despatch Centre. Sub-section (4) of Section 29 of the Act provides that the Regional Power Committee in the region may, from time to time, agree on matters concerning the stability and smooth operation of the integrated grid and economy and efficiency of the power system within the region. While Section 38 and Section 39 deal with the functions of the Central Transmission Utility and State Transmission Utility respectively, Section 40 and Section 42 deal with the duties of the transmission licensees and distribution licensees respectively. Therefore, the Act envisages and assigns specific roles and functions to Central Electricity Authority, Regional Power Committees, Central Transmission Utility, National Load Despatch Centre, Regional Load Despatch Centres, State Transmission Utilities, State Load Despatch Centres, generating companies and licensees and any other person connected with the operation of the power system in order to achieve real time operation and control of the grid and optimum scheduling and dispatch of electricity within the regions and amongst the regions as well as within the States for not only for ensuring secure, economic and stable operation of the grid but also for achieving maximum economy and efficiency of the power system.

Accordingly, the Grid Code hereinafter specified by the Central Commission contains the provisions regarding the roles, functions and responsibilities of the concerned statutory bodies, generating companies, licensees, and any other person connected with the operation of the power systems within the statutory framework envisaged in the Act and the Rules and Notifications issued by the Central Government.

Under clause (h) of sub-section (1) of Section 86 of the Act, the State Commissions are mandated to specify the State Grid Codes consistent with the Grid Code specified by the Central Commission under clause (h) of sub-section (1) of Section 79 of the Act. This has been duly recognized by the Hon'ble Supreme Court in its judgement dated 17.8.2007 in Civil Appeal No. 2104 of 2006 in the matter of Central Power Distribution Company & Others Vs Central Electricity Regulatory Commission.

Keeping in view the mandate and statutory framework as envisaged in the Act for stable, reliable and secure grid operation in order to achieve maximum economy and efficiency of the power system, the Grid Code apart from the provisions relating to the role of various statutory bodies and organizations and functional linkages among them, contains extensive provisions pertaining to (a) reliability and adequacy of resources; (b) technical and design criteria for connectivity to the grid including integration of new elements, trial operation and declaration of commercial operation of generating stations and inter-State transmission systems; (c) protection setting and performance monitoring of the protection systems including protection audit; (d) operational requirements and technical capabilities for secure and reliable grid operation including load generation balance, outage planning and system operation; (e) unit commitment, scheduling and despatch criteria for physical delivery of electricity; (f) integration of renewables; (g) ancillary services and reserves; and (g) cyber security etc.

NOTIFICATION

In exercise of powers conferred under clause (h) of sub-section (1) of Section 79 read with clause (g) of sub-section (2) of Section 178 of the Electricity Act, 2003 (36 of 2003), and all other powers enabling it in this behalf, the Central Electricity Regulatory Commission hereby specifies the Grid Code as under:

CHAPTER1

PRELIMINARY

1. SHORT TITLE, EXTENT AND COMMENCEMENT

(1) These regulations may be called the Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2023.

(2) These regulations shall come into force from such date as the Central Commission may notify:

Provided that different dates may be appointed for commencement of different regulations.

2. SCOPE AND EXTENT OF APPLICATION

(1) These regulations shall apply to: all users, State Load Despatch Centres, Renewable Energy Management Centres, Regional Load Despatch Centres, National Load Despatch Centre, Central Transmission Utility, State Transmission Utilities, licensees,

Regional Power Committees, Settlement Nodal Agencies, Qualified Coordinating Agencies and Power Exchanges to the extent applicable.

(2) For the purpose of these regulations, Damodar Valley Corporation (DVC) shall be treated as a regional entity and a separate control area. The DVC Load Despatch Centre shall perform functions of an SLDC for the control area of DVC.

(3) The generating stations of the Bhakra Beas Management Board (BBMB) and Sardar Sarovar Project (SSP) shall be treated as regional entities and their generating units shall be scheduled and despatched by respective RLDC in coordination with BBMB or Narmada Control Authority, as the case may be, having due regard to the irrigation and drinking requirements of the participating States.

(4) Any country inter-connected with the National Grid or Regional Grid shall be treated as a separate control area.

3. DEFINITIONS

(1) In these regulations, unless the context otherwise requires:

Sr.No.	Particulars	Definition
1.	'Act'	means the Electricity Act, 2003;
2.	'Alert State'	means the state in which the operational parameters of the power system are within their respective operational limits, but a single n-1 contingency leads to violation of system security;
3.	'Ancillary Services'	in relation to power system operation, means the services necessary to support the grid operation in maintaining power quality, reliability and security of the grid and includes Primary Reserve Ancillary Service, Secondary Reserve Ancillary Service, Tertiary Reserve Ancillary

Sr.No.	Particulars	Definition
		Service, active power support for load following, reactive power support, black start and such other services as defined in these regulations;
4.	‘Ancillary Services Regulations’ or ‘AS Regulations’	Means the Central Electricity Regulatory Commission (Ancillary Services) Regulations, 2022;
5.	‘Associated Transmission System’ or ‘ATS’	shall have the same meaning as defined in the GNA Regulations;
6.	‘Area Control Error’ or ‘ACE’	shall be as specified under clause (11) of Regulation 30 of these regulations;
7.	‘Automatic Generation Control’ or ‘AGC’	means a mechanism that automatically adjusts the generation of a control area to maintain its interchange schedule plus its share of frequency response;
8.	‘Automatic Voltage Regulator’ or ‘AVR’	means a continuously acting automatic excitation control system to control the voltage of a generating unit measured at the generator terminals;
9.	‘Auxiliary Energy Consumption’	shall have the same meaning as defined in the Tariff Regulations;
10.	‘Available Transfer Capability’ or ‘ATC’	means available power transfer capability across control areas or across regions or between ISTS and state network or between cross-border interconnections declared by the concerned load despatch centre for scheduling transactions in a specific direction with due consideration for the network security. Mathematically, ATC is the Total

Sr.No.	Particulars	Definition
		Transfer Capability less Transmission Reliability Margin;
11.	'Available Capacity'	shall have the same meaning as defined in the DSM Regulations;
12.	'Beneficiary'	means a person who has a share in an ISGS in terms of sub-clause (117) of this clause;
13.	'Bilateral Transaction'	means a transaction, other than collective transaction, for exchange of power between a specified buyer and a specified seller directly or through a trading licensee or at a Power Exchange;
14.	'Blackout State'	means a condition at a specific time where a part or all the operations of the power system have got suspended;
15.	'Black Start Procedure'	means the procedure necessary to recover from a partial or a total blackout in the region;
16.	'Bulk Consumer'	shall have the same meaning as defined in CEA Technical Standards for Connectivity;
17.	'Buyer'	means a person purchasing electricity through a transaction scheduled through inter-State transmission system in accordance with these regulations;
18.	'Captive Generating Plant'	shall have the same meaning as defined in the Act;
19.	'CEA Grid Standards'	means the Central Electricity Authority (Grid Standards) Regulations, 2010;

Sr.No.	Particulars	Definition
20.	'CEA Technical Standards for Communication'	means the Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020;
21.	'CEA Technical Standards for Connectivity'	means the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007;
22.	'CEA Technical Standards for Construction'	means the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010;
23.	'Central Generating Station'	means the generating station owned by a company owned or controlled by the Central Government;
24.	'Central Transmission Utility' or 'CTU'	means any government company, which the Central Government may notify under sub-section (1) of Section 38 of the Act;
25.	'Cold Start'	in relation to steam turbine means start up after a shutdown period exceeding 72 hours (turbine metal temperatures below approximately 40% of their full load values);
26.	'Collective Transaction'	shall have the same meaning as defined in the Central Electricity Regulatory Commission (Power Market) Regulations, 2021;
27.	'Commission'	means the Central Electricity Regulatory Commission referred to in sub-section (1) of Section 76 of the Act;
28.	'Communication System'	shall have the same meaning as defined in the Central Electricity Regulatory Commission

Sr.No.	Particulars	Definition
		(Communication System for inter-State transmission of electricity) Regulations, 2017;
29.	‘Congestion’	means a situation where the demand for transmission capacity or power flow on any transmission corridor exceeds its Available Transfer Capability;
30.	‘Connectivity Agreement’	means an agreement between CTU and any other person(s) setting out the terms and conditions relating to connection to and/or use of the Inter-State Transmission System in terms of GNA Regulations and as specified in Regulation 9 of these regulations;
31.	‘Connectivity’	means the state of getting connected to the inter-State transmission system by a generating station including a captive generating plant, a bulk consumer or an Inter-State Transmission licensee, in terms of the GNA Regulations;
32.	‘Control Area’	means an electrical system bounded by interconnections (tie lines), metering and telemetry which controls its generation and/or load to maintain its interchange schedule with other control areas and contributes to regulation of frequency as specified in these regulations;
33.	‘Control Centre’	includes NLDC or RLDC or REMC or SLDC or Area LDC or Sub-LDC or DISCOM LDC including main and backup Centres, as applicable;
34.	‘Date of Commercial Operation’ or ‘COD’	shall have the same meaning as specified under Regulation 27 of these regulations;

Sr.No.	Particulars	Definition
35.	'Declared Capacity' or 'DC'	in relation to a generating station means, the capability to deliver ex-bus electricity in MW declared by such generating station in relation to any time-block of the day as defined in the Grid Code or whole of the day, duly taking into account the availability of fuel or water, and subject to further qualification as per provisions of Chapter-7 of these regulations;
36.	'Demand'	means the demand of active power in MW and reactive power in MVAr;
37.	'Demand Response'	means variation in electricity usage by the end consumers or by a control area manually or automatically, on standalone or aggregated basis, in response to the system requirements as identified by the concerned load despatch centre;
38.	'Despatch Schedule'	means the ex-power plant net MW and MWh output of a generating station, for a time block, scheduled to be injected to the Grid from time to time;
39.	'DSM Regulations'	means the Central Electricity Regulatory Commission (Deviation Settlement Mechanism and related matters) Regulations, 2022;
40.	'Disturbance Recorder' or 'DR'	means a device for recording the behavior of the pre-selected digital and analog values of the system parameters during an event;
41.	'Data Acquisition System' or 'DAS'	means a system for recording the sequence of operation in time, of the relays or equipment as well as the measurement of pre-selected system parameters;

Sr.No.	Particulars	Definition
42.	‘Drawal Schedule’	means the summation of the station-wise ex-power plant drawal schedules from all ISGS and drawal from or injection to regional grid under GNA and T-GNA;
43.	‘DVC’	means the Damodar Valley Corporation established under sub-section (1) of Section 3 of the Damodar Valley Corporation Act, 1948;
44.	‘Emergency State’	means the state in which one or more operational parameters are outside their operating limit or many of the equipment connected to the grid are operating above their respective loading limit;
45.	‘Energy Charge’	Means the energy charge for the generating stations whose tariffs are determined by the Commission under Section 62 of the Act.
46.	‘Energy Storage System’ or ‘ESS’	in relation to the electricity system, means a facility where electrical energy is converted into any form of energy which can be stored, and subsequently reconverted into electrical energy and injected back into the grid;
47.	‘Event’	means an unscheduled or unplanned occurrence in the grid including faults, incidents and breakdowns;
48.	‘Event Logging Facilities’	means a device for recording the chronological sequence of operations, of the relays and other equipment;
49.	‘Ex-Power Plant’	means net MW or MWh output of a generating station, after deducting auxiliary consumption and transformation losses;

Sr.No.	Particulars	Definition
50.	‘Fault Locator’ or ‘FL’	means a device installed at the end of a transmission line to measure or indicate the distance at which a line fault may have occurred;
51.	‘Flat frequency control’	means a mechanism for correcting ACE by factoring in only the frequency deviation and ignoring the deviation of net actual interchange from net scheduled interchange;
52.	‘Flat tie-line control’	means a mechanism for correcting ACE by factoring in only the deviation of net actual interchange from net scheduled interchange ignoring frequency deviation;
53.	‘Flexible Alternating Current Transmission System’ or ‘FACTS’	means a power electronics based system and other static equipment that provide control of one or more AC transmission system parameters to improve power system stability, enhance controllability and increase power transfer capability of transmission systems;
54.	‘Flow-gate’	means a group of parallel transmission line (s), outage of which may lead to cascade tripping or separation of systems or loss of generation complex or loss of load centre;
55.	‘Forced Outage’	means an outage of a generating unit or a transmission facility due to a fault or any other reasons which have not been planned;
56.	Free Governor Mode of Operation	Means the mode of operation of governor where machines are loaded or unloaded directly in response to grid frequency i.e machine unloads when grid frequency is more than 50 Hz and loads when grid frequency is less than 50 Hz. The

Sr.No.	Particulars	Definition
		amount of loading or unloading is proportional to the governor droop.
57.	'Frequency Response Characteristics' or 'FRC'	means automatic, sustained change in the power consumption by load or output of the generators that occurs immediately after a change in the load-generation balance of a control area and which is in a direction to oppose any change in frequency. Mathematically it is equivalent to FRC = Change in Power (ΔP) / Change in Frequency (Δf);
58.	'Frequency Response Obligation' or 'FRO'	means the minimum frequency response a control area has to provide in the event of any frequency deviation;
59.	'Frequency Response Performance' or 'FRP'	means the ratio of actual frequency response with frequency response obligation;
60.	'Frequency Stability'	means the ability of the transmission system to maintain stable frequency in the normal state and after being subjected to a disturbance;
61.	'Gate Closure'	means the time at which the bidding for a specific delivery period closes at the power exchange and no further bidding or modification of already placed bids can take place for the said delivery period.
62.	'Generating Unit'	means a) an unit of a generating station (other than those covered in sub-clauses (b) and (c) of this clause) having electrical generator coupled to a prime mover within a power station together with all plant and apparatus at the power station

Sr.No.	Particulars	Definition
		which relate exclusively to operation of that turbo-generator , ; b) an inverter along with associated photovoltaic modules and other equipment in respect of generating station based on solar photo voltaic technology; c) a wind turbine generator with associated equipment, in respect of generating station based on wind energy; d) in respect of RHGS, combination of hydro generator under sub-clause (a); or solar generator under sub-clause (b) or wind generator under sub-clause (c) of this clause;
63.	'GNA Regulations'	means the Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022;
64.	'GNA Grantee'	means a person who has been granted GNA or is deemed to have been granted GNA under GNA Regulations;
65.	'Governor Droop'	in relation to the operation of the governor of a generating unit means the percentage drop in system frequency which would cause the generating unit under governor action to change its output from no load to full load;
66.	'Grid Security'	means the power system's capability to retain a normal state or to return to a normal state as soon as possible, and which is characterized by operational security limits;

Sr.No.	Particulars	Definition
67.	'Hot Start'	in relation to steam turbine, means the start up after a shutdown period of less than 10 hours (turbine metal temperatures below approximately 80% of their full load values);
68.	'Inertia'	means the contribution to the capability of the power system to resist changes in frequency by means of an inertial response from a generating unit, network element or other equipment that is coupled with the power system and synchronized to the frequency of the power system;
69.	'Infirm Power'	means the electricity injected into the grid prior to the date of commercial operation of a unit of the generating station;
70.	Intermediary Procurer	shall have the same meaning as defined in Electricity (Amendment) Rules, 2022
71.	'Inter-State Generating Station' or 'ISGS'	means a central generating station or any other generating station having a scheme for generation and sale of electricity in more than one state;
72.	'Inter-State Transmission System' or 'ISTS'	shall have the same meaning as defined in sub-section (36) of Section 2 of the Act;
73.	'Load'	means the active, reactive or apparent power consumed by a utility/installation of consumer;
74.	'Maximum Continuous Rating' or 'MCR'	means the maximum continuous output in MW at the generator terminals guaranteed by the manufacturer at rated parameters;
75.	'Merit Order'	means the order of ranking of available electricity generation in ascending order from least energy charge to highest energy charge to be used for

Sr.No.	Particulars	Definition
		deciding despatch instructions to minimize the overall cost of generation;
76.	'Minimum Turndown Level'	means the minimum output power expressed in percentage of maximum continuous power rating that the generating unit can sustain continuously; to be on bar and includes minimum power level as defined in CEA (Flexible Operation of Coal based Thermal Power Generating Units) Regulations, 2023
77.	'Nadir Frequency'	means minimum frequency after a contingency in case of generation loss and maximum frequency after a contingency in case of load loss;
78.	'National Grid'	means the entire inter-connected electric power network of the country;
79.	'National Load Despatch Centre' or 'NLDC'	means the centre established under sub-section (1) of Section 26 of the Act;
80.	'Near Miss Event'	means an incident of multiple failures that has the potential to cause a grid disturbance, power failure or partial collapse but does not result in a grid disturbance;
81.	'Net Drawal Schedule'	means the drawal schedule of a regional entity which is the algebraic sum of all its transactions through the inter-State transmission system at ISTS periphery after deducting the transmission losses;
82.	'Net Injection Schedule'	means the injection schedule of a regional entity which is the algebraic sum of all its transactions

Sr.No.	Particulars	Definition
		through the inter-State transmission system at ISTS periphery;
83.	'Normal State'	means the state in which the operational parameters of the power system are within their respective operational limits and equipments are within their respective loading limits;
84.	'Off-Bar Declared Capability'	means the difference between Declared Capacity and On-Bar Declared Capacity in MW;
85.	'On-Bar Declared Capacity'	in relation to a generating station means the capability to deliver ex-bus electricity in MW from the units on-bar declared by such generating station in relation to any time block of the day or whole of the day, duly taking into account the availability of fuel and water and subject to further qualification in the relevant regulations;
86.	'On-Bar Installed Capacity'	means the summation of name plate capacities or the capacities as approved by the Commission from time to time, of all units of the generating station in MW which are on- bar. In case of a combined cycle module of a gas or liquid fuel-based stations, the installed capacity of steam turbine shall be in proportion to the on-bar capacity of gas turbines of the module;
87.	'Operation Co-ordination Sub-Committee' or 'OCC'	means a sub-committee of RPC which deliberates and decides the operational aspects of the regional grid;
88.	'Operational Parameters'	means the parameters for system security as specified by the system operator including

Sr.No.	Particulars	Definition
		frequency, voltage at station-bus, angular separation, damping ratio, short circuit level, inertia;
89.	'Pool Account'	means Deviation and Ancillary Service Pool Account as defined in the DSM Regulations, where the following transactions shall be accounted: i. deviations and ancillary services ii. reactive energy exchanges iii. congestion charge;
90.	'Pooling Station'	means the ISTS grid sub-station where pooling of generation of connected individual generating stations is done for interfacing with the next higher voltage level;
91.	'Power System'	shall have the same meaning as defined in sub-section (50) of Section 2 of the Act
92.	'Primary Reserve'	means the maximum quantum of power which will immediately come into service through governor action of the generator or frequency controller or through any other resource in the event of sudden change in frequency as specified in clause (10) of Regulation 30 of these regulations;
93.	'Protection Co-ordination Sub-Committee'	means a sub-committee of RPC with members from all the regional entities which decides on the protection aspects of the regional grid;
94.	'Qualified Coordinating Agency' or 'QCA'	means the lead generator or any authorized agency on behalf of REGS or RHGS (as per GNA Regulations) including Energy Storage Systems

Sr.No.	Particulars	Definition
		connected to one or more pooling station(s) for coordinating with concerned load despatch centre for scheduling, operational coordination and deviation settlement;
95.	‘Ramp Rate’	means rate of change of a generating station output expressed in %MW per minute;
96.	‘Rate of Change of Frequency’ or ‘*df/dt*’	means the time derivative of the power system frequency which negates short term transients and therefore reflects the actual change in synchronous network frequency;
97.	‘Reference contingency’	means the maximum positive power deviation occurring instantaneously between generation and demand and considered for estimation of reserves;
98.	‘Regional Entity’	means the entitiy which is in the RLDC control area and whose metering and energy accounting is done at the regional level;
99.	‘Regional Power Committee’ or ‘RPC’	shall have the same meaning as defined under sub-section (55) of Section 2 of the Act.
100.	‘Restorative State’	means a condition in which control action is being taken to reconnect the system elements and to restore system load;
101.	‘Regional Energy Account’ or ‘REA’	means account of energy and other parameters issued by the respective RPC for the purpose of billing and settlement of charges of ISGS and other users of the concerned region;

Sr.No.	Particulars	Definition
102.	'Regional Transmission Account' or 'RTA'	means accounts of transmission issued by the RPC for the purpose of billing and settlement of transmission charges of ISTS in the concerned region in accordance with the Sharing Regulations;
103.	'Regional Grid'	means the high voltage backbone system of inter-connected transmission lines, sub-stations and generating plants in a region;
104.	'Regional Load Despatch Centre' or 'RLDC'	means the Centre established under sub-section (1) of Section 27 of the Act;
105.	'Renewable Energy Generating Station' or REGS'	means a generating station based on a renewable source of energy with or without Energy Storage System and shall include Renewable Hybrid Generating Station;
106.	"Renewable Hybrid Generating Station" or "RHGS"	means a generating station based on hybrid of two or more renewable source(s) of energy with or without Energy Storage System, connected at the same inter-connection point;
107.	'Resilience'	means the ability to withstand and reduce the magnitude or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, or rapidly recover from such an event;
108.	'SCED Account'	means a bank account from where all payments to and from the generating station(s) on account of SCED schedules flows.

Sr.No.	Particulars	Definition
109.	'SCED Compensation Charge'	means the charge declared by a generating station other than the generating station whose tariff is determined by the Commission under Section 62 of the Act, for participation in SCED;
110.	'Secondary Reserve'	means the maximum quantum of power which can be activated through secondary control signal by which injection or drawal or consumption of an SRAS provider is adjusted in accordance with Ancillary Service Regulations;
111.	'Secondary Reserve Ancillary Service' or 'SRAS'	means the Ancillary Service comprising SRAS-Up and SRAS-Down, which is activated and deployed through secondary control signals;
112.	'Secondary Reserve Ancillary Service Provider' or 'SRAS Provider'	means an entity which provides SRAS-Up or SRAS-Down service in accordance with Ancillary Service Regulations;
113.	'Security Constrained Economic Despatch' or 'SCED'	Means optimised despatch of generating units subject to operational and technical limits of generation and transmission facilities as specified in these regulations;
114.	'Security Constrained Unit Commitment' or 'SCUC'	means committing generating units while respecting limitations of the transmission system and unit operating characteristics as specified in these regulations;
115.	"Seller'	means a person, including a generating station, supplying electricity through a transaction scheduled in accordance with these regulations;

Sr.No.	Particulars	Definition
116.	‘Settlement Nodal Agency’ or ‘SNA’	means the nodal agency as notified by Ministry of Power, Government of India for each neighboring country for settlement of grid operation related charges in terms of Central Electricity Regulatory Commission (Cross Border Trade of Electricity) Regulations, 2019;
117.	‘Share’	means percentage or MW entitlement of a beneficiary in an ISGS either notified by Government of India or agreed between the generating company and beneficiary through contracts and implemented through GNA or TGNA, as the case may be;
118.	‘Sharing Regulations’	means the Central Electricity Regulatory Commission (Sharing of Inter-State Transmission Charges and Losses) Regulations, 2020;
119.	‘State Load Despatch Centre’ or ‘SLDC’	means the Centre established under sub-section (1) of Section 31 of the Act;
120.	‘State Transmission Utility’ or ‘STU’	means the board or the government company specified as such by the concerned State Government under sub-section (1) of section 39 of the Act;
121.	‘System Constraint’	means a situation in which there is a need to prepare and activate a remedial action in order to respect operational security limits;
122.	‘System State’	means the operational state of the power system in relation to the operational security limits which can be normal state, alert state, emergency state, extreme emergency state and restorative state;

Sr.No.	Particulars	Definition
123.	'Tariff Regulations'	means the Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations, 2019;
124.	'Technical Co-ordination Committee' or 'TCC'	means the sub-committee set up by the respective RPC to coordinate the technical and commercial aspects of the operation of the regional grid;
125.	'Tertiary Reserve'	means the quantum of power which can be activated in order to take care of contingencies and to cater to the need for replacing secondary reserves;
126.	'Tie-line bias control'	means a mechanism of correcting ACE by factoring in deviation of net actual interchange from net scheduled interchange as well as frequency deviation;
127.	'Time Block'	means block of duration as specified by the Commission for which energy meters record values of specified electrical parameters with first time block starting at 00.00 Hours, presently of fifteen (15) minutes duration;
128.	'Total Transfer Capability' or 'TTC'	means the amount of electric power that can be transferred reliably over the inter-control area transmission system under a given set of operating conditions considering the effect of occurrence of the worst credible contingency;
129.	'Transmission Planning Criteria'	means the criteria issued by CEA for transmission system planning;
130.	'Transmission Reliability Margin' or 'TRM'	means the amount of margin earmarked in the total transfer capability to ensure that the

Sr.No.	Particulars	Definition
		interconnected transmission network is secure under a reasonable range of uncertainties in system conditions;
131.	‘Trial Operation’ or ‘Trial Run’	shall have the same meaning as specified in Regulation 22 or Regulation 23 of these regulations, as applicable;
132.	‘User’	means and includes generating company, captive generating plant, energy storage system, transmission licensee including deemed transmission licensee, distribution licensee, solar park developer, wind park developer, wind-solar photo voltaic hybrid system, or bulk consumer which is or whose electrical plant is connected to the grid at voltage level 33 kV and above;
133.	‘Voltage Stability’	means the ability of a transmission system to maintain steady acceptable voltages at all nodes in the transmission system in the normal situation and after being subjected to a disturbance;
134.	‘Warm Start’	means the start up after a shutdown period between 10 hours and 72 hours (turbine metal temperatures between approximately 40% to 80% of their full load values) in relation to steam turbine;
135.	‘WS Seller’	shall have the same meaning as defined in the DSM Regulations.

(2) Words and expressions used in these regulations that are not defined herein but defined in the Act or other regulations of the Commission shall have the meaning as assigned to them under the Act or the said regulations of the Commission.

(3) Reference to any Acts, Rules and Regulations shall include amendments or consolidation or re-enactment thereof.

CHAPTER 2

RESOURCE PLANNING CODE

4. GENERAL

(1) This chapter covers the integrated resource planning including demand forecasting, generation resource adequacy planning and transmission resource adequacy assessment, required for secure grid operation.

(2) The planning of generation and transmission resources shall be for reliably meeting the projected demand in compliance with specified reliability standards for serving the load with optimum generation mix with a focus on integration of environmentally benign technologies after taking into account the need, inter alia, for flexible resources, storage systems for energy shift and demand response measures for managing the intermittency and variability of renewable energy sources.

5. INTEGRATED RESOURCE PLANNING

(1) The integrated resource planning shall include:

(a) Demand forecasting as detailed in clause (2) of this Regulation;

(b) Generation resource adequacy planning to meet the projected demand as detailed in clause (3) of this Regulation; and

(c) Transmission resource planning as detailed in clause (4) of this Regulation

(2) Demand Forecasting:

(i) Each distribution licensee within a State shall estimate the demand in its control area including the demand of open access consumers and factoring in captive generating plants, energy efficiency measures, distributed generation, demand response, in different time horizons, namely long-term, medium term and short-term. The demand estimation shall be done using trend method, time series, econometric methods or any state of the art methods and shall include daily load curve (hourly basis) for a typical day of each month.

(ii) STU or such other agency as may be designated by the State Commission, based on the demand estimates of the distribution licensees of the concerned State as per sub-clause (i) of this clause and in co-ordination with all the distribution licensees, shall estimate, in different time horizons, namely long-term, medium term and short-term, the demand for the entire State duly considering the diversity of the State.

(iii) Forum of Regulators may develop guidelines for demand estimation by the distribution licensees for achieving consistency and statistical accuracy by taking into consideration the factors such as economic parameters, historical data and sensitivity and probability analysis.

(3) Generation Resource Adequacy Planning:

(a) After the demand estimation as per clause (2) of this Regulation, each distribution licensee shall

(i) assess the existing generation resources and identify the additional generation resource requirement to meet the estimated demand in different time horizons, and

(ii) prepare generation resource procurement plan.

(b) Assessment of the existing generation resources shall be done with due regard to their capacity contribution to meet the peak demand of the distribution licensee and the state.

(c) Generation resource procurement planning (specifying procurement from resources under State control area and regional control area) shall be undertaken in different time horizons, namely long-term, medium term and short-term to ensure

(i) adequacy of generation resources and

(ii) planning reserve margin (PRM) taking into account loss of load probability and energy not served as specified by CEA.

(d) In order to ensure optimum and least cost generation resource procurement planning, each distribution licensee shall give due consideration to the factors such as its share in the state, regional and national coincident peak; seasonal requirement and possibility of sharing generation capacity seasonally with other States. For this purpose, each STU or such other agency as may be designated by the State Commission, on behalf of the distribution licensees in the State shall provide to NLDC every year, the details regarding demand forecasting, assessment of existing generation resources and such other details as may be required for carrying out a national level simulation for generation resource adequacy for States.

(e) Based on the information received under sub-clause (d) of this clause and after considering inter alia the national level planning reserve margin, share of each State in the regional and national coincident peak, seasonal requirements of States and possibility of sharing generation capacity seasonally among States, NLDC shall carry out a simulation, to assist the States in drawing their optimal generation resource adequacy plan. While carrying out the simulation, NLDC shall also take into consideration the information related to demand estimation, generation planning and related matters as available with CEA. The simulation carried out by NLDC for this purpose shall be considered merely as an aid to the distribution licensees in the respective States in their exercise of generation resource adequacy planning and the distribution licensees shall be responsible for all commercial decisions on generation resource procurement.

(f) After considering the demand forecasting and the generation resource procurement planning carried out based on the principles specified under this Regulation, each distribution licensee shall ensure demonstrable generation resource adequacy for such period as specified by the respective SERC. Failure of a distribution licensee to meet the generation resource adequacy target approved by the SERC shall render the concerned distribution licensee liable for payment of resource adequacy non-compliance charge as may be specified by the respective SERC.

(g) For the sake of uniformity in approach and in the interest of optimality in generation resource adequacy in the States, FOR may develop a model Regulation stipulating inter alia the methodology for generation resource adequacy assessment, generation resource procurement planning and compliance of resource adequacy target by the distribution licensees.

(4) Transmission resource adequacy assessment

(a) CTU shall undertake assessment and planning of the inter-State transmission system as per the provisions of the Act and shall inter alia take into account:

(i) adequate power transfer capability across each flow-gate;

(ii) import and export capability for each control area;

(iii) import and export capability between regions; and

(iv) cross-border import and export capability.

(b) STU shall undertake assessment and planning of the intra-State transmission system as per the provisions of the Act and shall inter alia take into account:

(i) import and export capability across ISTS and STU interface; and

(ii) adequate power transfer capability across each flow-gate.

CHAPTER 3

CONNECTION CODE

6. GENERAL

(1) This chapter covers the technical and design criteria for connectivity, procedure and requirements for physical connection and integration of grid elements.

(2) The connectivity to the ISTS shall be granted by CTU in accordance with the GNA Regulations.

(3) Users seeking to get connected to the ISTS for the first time through a new or modified power system element shall fulfill the requirements and follow the procedures specified under this Code prior to obtaining the permission of the NLDC or RLDC or SLDC, as the case may be. Transmission licensees including deemed transmission licensees or cross-border entities shall comply with the technical requirements specified under this Connection Code prior to being allowed by NLDC or RLDC or SLDC to energize a new or modified power system element.

(4) After grant of connectivity and prior to the declaration of commercial operation, the tests as specified under Chapter-5 of these regulations shall be performed.

7. COMPLIANCE WITH EXISTING RULES AND REGULATIONS

(1) All Users connected to or seeking connection to the grid shall comply with all the applicable regulations as enacted or amended from time to time, such as:

(a) Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007;

(b) Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010;

(c) Central Electricity Authority (Measures Relating to Safety & Electric Supply) Regulations, 2010;

(d) Central Electricity Regulatory Commission (Communication System for Inter-State Transmission of Electricity) Regulations,2017;

(e) Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006;

(f) Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022;

(g) Central Electricity Regulatory Commission (Fees and Charges for Regional Load Despatch Centres) Regulations, 2019;

(h) Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020;

(i) Central Electricity Regulatory Commission (Furnishing of Technical Details by the Generating Companies) Regulations, 2009.

(j) Central Electricity Authority (Grid Standards) Regulations, 2010.

(k) Central Electricity Authority (Cyber Security in Power Sector) Guidelines, 2021.

(l) Central Electricity Authority (Flexible Operation of Coal based Thermal Power Generating Units) Regulations, 2023

(m) Any other regulation and standard as specified from time to time.

8. PROCEDURE FOR CONNECTION

(1) The grant of connectivity to the ISTS by the CTU shall be governed by the GNA Regulations.

(2) NLDC, in coordination with RPCs and RLDCs after due consultation of stakeholders, shall prepare a detailed procedure covering modalities for first time energization and integration

of new or modified power system element and submit for approval of the Commission. The procedure shall specify requirements for integration with the grid such as protection, telemetry and communication systems; metering; statutory clearances; modelling data requirements for system studies and timeline for submission of data for system study.

(3) Post completion of all physical arrangements of connectivity and necessary site tests, the concerned user shall request the RLDC for permission of first time energization in the specified format as per the procedure published by NLDC.

(4) SLDC shall prepare procedure for first time energization of new or modified power system elements to intra-State transmission system. In the absence of such procedure of SLDC, the NLDC procedure shall apply for the elements of 220 kV and above (132 kV and above in case of North Eastern region).

9. CONNECTIVITY AGREEMENT

(1) In case of users seeking connectivity to the ISTS under GNA Regulations, Connectivity Agreement shall be signed between such users and CTU. In case of multiple transmission licensees connected at same station, the Site Responsibility Schedule including the responsibility for operation & protection coordination and data sharing among the licensees, shall be specified in the Connectivity Agreement.

(2) In case of an inter-State transmission licensee, Connectivity Agreement shall be signed between such licensee and CTU after the award of the project and before physical connection to ISTS.

(3) In case of intra-State transmission system getting connected to inter-State transmission system, Connectivity Agreement shall be signed between intra-State transmission

licensee, CTU and inter-State transmission licensee after the award of the project and before physical connection to ISTS.

10. TECHNICAL REQUIREMENTS

(1) NLDC or RLDC, as the case may be, in consultation with CTU, STU or SLDC, as the case may be, shall carry out a joint system study six (6) months before the expected date of first energization of a new power system element to identify operational constraints, if any. In case of constraints, CTU, NLDC or RLDC, as the case may be and SLDC shall identify measures for facilitating the integration of the element, subject to grid security. The connectivity grantee, transmission licensee and SLDC/STU shall furnish all technical data including that of its embedded generators and other elements to the CTU and NLDC or RLDC, as the case may be, for necessary technical studies.

(2) Similar exercise shall be done by SLDC in consultation with STU for the intra-state system, and specifically for elements of 220 kV and above (132 kV and above in case of North Eastern region).

(3) NLDC shall publish a detailed Procedure covering modalities for carrying out interconnection studies.

11. DATA AND COMMUNICATION FACILITIES

(1) Reliable speech and data communication systems shall be provided to facilitate necessary communication, data exchange, supervision and control of the grid by the NLDC, RLDC and SLDC in accordance with the CERC (Communication System for Inter-State Transmission of Electricity) Regulations, 2017 and the CEA Technical Standards for Communication.

(2) The associated communication system to facilitate data flow up to appropriate data collection point on CTU system including inter-operability requirements shall also be established by the concerned user as specified by CTU in the Connectivity Agreement.

(3) All users, STU and participating entities in case of cross-border trade shall provide, in coordination with CTU, the required facilities at their respective ends as specified in the connectivity agreement. The communication system along with data links provided for speech and real time data communication shall be monitored in real time by all users, CTU, STU, SLDC and RLDC to ensure high reliability of the communication links.

CHAPTER 4

PROTECTION CODE

12. GENERAL

(1) This chapter covers the protection protocol, protection settings and protection audit plan of electrical systems.

(2) There shall be a uniform protection protocol for the users of the grid:

(a) for proper co-ordination of protection system in order to protect the equipment/system from abnormal operating conditions, isolate the faulty equipment and avoid unintended operation of protection system;

(b) to have a repository of protection system, settings and events at regional level;

(c) specifying timelines for submission of data;

(d) to ensure healthiness of recording equipment including triggering criteria and time synchronization; and

(e) to provide for periodic audit of protection system.

13. PROTECTION PROTOCOL

(1) All users connected to the integrated grid shall provide and maintain effective protection system having reliability, selectivity, speed and sensitivity to isolate faulty section and protect element(s) as per the CEA Technical Standards for Construction, the CEA Technical Standards for Connectivity, the CEA (Grid Standards) Regulations, 2010, the CEA Technical Standards for Communication and any other applicable CEA Standards specified from time to time.

(2) Back-up protection system shall be provided to protect an element in the event of failure of the primary protection system.

(3) RPC shall develop the protection protocol and revise the same, after review from time to time, in consultation with the stakeholders in the concerned region, and in doing so shall be guided by the principle that minimum electrical protection functions for equipment connected with the grid shall be provided as per the CEA Technical Standards for Construction, the CEA Technical Standards for Connectivity, the CEA Technical Standards for Communication, the CEA (Grid Standards) Regulations, 2010, the CEA (Measures relating to Safety and Electric Supply) Regulations, 2010, and any other CEA standards specified from time to time.

(4) The protection protocol in a particular system may vary depending upon operational experience. Changes in protection protocol, as and when required, shall be carried out after deliberation and approval of the concerned RPC.

(5) Violation of the protection protocol of the region shall be brought to the notice of concerned RPC by the concerned RLDC or SLDC, as the case may be.

14. PROTECTION SETTINGS

(1) RPCs shall undertake review of the protection settings, assess the requirement of revisions in protection settings and revise protection settings in consultation with the stakeholders of the respective region, from time to time and at least once in a year. The necessary studies in this regard shall be carried out by the respective RPCs. The data including base case (peak and off-peak cases) files for carrying out studies shall be provided by RLDC and CTU to the RPCs:

(2) All users connected to the grid shall:

(a) furnish the protection settings implemented for each element to respective RPC in a format as prescribed by the concerned RPC;

(b) obtain approval of the concerned RPC for (i) any revision in settings, and (ii) implementation of new protection system;

(c) intimate to the concerned RPC about the changes implemented in protection system or protection settings within a fortnight of such changes;

(d) ensure correct and appropriate settings of protection as specified by the concerned RPC.

(e) ensure proper coordinated protection settings.

(3) RPCs shall:

(a) maintain a centralized database and update the same on periodic basis in respect of their respective region containing details of relay settings for grid elements connected to 220 kV and above (132 kV and above in NER). RLDCs shall also maintain such database.

(b) carry out detailed system studies, once a year, for protection settings and advise modifications / changes, if any, to the CTU and to all users and STUs of their respective regions. The data required to carry out such studies shall be provided by RLDCs and CTU.

(c) provide the database access to CTU and NLDC and to all users, RLDC, SLDCs, and STUs of the respective regions. The database shall have different access rights for different users.

(4) The changes in the network and protection settings of grid elements connected to 220kV and above (132 kV and above in NER) shall be informed to RPCs by CTU and STUs, as the case may be.

(5) The elements of network below 66kV and radial in nature which do not impact the National Grid may be excluded as finalized by the respective RPC.

15. PROTECTION AUDIT PLAN

(1) All users shall conduct internal audit of their protection systems annually, and any shortcomings identified shall be rectified and informed to their respective RPC. The audit report along with action plan for rectification of deficiencies detected, if any, shall be shared with respective RPC for users connected at 220 kV and above (132 kV and above in NER).

(2) All users shall also conduct third party protection audit of each sub-station at 220 kV and above (132 kV and above in NER) once in five years or earlier as advised by the respective RPC.

(3) After analysis of any event, each RPC shall identify a list of substations / and generating stations where third-party protection audit is required to be carried out and accordingly advise the respective users to complete third party audit within three months.

(4) The third-party protection audit report shall contain information sought in the format enclosed as Annexure–1. The protection audit reports, along with action plan for rectification of deficiencies detected, if any, shall be submitted to the respective RPC and RLDC or SLDC, as the case may be, within a month of submission of third party audit report. The necessary compliance to such protection audit report shall be followed up regularly in the respective RPC.

(5) Annual audit plan for the next financial year shall be submitted by the users to their respective RPC by 31st October. The users shall adhere to the annual audit plan and report compliance of the same to their respective RPC.

(6) Users shall submit the following protection performance indices of previous month to their respective RPC and RLDC on monthly basis for 220 kV and above (132 kV and above in NER) system, which shall be reviewed by the RPC:

(a) The Dependability Index defined as $D = \frac{Nc}{Nc+Nf}$

where,

N_c is the number of correct operations at internal power system faults and

N_f is the number of failures to operate at internal power system faults.

(b) The Security Index defined as $S = \frac{Nc}{Nc+Nu}$

Where,

N_c is the number of correct operations at internal power system faults

N_u is the number of unwanted operations.

(c) The Reliability Index defined as $R = \frac{Nc}{Nc+Ni}$

Where,

N_c is the number of correct operations at internal power system faults

N_i is the number of incorrect operations and is the sum of N_f and N_u

(7) Each user shall also submit the reasons for performance indices less than unity of individual element wise protection system to the respective RPC and action plan for corrective measures. The action plan will be followed up regularly in the respective RPC.

(8) In case any user fails to comply with the protection protocol specified by the RPC or fails to undertake remedial action identified by the RPC within the specified timelines, the concerned RPC may approach the Commission with all relevant details for suitable directions.

16. SYSTEM PROTECTION SCHEME (SPS)

(1) SPS for identified system shall have redundancies in measurement of input signals and communication paths involved up to the last mile to ensure security and dependability.

(2) For the operational SPS, RLDC or NLDC, as the case may be, in consultation with the concerned RPC(s) shall perform regular load flow and dynamic studies and mock testing for reviewing SPS parameters & functions, at least once in a year. RLDC or NLDC shall share the report of such studies and mock testing including any short comings to respective RPC(s). The data for such studies shall be provided by CTU to the concerned RPC, RLDC and NLDC.

(3) The users and SLDCs shall report about the operation of SPS immediately and detailed report shall be submitted within three days of operation to the concerned RPC and RLDC in the format specified by the respective RPCs.

(4) The performance of SPS shall be assessed as per the protection performance indices specified in these Regulations. In case, the SPS fails to operate, the concerned User shall take corrective actions and submit a detailed report on the corrective actions taken to the concerned RPC within a fortnight.

17. RECORDING INSTRUMENTS

(1) All users shall keep the recording instruments (disturbance recorder and event logger) in proper working condition.

(2) The disturbance recorders shall have time synchronization and a standard format for recording analogue and digital signals which shall be included in the guidelines issued by the respective RPCs.

(3) The time synchronization of the disturbance recorders shall be corroborated with the PMU data or SCADA event loggers by the respective RLDC. Disturbance recorders which are non- compliant shall be listed out for discussion at RPC.

CHAPTER 5

COMMISSIONING AND COMMERCIAL OPERATION CODE

18. GENERAL

This chapter covers aspects related to (i) drawl of startup power from and injection of infirm power into the grid, (ii) trial run operation (iii) documents and tests required to be furnished before declaration of COD, (iv) requirements for declaration of COD.

19. DRAWAL OF START UP POWER AND INJECTION OF INFIRM POWER

(1) A unit of a generating station including unit of a captive generating plant that has been granted connectivity to the inter-State Transmission System in accordance with GNA Regulations shall be allowed to inter-change power with the grid during the commissioning period, including testing and full load testing before the COD, after obtaining prior permission of the concerned Regional Load Despatch Centre:

Provided that the concerned Regional Load Despatch Centre while granting such permission shall keep grid security in view.

(2) The period for which such inter-change shall be allowed-shall be as follows:-

(a) Drawal of start-up power shall not exceed 15 months prior to the expected date of first synchronization and one year after the date of first synchronization; and

(b) Injection of infirm power shall not exceed one year from the date of first synchronization.

(3) Notwithstanding the provisions of clause (2) of this Regulation, the Commission may allow extension of the period for inter-change of power beyond the stipulated period on

an application made by the generating station at least two months in advance of the completion of the stipulated period:

(4) Drawal of start-up power shall be subject to payment of transmission charges as per the Sharing Regulations;

(5) The charges for deviation for drawal of start up power or for injection of infirm power shall be as per the DSM Regulations;

(6) Start-up power shall not be used by the generating station for construction activities;

(7) The onus of proving that the interchange of infirm power from the unit(s) of the generating station is for the purpose of pre-commissioning activities, testing and commissioning, shall rest with the generating station, and the concerned RLDC shall seek such information on each occasion of the interchange of power before COD. For this, the generating station shall furnish to the concerned RLDC relevant details, such as those relating to the specific commissioning activity, testing, and full load testing, its duration and the intended period of interchange. The generating station shall submit a tentative plan for the quantum and time of injection of infirm power on day ahead basis to the respective RLDC.

(8) In the case of multiple generating units of the same generating station or multiple generating stations owned by different entities connected at a common ISTS interface point, RLDC shall ensure segregation of firm power from generating units that have achieved COD from power injected or drawn by generating units which have not achieved COD through appropriate accounting of energy.

(9) RLDC shall stop the drawl of the start-up Power in the following events:

    (a) In case, it is established that the start-up power has been used by the generating station for construction activity;

    (b) In the case of default in payment of monthly transmission charges, charges under

RLDC Fees and Charges Regulations and deviation charges under the DSM Regulations.

20. DATA TO BE FURNISHED PRIOR TO NOTICE OF TRIAL RUN

(1) The following details, as applicable, shall be furnished by each regional entity generating station to the concerned RLDC, RPC and the beneficiaries of the generating station, wherever identified, prior to notice of trial run:

TABLE 1: DETAILS TO BE FURNISHED BY GENERATING ENTITY PRIOR TO TRIAL RUN

Description	Units
Installed Capacity of generating station	MW
Installed Capacity of generating station	MVA
MCR	MW
Number x unit size	No x MW
Time required for cold start	Minute
Time required for warm start	minute
Time required for hot start	Minute
Time required for combined cycle operation under cold conditions	Minute
Time required for combined cycle operation under warm conditions	Minute
Ramping up capability	% per minute
Ramping down capability	% per minute
Minimum turndown level	% of MCR
Minimum turndown level	MW (ex-bus)
Inverter Loading Ratio (DC/AC capacity)	
Name of QCA (where applicable)	
Full reservoir level (FRL)	Metre

Description	Units
Design Head	Metre
Minimum draw down level (MDDL)	Metre
Water released at Design Head	M^3/ MW
Unit-wise forbidden zones	MW

21. NOTICE OF TRIAL RUN

(1) The generating company proposing its generating station or a unit thereof for trial run or repeat of trial run shall give a notice of not less than seven (7) days to the concerned RLDC, and the beneficiaries of the generating stations, including intermediary procurers, wherever identified:

Provided that in case the repeat trial run is to take place within forty eight (48) hours of the failed trial run, fresh notice shall not be required.

(2) The transmission licensee proposing its transmission system or an element thereof for trial run shall give a notice of not less than seven days to the concerned RLDC, CTU, distribution licensees of the region and the owner of the inter-connecting system.

(3) The concerned RLDC shall allow commencement of the trial run from the requested date or in the case of any system constraints, not later than seven (7) days from the proposed date of the trial run. The trial run shall commence from the time and date as decided and informed by the concerned RLDC.

(4) A generating station shall be required to undergo a trial run in accordance with Regulation 22 of these regulations after completion of Renovation and Modernization for extension of the useful life of the project as per the Tariff Regulations.

22. TRIAL RUN OF GENERATING UNIT

(1) Trial Run of the Thermal Generating Unit shall be carried out in accordance with the following provisions:

(a) A thermal generating unit shall be in continuous operation at MCR for seventy-two (72) hours on designated fuel:

Provided that:

(i) short interruption or load reduction shall be permissible with the corresponding increase in duration of the test;

(ii) interruption or partial loading may be allowed with the condition that the average load during the duration of the trial run shall not be less than MCR, excluding the period of interruption but including the corresponding extended period;

(iii) cumulative interruption of more than four (4) hours shall call for a repeat of trial run.

(b) Where, on the basis of the trial run, a thermal generating unit fails to demonstrate the unit capacity corresponding to MCR, the generating company has the option to de-rate the capacity of the generating unit or to go for a repeat trial run. If the generating company decides to de-rate the unit capacity, the de-rated capacity in such cases shall not be more than 95% of the demonstrated capacity, to cater for primary response.

(2) Trial Run of Hydro Generating Unit shall be carried out in accordance with the following provisions:

(a) A hydro generating unit shall be in continuous operation at MCR for twelve (12) hours:

Provided that-

(i) short interruption or load reduction shall be permissible with a corresponding increase in duration of the test;

(ii) interruption or partial loading may be allowed with the condition that the average load during the duration of trial run shall not be less than MCR excluding period of interruption but including the corresponding extended period;

(iii) cumulative interruption of more than four (4) hours shall call for a repeat of trial run;

(iv) if it is not possible to demonstrate the MCR due to insufficient reservoir or pond level or insufficient inflow, COD may be declared, subject to the condition that the same shall be demonstrated immediately when sufficient water is available after COD:

Provided that if such a generating station is not able to demonstrate the MCR when sufficient water is available, the generating company shall de-rate the capacity in terms of sub-clause (b) of this clause, and such de-rating shall be effective from COD.

(b) Where, on the basis of the trial run, a hydro generating unit fails to demonstrate the unit capacity corresponding to MCR, the generating company shall have the option to either de-rate the capacity or go for a repeat trial run. If the generating company decides to de-rate the unit capacity, the de-rated capacity in such cases shall not be more than 90% of the demonstrated capacity to cater for primary response.

(3) Trial Run of Wind / Solar / ESS / Hybrid Generating Station

(a) Trial run of the solar inverter unit(s) shall be performed for a minimum capacity aggregating to 50 MW:

Provided that in the case of a project having a capacity of more than 50 MW, the trial run for the balance capacity shall be performed in a maximum of four instalments with a minimum capacity of 5 MW:

Provided further that the trial run for solar inverter unit(s) aggregating to less than 50 MW for entities covered under clause (e) of Regulation 4.1 of the GNA Regulations, shall be allowed for the capacity for which Connectivity has been granted to such entity.

(b) Successful trial run of a solar inverter unit(s) covered under sub-clause (a) of this clause shall mean the flow of power and communication signal for not less than four (4) hours on a cumulative basis between sunrise and sunset in a single day with the requisite metering system, power plant controller, telemetry and protection system in service. The generating company shall record the output of the unit(s) during the trial run and shall corroborate its performance with the temperature and solar irradiation recorded at site during the day and plant design parameters:

Provided that:

(i) the output below the corroborated performance level with the solar irradiation of the day shall call for a repeat of the trial run;

(ii) if it is not possible to demonstrate the rated capacity of the plant due to insufficient solar irradiation, COD may be declared subject to the condition that the same shall be demonstrated immediately when sufficient solar irradiation is available after COD, within one year from the date of COD:

Provided that if such a generating station is not able to demonstrate the rated capacity when sufficient solar irradiation is available after COD, the generating company shall de-rate the capacity in terms of sub-clause (h) of clause (3) of this Regulation.

(c) Trial run of a wind turbine(s) shall be performed for a minimum capacity aggregating to 50 MW:

Provided that in the case of a project having a capacity of more than 50 MW, the trial run for wind turbine(s) above the capacity of 50 MW shall be performed in batch sizes of not less than 5 MW:

Provided further that the trial run for wind turbine(s) aggregating to less than 50 MW for entities covered under clause (e) of Regulation 4.1 of the GNA Regulations, shall be allowed for the capacity for which Connectivity has been granted to such an entity.

(d) Successful trial run of a wind turbine(s) covered under sub-clause (c) of this clause shall mean the flow of power and communication signal for a period of not less than continuous four (4) hours during periods of wind availability with the requisite metering system, power plant controller, telemetry and protection system in service. The generating company shall record the output of the unit(s) during the trial run and corroborate its performance with the wind speed recorded at the site(s) during the day and plant design parameters:

Provided that-

(i) the output below the corroborated performance level with the wind speed of the day shall call for a repeat of the trial run;

(ii) if it is not possible to demonstrate the rated capacity of the plant due to insufficient wind velocity, COD may be declared subject to the condition that the same shall be demonstrated immediately when sufficient wind velocity is available after COD, within one year from the date of COD:

Provided that if such a generating station is not able to demonstrate the rated capacity when sufficient wind velocity is available after COD, the generating company shall de-rate the capacity in terms of sub-clause (h) of clause (3) this Regulation.

(e) Successful trial run of a standalone Energy Storage System (ESS) shall mean one (1) cycle of charging and discharging of energy as per the design capabilities with the requisite metering, telemetry and protection system being in service.

(f) Successful trial run of a pumped storage plant shall mean one (1) cycle of turbo-generator and pumping motor mode as per the design capabilities up to the rated water drawing levels with the requisite metering, telemetry and protection system being in service.

(g) Successful trial run of a hybrid system shall mean successful trial run of each individual source of the hybrid system in accordance with the applicable provisions of these regulations.

(h) Where, on the basis of the trial run, solar / wind / storage / hybrid generating station fails to demonstrate its rated capacity, the generating company shall have the option to either go for a repeat trial run or de-rate the capacity subject to a minimum aggregated de-rated capacity of 50 MW or 5 MW, as the case may be.

(i) Notwithstanding the provisions contained in this Regulation, where Power purchase Agreement provides for a specific capacity that can be declared COD, trial run shall be allowed for such capacity in terms of such Power purchase agreement.

23. TRIAL RUN OF INTER-STATE TRANSMISSION SYSTEM

(1) Trial run of a transmission system or an element thereof shall mean successful energisation of the transmission system or the element thereof at its nominal system voltage through interconnection with the grid for a continuous twenty-four (24) hours flow of power and communication signal from the sending end to the receiving end and with the requisite metering system, telemetry and protection system:

Provided that under exceptional circumstances and with the prior approval of CEA, a transmission element can be energized at lower nominal system voltage level.

Provided further that the RLDC may allow anti-theft charging where the transmission line is not carrying any power.

24. DOCUMENTS AND TESTS PRIOR TO DECLARATION OF COMMERCIAL OPERATION

(1) Notwithstanding the requirements in other standards, codes and contracts, for ensuring grid security, the tests as specified in the following clauses shall be scheduled and carried out in coordination with NLDC and the concerned RLDC by the generating company or the transmission licensee, as the case may be, and relevant reports and other documents as specified shall be submitted to NLDC and the concerned RLDC before a certificate of successful trial run is issued to such a generating company or the transmission licensee, as the case may be.

(2) All thermal generating stations having a capacity of more than 200 MW and hydro generating stations having a capacity of more than 25 MW shall submit documents confirming the enablement of automatic operation of the plant from the appropriate load despatch centre by integrating the controls and tele-metering features of their system into the automatic generation control in accordance with the CEA Technical Standards for Construction and the CEA Technical Standards for Connectivity.

(3) Documents and Tests Required for Thermal (coal/lignite) Generating Stations:

(a) The generating company shall submit the following OEM documents, namely (i) startup curve for boiler and turbine including starting time of unit in cold, warm and hot conditions, (ii) capability curve of generator, (iii) design ramp rate of boiler and turbine.

(b) The following tests shall be performed:

(i) Operation at a load of fifty five (55) percent of MCR as per the CEA Technical Standards for Construction for a sustained period of four (4) hours.

(ii) Ramp-up from fifty five (55) percent of MCR to MCR at a ramp rate of at least one (1) percent of MCR per minute, in one step or two steps (with stabilization period of 30 minutes between two steps), and sustained operation at MCR for one (1) hour.

(iii) Demonstrate overload capability with the valve wide open as per the CEA Technical Standards for Construction and sustained operation at that level for at least five (5) minutes.

(iv) Ramp-down from MCR to fifty five(55) percent of MCR at a ramp rate of at least one (1) percent of MCR per minute, in one or two steps (with stabilization period of 30 minutes between two steps).

(v) Primary response through injecting a frequency test signal with a step change of ± 0.1 Hz at 55%, 60%, 75% and 100% load.

(vi) Reactive power capability as per the generator capability curve as provided by OEM considering over-excitation and under-excitation limiter settings and prevailing grid condition.

(4) Documents and Tests Required for Hydro Generating Stations including Pumped Storage Hydro Generating Station:

(a) The generating company shall submit OEM documents for the turbine characteristics curve indicating the operating zone(s) and forbidden zone(s). In order to demonstrate the operating flexibility of the generating unit, it shall be operated below and above the forbidden zone(s).

(b) The following tests shall be performed considering the water availability and head:

(i) Primary response through injecting a frequency test signal with a step change of ± 0.1 Hz for various loadings within the operating zone.

(ii) Reactive power capability as per the generator capability curve considering over-excitation and under-excitation limiter settings.

(iii) Black start capability, wherever feasible.

(iv) Operation in synchronous condenser mode wherever designed.

(5) Documents and Test Required for Gas Turbine based Generating Stations:

(a) The generating company shall submit OEM documents for (i) starting time of the unit in cold, warm and hot conditions (ii) design ramp rate.

(b) The following tests shall be performed:

(i) Primary response through injecting a frequency test signal with a step change of ± 0.1 Hz for various loadings within the operating zone.

(ii) Reactive power capability as per the generator capability curve considering over-excitation and under-excitation limiter settings.

(iii) Black start capability up to 100 MW capacity, wherever feasible.

(iv) Operation in synchronous condenser mode wherever designed.

(6) Documents and Tests Required for the Generating Stations based on wind and solar resources:

(a) The generating company shall submit a certificate confirming compliance with CEA Technical Standards for Connectivity in accordance with sub-clause (a) of clause (4) of Regulation 26 of these regulations.

(b) Type test report for Fault Ride through Test (LVRT and HVRT) for units commissioned after the specified date as per CEA Technical Standards for Connectivity mandating LVRT and HVRT capability shall be submitted.

(c) The following tests shall be performed at the point of interconnection:

(i) Frequency response of machines as per the CEA Technical Standards for Connectivity.

(ii) Reactive power capability as per OEM rating at the available irradiance or the wind energy, as the case may be.

Provided that the generating company may submit offline simulation studies for the specified tests, in case testing is not feasible before COD, subject to the condition that tests shall be performed within a period of one year from the date of achieving COD.

(7) Documents and Tests Required for Energy Storage Systems:

(a) The ESS shall submit a certificate confirming compliance with the CEA Technical Standards for Connectivity in accordance with sub-clause (a) of clause (4) of Regulation 26 of these regulations.

(b) The following tests shall be performed at the point of interconnection:

(i) Power output capability in MW and energy output capacity in MWh.

(ii) Frequency response of ESS.

(iii) Ramping capability as per design.

(8) Documents and Tests Required for HVDC Transmission System:

(a) The transmission licensee shall submit technical details including operating guidelines such as filter bank requirements at various operating loads and monopolar/ or bipolar configuration, reactive power controller, run-back features, frequency controller, reduced voltage mode of operation, circuit design parameters and power oscillation damping, as applicable.

(b) The following tests shall be performed:

(i) Minimum load operation.

(ii) Ramp rate.

(iii) Overload capability, subject to grid condition.

(iv) Black start capability in the case of Voltage source convertor (VSC) HVDC wherever feasible.

(v) Dynamic Reactive Power Support (in the case of VSC based HVDC)

(8) Documents and Tests Required for SVC or STATCOM

(a) The transmission licensee shall submit technical particulars including a single line diagram, V/I characteristics, the rating of coupling transformer, the rating of each VSC, MSR and MSC branch, different operating modes, the IEEE standard Model, Power Oscillation Damping (POD) enabled and tuned (if not, then reasons for the same) and the results of an Offline simulation-based study to validate the performance of POD.

(b) The following tests shall be performed to validate the full reactive power capability of SVC and STATCOM in both directions i.e. absorption as well as injection mode:

(i) POD performance test.

(ii) dynamic performance testing:

Provided that the transmission licensee may submit offline simulation studies for the specified tests, in case the conduct of tests is not feasible before COD, subject to the condition that tests shall be performed within a period of one year from the date of achieving COD.

25. CERTIFICATE OF SUCCESSFUL TRIAL RUN

(1) In case any objection is raised by a beneficiary in writing to the concerned RLDC with a copy to all concerned regarding the trial run within two (2) days of completion of such trial run, the concerned RLDC shall, within five (5) days of receipt of such objection, in coordination with the concerned entity and the beneficiaries, decide if the trial run was successful or if there is a need for a repeat trial run.

(2) After completion of a successful trial run and receipt of documents and test reports as per Regulation 24 of these regulations, the concerned RLDC shall issue a certificate to that effect to the concerned generating station, ESS or transmission licensee, as the case may be, with a copy to their respective beneficiary(ies) and the respective RPC, within three days.

26. DECLARATION BY GENERATING COMPANY AND TRANSMISSION LICENSEE

(1) Thermal Generating Station

(a) The generating company shall certify that:

(i) The generating station or unit thereof meets the relevant requirements and provisions of the CEA Technical Standards for Construction, CEA Technical Standards for Connectivity, CEA Technical Standards for Communication, Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations,2010, CEA (Flexible operation of thermal power plants) Regulations,2023 and these regulations, as applicable.

(ii) The main plant equipment and auxiliary systems including the balance of the plant such as the fuel oil system, coal handling plant, DM plant, pre-treatment plant, fire-fighting system, ash disposal system and any other site specific system have been commissioned and are capable of full load operation of the units of the generating station on a sustained basis.

(iii) Permanent electric supply system including emergency supplies and all necessary instrumentation, control and protection systems and auto loops for full load operation of the unit has been put into service.

(b) The certificates required under sub-clause (a) of this clause shall be signed by the authorized signatory not below the rank of CMD or CEO or MD of the generating company and shall be submitted to the concerned RLDC and to the Member Secretary of the concerned RPC before the declaration of COD.

(2) Hydro Generating Station

(a) The generating company shall certify that:

(i) The generating station or unit thereof meets the requirement and relevant provisions of the CEA Technical Standards for Construction, CEA Technical Standards for Connectivity, CEA Technical Standards for Communication, Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations,2010 and these regulations, as applicable.

(ii) The main plant equipment and auxiliary systems including the drainage de-watering system, primary and secondary cooling system, LP and HP air compressor and firefighting system have been commissioned and are capable of full load operation of units on a sustained basis.

(iii) Permanent electric supply systems including emergency supplies and all necessary Instrumentations Control and Protection Systems and auto loops for full load operation of the unit are put into service.

(b) The certificates required under sub-clause (a) of this clause shall be signed by the authorized signatory not below the rank of CMD or CEO or MD of the generating company and shall be submitted to the concerned RLDC and to the Member Secretary of the concerned RPC before the declaration of COD.

(3) Transmission system

(a) The transmission licensee shall submit a certificate signed by the authorized signatory not below the rank of CMD or CEO or MD of the company to the concerned

RLDC and to the Member Secretary of the concerned RPC before declaration of COD that the transmission line, sub-station and communication system conform to the CEA Technical Standards for Construction, CEA Technical Standards for Connectivity, CEA Technical Standards for Communication, Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations,2010 and these regulations and are capable of operation to their full capacity.

(4) Wind, Solar, Storage, and Hybrid Generating Station

(a) The generating station based on wind and solar resources, the ESS and the hybrid generating station shall submit a certificate signed by the authorized signatory not below the rank of CMD or CEO or MD to the concerned RLDC and to the Member Secretary of the concerned RPC before declaration of COD, that the said generating station or the ESS as the case may be, including main plant equipment such as wind turbines or solar inverters or auxiliary systems, as the case may be, has complied with all relevant provisions of CEA Technical Standards for Connectivity, CEA Technical Standards for Communication, Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations,2010 and these regulations.

27. DECLARATION OF COMMERCIAL OPERATION (DOCO) AND COMMERCIAL OPERATION DATE (COD)

(1) A generating station or unit thereof or a transmission system or an element thereof or ESS may declare commercial operation as follows and inform CEA, the concerned RLDC, the concerned RPC and its beneficiaries:

(a) Thermal Generating Station or a unit thereof

(i) The commercial operation date in the case of a unit of the thermal generation station shall be the date declared by the generating company after a successful trial run at MCR or de-rated capacity as per sub-clause (b) of clause (1) of Regulation 22 of these regulations, as the case may be, and submission of a declaration as per clause (1) of Regulation 26 of these regulations.

(ii) In the case of the generating station, the COD of the last unit of the generating station shall be considered as the COD of the generating station.

(b) Hydro Generating Station

(i) The commercial operation date in the case of a unit of the hydro generating station including a pumped storage hydro generating station shall be the date declared by the generating station after after a successful trial run at MCR or de-rated capacity as per sub-clause (b) of clause (2) of Regulation 22 of these regulations, as the case may be, and submission of a declaration as per clause (2) of Regulation 26 of these regulations.

(ii) In the case of the generating station, the COD of the last unit of the generating station shall be considered as the COD of the generating station.

(c) Transmission System

(i) The commercial operation date in the case of an Inter-State Transmission System or an element thereof shall be the date declared by the transmission licensee on which the Transmission System or an element thereof is in regular service at 0000 hours after successful trial operation for transmitting electricity and communication signals from the sending end to the receiving end as per Regulation 23 and submission of a declaration as per clause (3) of Regulation 26 of these regulations :

Provided that the commercial operation date of a transmission element that is a part of the Associated Transmission System (ATS) shall be declared only after a successful trial run of the last element of the said ATS:

Provided further that where only some of the transmission elements of the ATS have achieved a successful trial run and the Connectivity grantee under GNA Regulations seeks commercial operation of such elements for utilization by such grantee and is agreed upon by the Central Transmission Utility~~,~~ the commercial operation date of such transmission elements of the ATS may be declared by the transmission licensee as per this Regulation:

Provided also that where only some of the transmission element(s) of the ATS have achieved a successful trial run and if the operation of such transmission elements is certified by the concerned Regional Power Committee(s) for improving the performance, safety and security of the grid, the commercial operation date of such transmission element(s) of the ATS may be declared by the transmission licensee as per this Regulation:

Provided also that in case a transmission system or an element thereof executed under regulated tariff mechanism is prevented from regular service on or after the scheduled COD for reasons not attributable to the transmission licensee or its supplier or its contractors but is on account of the delay in commissioning of the concerned generating station or in commissioning of the upstream or downstream transmission system of other transmission licensee, the transmission licensee shall approach the Commission through an appropriate petition along with a certificate from the CTU to the effect that the transmission system is complete as per the applicable CEA Standards, for approval of the commercial operation date of such transmission system or an element thereof:

Provided also that in the case of inter-State Transmission System executed through Tariff Based Competitive Bidding, the transmission licensee may declare deemed COD of the ISTS in accordance with the provisions of the Transmission Service Agreement after obtaining (a)a certificate from the CTU to the effect that the transmission system is complete as per the specifications of the bidding guidelines and applicable CEA Standards and (b) no load charging certificate from the respective RLDC, where no load charging is possible.

(ii) The COD of a transmission element of the transmission system under Tariff Based Competitive Bidding shall be declared only after the declaration of the COD of all the pre-required transmission elements as per the Transmission Services Agreement:

Provided that in case any transmission element is required in the interest of the power system as certified by the concerned RPC(s), the COD of the said transmission element may be declared prior to the declaration of the COD of its pre-required transmission elements.

(d) Communication System

Date of commercial operation in relation to a communication system or an element thereof shall mean the date declared by the transmission licensee from 0000 hours of which a communication system or element thereof shall be put into service after completion of the site acceptance test including transfer of voice and data to the respective control centres as certified by the respective Regional Load Despatch Centre.

(e) Generating Stations based on Wind and Solar resources; ESS and Hybrid Generating Station

(i) The commercial operation date in the case of units of a renewable generating station aggregating to 50 MW and above or such other limit as specified in clause (3) of Regulation 22 of these regulations, shall mean the date declared by the generating station after undergoing a successful trial run as per clause (3) of Regulation 22 of these regulations, submission of declaration as per clause (4) of Regulation 26 of these regulations, and subject to fulfilment of other conditions, if any, as per PPA.

(ii) In the case of a generating station as a whole, the commercial operation date of the last unit of the generating station shall be considered as the COD of the generating station.

(2) Scheduling of the generating station or unit thereof shall start from 0000 hours of D+2 (where D is the Commercial Operation Date of the said generating station or unit thereof).

CHAPTER 6

OPERATING CODE

28. OPERATING PHILOSOPHY

(1) All entities, such as NLDC, RLDCs, SLDCs, CTU, STUs, RPCs, power exchanges, QCAs, SNAs, licensees, generating stations, and other grid connected entities shall at all times function in coordination to ensure integrity, stability and resilience of the grid and achieve economy and efficiency in the operation of power system.

(2) Operation of the State grid shall be monitored by the respective SLDC. Operation of the regional grid shall be monitored by the respective RLDC. Operation of the National grid shall be monitored by NLDC.

(3) Detailed Operating Procedures for the National grid shall be developed, maintained and updated by NLDC in consultation with RLDCs and relevant stakeholders and shall be kept posted on NLDC's website.

(4) Detailed Operating Procedures for each regional grid shall be developed, maintained and updated by respective RLDCs in consultation with NLDC, concerned RPC and regional entities and shall be kept posted on the respective RLDC's website.

(5) Detailed Operating Procedures for each State grid shall be developed, maintained and updated by the SLDCs, consistent with the Detailed Operating Procedures of respective RLDC.

(6) NLDC, RLDCs and SLDCs shall have qualified operating personnel manning the control room round the clock.

(7) Every generating station, and transmission substation of 110 kV and above shall have a control room manned by qualified operating personnel round the clock. Alternatively, the same may be operated round the clock from a remotely located control room, subject to the condition that such remote operation does not result in a delay in the execution of any switching instructions and information flow:

Provided that a transmission licensee owning a transmission line but not owning the connected substation, shall have a coordination centre functioning round the clock, manned by qualified personnel for operational coordination with the concerned load despatch centres and equipped to carry out the operations as directed by concerned load despatch centres.

(8) SNA and QCA shall have coordination centres functioning round the clock, manned by qualified personnel for operational coordination with the concerned load despatch centres and generating stations. ESS and Bulk Consumers, which are regional entities shall have coordination centres functioning round the clock and manned by qualified personnel for operational coordination with the concerned load despatch centres.

29. SYSTEM SECURITY

(1) All users shall operate their respective power systems in an integrated manner at all times in coordination with the concerned load despatch centres.

(2) Isolation, Taking out of service and Switching off an element of the grid:

(a) No element(s) of the grid shall be isolated from the grid, except (i) during an emergency as per the Detailed Operating Procedure(s) of NLDC or RLDC or SLDC, as the case may be, where such isolation would prevent a total grid collapse or would enable early restoration of power supply; (ii) for the safety of human life; (iii) when serious damage to a critical equipment is imminent and such isolation would prevent it; and (iv) when such isolation is specifically instructed by NLDC or RLDC or SLDC, as the case may be. Any such isolation shall be reported to the respective RLDC or SLDC within the next 15 minutes.

(b) Each RLDC, in consultation with the concerned RPCs, users, SLDCs, shall prepare a list of important elements in the regional grid, including those in the State grids that are critical for regional grid operation and shall make the said list available to all concerned.

(c) An important element of the grid as listed at sub-clause (b) of this clause can be taken out of service only after prior clearance of the concerned RLDC, except in emergencies as per the Detailed Operating Procedure(s) of NLDC or RLDC or SLDC, as the case may be. RLDC shall inform the opening or removal of any such important element (s) of the regional grid to NLDC, the concerned RPCs and the concerned regional entities who are likely to be affected, as specified in the Detailed Operating Procedure of RLDC or NLDC.

(d) In case of switching off or tripping of any of the important elements of the regional grid under emergency conditions or otherwise, it shall be intimated immediately by the users with available details (i) to SLDC if the element is within the control area of SLDC, who in turn shall intimate the concerned RLDC and (ii) to RLDC if the element is within the control area of RLDC, who in turn will intimate the concerned SLDC(s). The reasons for such switching off or tripping to the extent determined and the likely time of restoration shall also be intimated within half an hour. The concerned RLDC or SLDC and the users shall ensure restoration of such elements within the estimated time of restoration as intimated.

(e) The isolated, taken out or switched off elements shall be restored as soon as the system conditions permit. The restoration process shall be supervised by the concerned Load Despatch Centre, in coordination with NLDC, concerned RLDC(s) and SLDC(s) in accordance with the system restoration procedures of NLDC and RLDC(s).

(3) Maintenance of grid elements shall be carried out by the respective users in accordance with the provisions of the CEA Grid Standards. Outage of an element that is causing or likely to cause danger to the grid or sub-optimal operation of the grid shall be monitored by the concerned RLDC. RLDC shall report such outages to RPC and RPC shall issue suitable instructions to restore such elements in a specified time period.

(4) Except in an emergency, or when it becomes necessary to prevent imminent damage to critical equipment, no user shall suddenly reduce its generating unit output by more than 100 (one hundred) MW [20 (twenty) MW in the case of NER] without prior permission of the respective RLDC.

(5) Except in an emergency, or when it becomes necessary to prevent imminent damage to critical equipment, no user shall cause a sudden variation in its load by more than 100 (one hundred) MW without the prior permission of the respective RLDC.

(6) All generating units shall have their automatic voltage regulators (AVRs), Power System Stabilizers (PSSs), voltage (reactive power) controllers (Power Plant Controller) and any other requirements in operation, as per the CEA Technical Standards for Connectivity. If a generating unit with a capacity higher than 100 (hundred) MW is required to be operated without its AVR or voltage controller in

service, the generating station shall immediately inform the concerned RLDC of the reasons thereof and the likely duration of such operation and obtain its permission.

(7) The tuning of AVR, PSS, Voltage Controllers (PPC) including for low and high voltage ride through capability of wind and solar generators or any other requirement as per CEA Technical Standards for Connectivity shall be carried out by the respective generating station:

– at least once every five (5) years;

– based on operational feedback provided by the RLDC after analysis of a grid event or disturbance; and

– in case of major network changes or fault level changes near the generating station as reported by NLDC or RLDC(s), as the case may be.

– in case of a major change in the excitation system of the generating station.

(8) Power System Stabilizers (PSSs), AVRs of generating units and reactive power controllers shall be properly tuned by the generating station as per the plan and the procedure prepared by the concerned RPC. In case the tuning is not complied with as per the plan and procedure, the concerned RLDC shall issue notice to the defaulting generating station to complete the tuning within a specified time, failing which the concerned RLDC may approach the Commission under Section 29 of the Act.

(9) Provisions of protection and relay settings shall be coordinated periodically throughout the regional grid, as per the plan finalized by the respective RPC in accordance with the Protection, Testing and Commissioning Code of these regulations.

(10) RPCs shall prepare the islanding schemes in accordance with the CEA Grid Standards for identified generating stations, cities and locations and ensure their implementation. The islanding schemes shall be reviewed and augmented depending on the assessment of critical loads at least once a year or earlier, if required.

(11) Mock drill of the islanding schemes shall be carried out annually by the respective RLDCs in coordination with the concerned SLDCs and other users involved in the islanding scheme. In case mock drill with field testing is not possible to be carried out for a particular scheme, simulation testing shall be carried out by the respective RLDC.

(12) All distribution licensees, STUs and bulk consumers shall provide automatic under-frequency relays (UFR) and df/dt relays for load shedding in their respective systems to arrest frequency decline that could result in grid failure as per the plan given by the RPCs from time to time. The default UFR settings shall be as specified in Table-2 below:

Table 2: Default UFR Settings

Sr. No.	Stage of UFR Operation	Frequency (Hz)
1	Stage-1	49.40
2	Stage-2	49.20
3	Stage-3	49.00
4	Stage-4	48.80
Note 1: All states (or STUs) shall plan UFR settings and df/dt load shedding schemes depending on their local load generation balance in coordination with and approval of the concerned RPC.		

Sr. No.	Stage of UFR Operation	Frequency (Hz)
Note 2: Pumped storage hydro plants operating in pumping mode or ESS operating in charging mode shall be automatically disconnected before the first stage of UFR.		

The load shedding for each stage of UFR operation, in percentage of demand or MW shall be as finalised by the respective RPCs.

(13) The following shall be factored in while designing and implementing the UFR and *df/dt* relay schemes:

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(a) The under-frequency and *df/dt* load shedding relays are always functional.

(b) Demand disconnection shall not be set with any time delay in addition to the operating time of the relays and circuit breakers.

(c) There shall be a uniform spatial spread of feeders selected for UFR and *df/dt* disconnection.

(d) SLDC shall ensure that telemetered data of feeders (MW power flow in real time and circuit breaker status) on which UFR and *df/dt* relays are installed is available at its control centre. SLDC shall monitor the combined load in MW of these feeders at all times. SLDC shall share the above data with the respective RLDC in real time and submit a monthly exception report to the respective RPC. RLDC shall inform SLDCs as well as the concerned RPC on a quarterly basis, durations during the quarter when the combined load in MW of these feeders was below the level considered while designing the UFR scheme by the RPC. SLDC shall take corrective measures within a reasonable period and inform the respective RLDC and RPC, failing which suitable action may be initiated by the respective RPC.

(e) RPC shall undertake a monthly review of the UFR and df/dt scheme and also carry out random inspection of the under-frequency relays. RPC shall publish such a monthly review along with an exception report on its website.

(f) SLDC shall report the actual operation of UFR and df/dt schemes and load relief to the concerned RLDCs and RPCs and publish the monthly report on its website.

(14) NLDC, RLDCs, SLDCs, CTU, STUs or users may identify the requirement of System Protection Schemes (SPS) (including inter-tripping and run-back) in the power system to operate the transmission system within operating limits and to protect against situations such as voltage collapse, cascade tripping and tripping of important corridors/flow-gates. Any such SPS at the intra-regional level shall be finalized by the concerned RPC. SPS at the inter-regional and cross-border levels shall be finalized by the NLDC in coordination with the concerned RPCs. SPS shall be installed and commissioned by the concerned users. SPS shall always be kept in service. If any SPS at the intra-regional level is to be taken out of service, the permission of the concerned RLDC shall be required. If any SPS at the inter-regional and cross-border levels is to be taken out of service, permission of NLDC shall be required.

(15) NLDC, RLDCs, SLDCs, and users shall operate in a manner to ensure that the steady state grid voltage as per the CEA Grid Standards remains within the following operating range:

TABLE 3 : VOLTAGE RANGE

Voltage (kV rms)		
Nominal	**Maximum**	**Minimum**
765	800	728
400	420	380
230*	245*	207*
220	245	198
132	145	122
110	121	99
66	72	60
33	36	30

**As per CEA Manual on Transmission Planning Criteria, 2023.*

(16) NLDC, RLDCs and SLDCs, as the case may be, shall take appropriate measures to control the voltage as per their operating procedures.

(17) The concerned users shall implement defence mechanisms as finalized by the respective RPCs to prevent voltage collapse and cascade tripping.

(18) All defense mechanisms shall always be in operation and any exception shall be immediately intimated by the concerned user to the concerned RLDC and SLDCs along with the reasons and the likely duration of such exception. The concerned user shall also obtain permission from the concerned RLDC or SLDC, as applicable.

30. FREQUENCY CONTROL AND RESERVES

(1) The National Reference Frequency shall be 50.000 Hz and the allowable band of frequency shall be 49.900-50.050 Hz. The frequency shall be measured with a resolution of +/-0.001 Hz by NLDC, RLDCs and SLDC and such frequency data measured every second shall be archived by RLDCs.

(2) The NLDC, RLDC and SLDC shall endeavour that the grid frequency remains close to 50.000 Hz and in case frequency goes outside the allowable band, ensure that the frequency is restored within the allowable band of 49.900-50.050 Hz at the earliest.

(3) All users shall adhere to their schedule of injection or drawl, as the case may be, and take such action as required under these regulations and as directed by NLDC or respective RLDCs or respective SLDCs so that the grid frequency is maintained and remains within the allowable band.

Reserves

(4) There shall be reserves as under:

(a) Primary, Secondary and Tertiary reserves:

(i) Primary, Secondary and Tertiary reserves shall be deployed for the purpose of frequency control, reducing area control error and relieving congestion.

(ii) The response under Primary reserve shall be provided as per these regulations.

(iii) Secondary reserves including automatic generation control and demand response shall be deployed by the control area as per these regulations or the Ancillary Services Regulations or the respective regulations on Ancillary Services of the State, as the case may be.

(iv) Tertiary reserves shall be deployed by the control area as per these regulations or the Ancillary Services Regulations or the respective regulations on Ancillary Services of the State, as the case may be.

(b) Black Start reserves:

Generating stations having black start capability, ESS and HVDC Station based on VSC shall be identified by NLDC and RLDCs in consultation with SLDC(s) at the inter-State level and by SLDC at the State level, to act as black start reserves.

(c) Voltage Control reserves:

Voltage Control reserves shall be deployed for controlling the voltage at a bus or sub-system through reactive power injection or drawl.

(5) The reserves shall be operated as Ancillary Services, namely (a) Primary Reserve Ancillary Service (PRAS); (b) Secondary Reserve Ancillary Service (SRAS); (c) Tertiary Reserve Ancillary Service (TRAS); (d) Black Start Ancillary Services; and (e) Voltage Control Ancillary Services.

(6) The mechanism of procurement and deployment of PRAS shall be as specified in these regulations or in the Ancillary Services Regulations, as the case may be.

(7) The mechanism of procurement, deployment and payment of SRAS and TRAS shall be as specified in the Ancillary Services Regulations.

(8) The primary response of the generating units shall be verified by the Load Despatch Centres (LDCs) during grid events. The concerned generating station shall furnish the requisite data to the LDCs within two days of notification of reportable event by the NLDC.

Control Hierarchy

(9) Inertia:

The power system shall be operated at all times with a minimum inertia to be stipulated by NLDC so that the minimum nadir frequency post reference contingency stays above the threshold set for under frequency load shedding (UFLS). To maintain the minimum inertia, the NLDC may, if required, bring quick start synchronous generation on bar and reschedule generation including curtailment of wind, solar and wind-solar hybrid generation, in coordination with the respective RLDCs and SLDCs. The compensation for such quick start synchronous generation shall be included in the procedure to be prepared by NLDC and approved by the Commission.

(10) Primary Control:

(a) Primary control is local automatic control in a generating unit or energy storage system or demand side resource for the purpose of adjusting its active power output or consumption, as the case may be, in response to frequency excursion. Primary control is the immediate automatic control implemented through turbine speed governors or frequency controllers.

(b) Primary control shall be provided by the Primary Reserves Ancillary Service (PRAS).

(c) The minimum quantum of PRAS required for reference contingency shall be declared by NLDC at the start of each financial year.

(d) The generating stations and units thereof shall have electronically controlled governing systems or frequency controllers in accordance with the CEA Technical Standards for Connectivity and are mandated to provide PRAS. The generating stations and units thereof with governors shall be under Free Governor Mode of Operation.

(e) NLDC may also identify other resources such as ESS and demand resource to provide PRAS for which PRAS Providers shall be compensated in accordance with the Ancillary Services Regulations.

(f) The minimum All India target frequency response characteristics (FRC) shall be estimated and based on such target FRC, the frequency response obligation of each control area shall be assessed by NLDC as per Annexure-2, giving due consideration to generation and load within each control area and details as given in Table 4 under sub-clause(g) of this clause. The same shall be informed to all control areas by 15th of March every year for the next financial year.

(g) All the generating units shall have their governors or frequency controllers in operation all the time with droop settings of 3 to 6 % (for thermal generating units and WS Seller) or 0-10% (for hydro generating units) as specified in the CEA Technical Standards for Connectivity

(h) The primary response requirement shall be as mentioned in Table 4.

TABLE 4 : PRIMARY RESPONSE OF VARIOUS TYPES OF GENERATING UNITS

Fuel/ Source	**Minimum unit size/Capacity**	**Up to**
Coal/Lignite Based	200 MW and above	±5% of MCR
Hydro	25 MW and above	±10% of MCR
Gas based	Gas Turbine above 50 MW	±5% of MCR (corrected for ambience

Fuel/ Source	Minimum unit size/Capacity	Up to
		temperature)
WS Seller (commissioned after the date as specified in the CEA Technical Standards for Connectivity)	Capacity of Generating station more than 10 MW and connected at 33 kV and above	As per CEA Technical Standards for Connectivity

Provided that:

1. WS Sellers commissioned after the date as specified in CEA Technical Standards for Connectivity shall have the option to provide primary response individually through ESS or through a common ESS installed at its pooling station.

2. Nuclear generating stations and hydro generating stations (with pondage up to 3 hours or Run of the river projects) shall be exempt from mandatory primary response. They may provide the primary response to the extent possible, considering the safety and security of machines and humans.

(i) All generating stations mentioned in Table-4 (under sub-clause (g) of this clause) shall have the capability of instantaneously picking up to a minimum of 105% of their operating level and up to 105% or 110% of their MCR, as the case may be, when the frequency falls suddenly and thus providing primary response whenever conditions arise.

Any generating station not complying with the above requirements shall be kept in operation (synchronized with the regional grid) only after obtaining the permission of the concerned RLDC.

(j) All generating stations, including the WS seller mentioned in Table-4 (under sub-clause (g) of this clause) shall have the capability of reducing output at least by 5% or 10%, as applicable, of their operating level and up to 5% or 10% of their MCR, as applicable, limited to the minimum turndown level when the frequency rises above the reference frequency and thus providing primary response, whenever condition arise. Any generating station not complying with the above requirements shall be kept in operation (synchronized with the regional grid) only after obtaining permission from the concerned RLDC.

(k) The normal governor action shall not be suppressed in any manner through load limiter, Automatic Turbine Run-up System (ATRS), turbine supervisory control or coordinated control system and no time delays shall be deliberately introduced. In the case of a renewable energy generating unit, a reactive power limiter or power factor controller or voltage limiter shall not suppress the primary frequency response within its capabilities. The inherent dead band of a generating unit or frequency controller shall not exceed +/- 0.03 Hz.

The governor shall be set with respect to a reference frequency of 50.000 Hz and response outside the dead band shall be with respect to a total change in frequency.

(l) The thermal and hydro generating units shall not resort to Valve Wide Open (VWO) operation to make available margin for providing governor action.

(m) The PRAS shall start immediately when the frequency deviates beyond the dead band as specified in sub-clause (k) of this clause and shall be capable of providing its full PRAS capacity obligation within 45 seconds and sustaining at least for the next five (5) minutes.

(n) Each control area shall assess its frequency response characteristics and share the assessment with the concerned RLDC along with high resolution data of at least 1 (one) second for regional entity generating stations and energy storage systems and 10 (ten) seconds for the state control area.

(o) The concerned RLDC shall calculate actual frequency response characteristics of all the control areas within its region. The performance of each control area in providing frequency response characteristics shall be calculated for each reportable event as per Annexure-2.

(p) The NLDC in consultation with RLDCs shall calculate the actual frequency response characteristics at national level by factoring in the FRC of all regions and shall also calculate the FRC for cross border control areas.

(q) NLDC, RLDCs and SLDCs shall grade the median Frequency Response Performance annually, considering at least 10 reportable events. In case the median Frequency Response Performance is less than 0.75 as calculated as per Annexure-2, NLDC, RLDCs, SLDCs, as the case may be, after analyzing the FRP shall direct the concerned entities to take corrective action. All such cases shall be reported to the concerned RPC for its review.

(11) Secondary Control:

(a) Secondary control is a centralized automatic function to regulate the generation or load in a control area to restore the frequency within the allowable band or replenish deployed primary reserves.

(b) Secondary Control shall be provided by a generating station or an entity having energy storage resource or an entity capable of providing demand response, on a standalone or aggregated basis, connected to an inter-State transmission system or an intra-State transmission system, as a Secondary Reserve Ancillary Service (SRAS) Provider, as specified in the Ancillary Services Regulations.

(c) Secondary control signals shall be automatically generated from NLDC and shall be transmitted to SRAS Providers through the concerned RLDC exercising the control area jurisdictions for desired automated response when the Area Control Error (ACE) for each region goes beyond the minimum threshold limit of ±10 MW, which may be reviewed from time to time based on the review of the performance of SRAS.

Provided that as and when the bi-directional communication system of SRAS providers with RLDCs is fully established, secondary control signals shall be automatically generated from the respective RLDC.

(d) ACE of each State or Regional control area, shall be auto calculated at the control centre of NLDC or RLDC or SLDC, as the case may be, based on telemetered values, and external inputs, namely, the Frequency Bias Coefficient and Offset referred to in sub-clauses (e) and (f) respectively of this clause as per the following formula:

$$ACE = (I_a - I_s) - 10 * B_f * (F_a - F_s) + Offset$$

Where,

I_a = Actual net interchange in MW (positive value for export)

I_s = Scheduled net interchange in MW (positive value for export)

B_f = Frequency Bias Coefficient in MW/0.1 Hz (negative value)

F_a = Actual system frequency in Hz

F_s = Schedule system frequency in Hz

Offset = Provision for compensating measurement error

(e) Frequency Bias Coefficient (B_f) shall be assessed and declared by NLDC in coordination with RLDC for each region. Frequency Bias Coefficient (B_f) shall be assessed and declared by SLDC for each State. Frequency Bias Coefficient shall normally be based on the median Frequency Response Characteristics (FRC) observed during the previous financial year of each control area and refined from time to time.

(f) Offset shall be used to account for measurement errors and shall be decided by NLDC or RLDC or SLDC, as the case may be, for its respective control area.

(g) Secondary control may be operated under tie-line bias control, flat frequency control or flat tie-line control mode depending on grid requirements:

Provided that Secondary control may be suspended due to system maintenance or grid security or for any other reasons to be recorded in writing:

Provided further that NLDC in coordination with RLDC and SLDC shall lay down in the Detailed operating procedure after stakeholder consultation, the conditions during which a particular mode shall be chosen and shall document the reasons for operating in a particular mode:

Provided also that the coordinated operation of AGC by the nested control areas shall be adopted based on mutually agreed protocols.

(h) Schedule system frequency (Fs) shall be a reference frequency of 50 Hz unless otherwise specified by NLDC under certain conditions to be recorded in writing.

(i) RLDCs and SLDCs shall compute the ACE of the respective regional or state control area in real time based on telemetered data. ACE data shall be archived at an interval of 10 seconds or less. RLDCs shall share the data with NLDC. SLDC shall share the data with the concerned RLDC and NLDC.

(j) The SRAS Providers shall start responding to SRAS signals within thirty (30) seconds of receipt of the signal and shall be capable of providing the entire SRAS capacity obligation within fifteen (15) minutes and sustaining it at least for the next thirty (30) minutes. The secondary reserves shall be gradually replaced by tertiary reserves within 30 minutes.

(k) With due regard to the requirement of planning reserve margin and resource adequacy referred to in Chapter 2 of these regulations and based on the following methodologies, the secondary reserve capacity requirements shall be estimated by RLDCs for their respective regional control areas:

The positive and negative secondary reserve capacity requirements for any control area for a calendar year shall be equal to the 99 percentile of positive and negative ACE respectively of that control area during the previous financial year (Detailed Procedure shall be as per Annexure-3 to these regulations, which may be reviewed as and when considered necessary),

OR

The secondary reserve capacity requirement for any control area shall be equal to the 110 % of the largest unit size in the respective regional control area or state control area plus load forecast error plus wind forecast error plus solar forecast error during the previous calendar year.

OR

Such other methodology as may be stipulated by NLDC after obtaining the due approval of the Commission.

(l) Unless otherwise specified by the concerned SERC, the methodology specified in sub-clause (k) of this clause shall be adopted by the SLDCs to estimate the secondary reserve capacity requirement in their respective control areas.

(m) The reserve capacity requirement as per the methodology mentioned in sub-clauses (k) and (l) of this clause shall be estimated by each RLDC and SLDC respectively by 15th January every year for the next financial year and submitted to NLDC.

(n) All India secondary reserve capacity requirement for the regional control area and the State control area shall be estimated by NLDC based on reference contingency and other factors such as forecast errors.

(o) NLDC shall allocate such All India secondary reserves capacity, to be maintained at regional control area and at State control area, based on the estimated reserves as per sub-clauses (k) and (l) of this clause and publish the information on its website by 25th January every year.

(p) NLDC through RLDCs shall re-assess the quantum of requirement of secondary reserves required at the state control area three days before the day of scheduling and communicate the same to the respective SLDC.

(q) Each State control area shall ensure the availability of the quantum of secondary reserve at the State control area with due regard to the secondary reserves estimated and allocated for that State as published by NLDC in terms of sub-clauses (o) and (p) of this clause, and inform the same to the concerned RLDC and NLDC two days before the day of scheduling. The modalities for information exchange and timelines in this respect shall be as per the detailed procedure to be issued by NLDC.

(r) NLDC through RLDCs shall re-assess the quantum of the requirement for secondary reserves at the regional level with due regard inter alia to the secondary reserves maintained at State control area and the need to replenish primary reserves two days before the day of scheduling inter alia to identify reserves to be brought on bar under SCUC (in terms of Regulation 46 of these regulations).

(s) As specified in the Ancillary Services Regulations, NLDC through RLDCs shall further re-assess the quantum of the requirement for secondary reserve at the regional level on day ahead basis and also on a real time basis.

(t) If a State falls short of maintaining secondary reserve capacity as allocated to it in terms of sub-clauses (o) or (p) of this clause, whichever is lower, the NLDC through RLDC shall procure such Secondary reserve capacity on behalf of the State under advance intimation to the concerned State and allocate the cost of procurement of such capacity to that State based on the methodology as per the detailed procedure to be issued by the NLDC after approval of the Commission.

(u) NLDC, RLDC, SLDC shall indicate the shortfall in secondary reserves, if any, and announce emergency alerts for such periods.

(v) Secondary reserves shall be procured by the NLDC from a generating station or an entity having energy storage resources or an entity capable of providing demand response, on a standalone or aggregated basis, connected to an inter-State transmission system or an intra-State transmission system in accordance with the Ancillary Services regulations.

(w) All thermal generating stations having a capacity of more than 200 MW and hydro generating stations having a capacity of more than 25 MW shall make arrangements to enable automatic operation of the plant from the appropriate load despatch centre by integrating the controls and telemetering features of their system into the automatic generation control in accordance with the CEA Technical Standards for Construction and the CEA Technical Standards for Connectivity. The communication system shall be established in accordance with the CEA Communication Regulations.

(x) All renewable energy generating stations and ESS shall be equipped with the facility to control active power injection in accordance with the CEA Connectivity Standards and the communication system shall be established in accordance with the CEA Technical Standards for Communication.

(y) SRAS shall have a bi-directional communication system along with metering and SCADA telemetry in place as per the requirements stipulated in the Detailed Procedure issued under the Ancillary Service Regulations.

(12) Tertiary Control:

(a) Tertiary reserve requirement for the regional control area and the State control area, shall be estimated by NLDC with due regard inter alia to the requirement of planning reserve margin and resource adequacy as referred to in Chapter 2 of these regulations, so as to take care of contingencies and to cater to the need for replacing secondary reserves estimated as per clause (11) of this Regulation by 25th January every year, which will be implemented for the next financial year from 1st April onwards by the respective control areas.

(b) NLDC shall allocate such tertiary reserve capacity, to be maintained at regional control areas and state control areas, based on the estimated reserves as per these regulations and publish the information on its website by 25th January every year.

(c) NLDC through RLDCs shall re-assess the quantum of requirements for tertiary reserves required at the state control area three days before the day of scheduling and communicate the same to the respective SLDC.

(d) Each State control area shall ensure the availability of the quantum of tertiary reserve at the State control area with due regard to the tertiary reserves estimated and allocated for that State as published by NLDC in terms of sub-clauses (b) and (c) of this clause, and inform the same to the concerned RLDC and NLDC two days before the day of scheduling. The modalities for information exchange and timelines in this respect shall be as per the detailed procedure to be issued by NLDC.

(e) Each State control area shall ensure availability of the quantum of tertiary reserve at the State control area on day ahead basis with due regard to the tertiary reserves estimated and allocated for that State by NLDC in terms of sub-clause (b) and (c) of this clause, and inform the same to the concerned RLDC and the NLDC.

(f) NLDC through RLDCs shall re-assess the quantum of requirements for tertiary reserve at the regional level with due regard to the estimation inter alia of tertiary reserves maintained at State control area and the need to replace secondary reserves, three days before the day of scheduling inter alia to identify reserves to be brought on bar under SCUC (in terms of Regulation 46 of these regulations).

(g) As specified under the Ancillary Services Regulations, NLDC through RLDCs shall further re-assess the quantum of the requirement for tertiary reserve at regional level on day ahead basis and also on a real time basis.

(h) If a State falls short of maintaining tertiary reserve capacity as allocated to it in terms of sub-clauses (b) or (c) of this clause , whichever is lower, the NLDC through RLDCs shall procure such tertiary reserve capacity on behalf of the said State under advance intimation to the concerned State and allocate the cost of procurement of such capacity to that State based on the methodology as per the detailed procedure to be issued by the NLDC after approval of the Commission.

(i) Tertiary reserves shall be procured by the NLDC from a generating station or an entity having energy storage resourced or an entity capable of providing demand response, on a standalone or aggregated basis, connected to an inter-State transmission system or an intra-State transmission system in accordance with the Ancillary Services regulations.

(j) Tertiary reserves to be provided by the TRAS provider shall be capable of providing TRAS within fifteen (15) minutes of despatch instructions from RLDC or SLDC, as the case may be, and shall be capable of sustaining the service for at least the next 60 minutes. TRAS shall be activated and deployed by the appropriate load despatch center on account of the following events:

i. To replenish the secondary reserve, in case the secondary reserve has been deployed continuously in one direction for fifteen (15) minutes for more than 100 MW (20 MW in the case of NER) or in respect of a State such other volume limit as may be specified by the respective SERC;

ii. Generation unit or transmission line outages;

iii. Any such other event affecting the grid security.

(k) The quantum of reserves procured by each State control area shall be communicated to the concerned RLDC.

(l) The modalities for information exchange and timelines in respect of tertiary reserves shall be as per detailed procedure prepared by NLDC.

(13) The control area wise performance of SRAS, TRAS providers shall be evaluated in accordance with the Detailed Procedure prepared by NLDC.

31. OPERATIONAL PLANNING

(1) Time Horizon

(a) Operational planning shall be carried out in advance by NLDC, RLDCs and SLDCs within their respective control areas with Monthly and Yearly time horizons in co-ordination with CTU, RPCs or STUs, as applicable.

(b) Operational planning shall be carried out in advance by NLDC, RLDCs and SLDCs within their respective control areas on Intra-day, Day Ahead, Weekly time horizons.

(c) RLDCs in consultation with NLDC shall issue procedures and formats for data collection to carry out:

(i) Operational planning analysis,

(ii) Real-time monitoring,

(iii) Real-time assessments.

(d) SLDC may also issue procedures and formats for data collection for the above purposes.

(2) Demand Estimation

(a) Each SLDC shall carry out demand estimation as part of operational planning after duly factoring in the demand estimation done by STU as part of resource adequacy planning referred to in Chapter 2 of these regulations. Demand estimation by SLDC shall be for both active power and reactive power incidents on the transmission system based on the details collected from distribution licensees, grid-connected distributed generation resources, captive power plants and other bulk consumers embedded within the State.

(b) Each SLDC shall develop methodology for daily, weekly, monthly, yearly demand estimation in MW and MWh for operational analysis as well as resource adequacy purposes. Each SLDC, while estimating demand may utilize state of the art tools, weather data, historical data and any other data. For this purpose, all distribution licensees shall maintain a historical database of demand.

(c) The demand estimation by each SLDC shall be done on day ahead basis with time block wise granularity for the daily operation and scheduling. In case SLDC observes a major change in demand in real time for the day, it shall immediately submit the revised demand estimate to the concerned RLDC for demand estimate correction.

(d) Each SLDC shall submit node-wise morning peak, evening peak, day shoulder and night off-peak estimated demand in MW and MVA on a monthly and quarterly basis for the nodes 110 kV and above for the preparation of scenarios for computation of TTC and ATC by the concerned RLDC and NLDC.

(e) SLDC shall also estimate peak and off-peak demand (active as well as reactive power) on a weekly and monthly basis for load - generation balance planning as well as for operational planning analysis, which shall be a part of the operational planning data. The demand estimates mentioned above shall have granularity of a time block. The estimate shall cover the load incident on the grid as well as the net load incident taking into account embedded generation in the form of roof-top solar and other distributed generation.

(f) The entities such as bulk consumers or distribution licensees that are directly connected to ISTS shall estimate and furnish such a demand estimate to the concerned RLDC.

(g) Based on the demand estimate furnished by the SLDCs and other entities directly connected to ISTS, each RLDC shall prepare the regional demand estimate and submit it to the NLDC. NLDC, based on regional demand estimates furnished by RLDCs, shall prepare national demand estimate.

(h) Timeline for submission of demand estimate data by SLDCs or other entities directly connected to ISTS, as applicable, to the respective RLDC and RPC shall be as follows:

TABLE 5 : TIMELINE FOR DEMAND ESTIMATION

Daily demand estimation	10:00 hours of previous day
Weekly demand estimation	First working day of previous week
Monthly demand estimation	Fifth day of previous month
Yearly demand estimation	30th September of the previous year

(i) SLDCs, RLDCs and NLDC shall compute forecasting error for intra-day, day-ahead, weekly, monthly and yearly forecasts and analyse the same in order to reduce forecasting error in the future. The computed forecasting errors shall be made available by SLDCs, RLDCs and NLDC on their respective websites.

(3) Generation Estimation

(a) The modalities of generation estimation by entities shall be as per the Procedure referred to in sub-clause (c) of clause (1) of Regulation 31 of these regulations.

(b) RLDC shall forecast generation from wind, solar, ESS and Renewable Energy hybrid generating stations that are regional entities and SLDC shall forecast generation from such sources that are intra-state entities, for different time horizons as referred to in clause (1) of Regulation 31 of these regulations for the purpose of operational planning.

(4) Adequacy of Resources

(a) SLDCs shall estimate and ensure the adequacy of resources, identify generation reserves, demand response capacity and generation flexibility requirements with due regard to the resource adequacy framework as specified under Chapter 2 of these regulations.

(b) SLDCs shall furnish time block-wise information for the following day in respect of all intra-state entities to the concerned RLDC who shall validate the adequacy of resources with due regard to the following:

(i) Demand forecast aggregated for the control area;

(ii) Renewable energy generation forecast for the control area;

(iii) Injection schedule for intra-State entity generating station;

(iv) Requisition from regional entity generating stations;

(v) Secondary and planned procurement through Tertiary reserve requirement;

(vi) Planned procurement of power through other bilateral or collective transactions, if any.

32. OUTAGE PLANNING

(1) Outage planning shall be prepared for the grid elements in a coordinated and optimal manner keeping in view the system operating conditions and grid security. The coordinated generation and transmission outage plan for the national and regional grid shall take into consideration all the available generation resources, demand estimates, transmission constraints, and factor in water for irrigation requirements, if any. To optimize the transmission outages of the national and regional grids, to avoid grid operation getting adversely affected and to maintain system security standards, the outage plan shall also take into account the generation outage schedule and the transmission outage schedule.

(2) Annual outage plan shall be prepared as follows:

(a) Annual outage plan of grid elements under regional control area and identified elements of State control areas under sub-clause (b) of clause (2) of Regulation 29 of these regulations, shall be prepared in advance for the financial year by the RPCs in consultation with the users, respective SLDCs, RLDCs and NLDC and reviewed before every quarter and every month.

(b) Annual outage plan shall be prepared in such a manner as to minimize the overall downtime, particularly where multiple entities are involved in the outage of any grid element(s).

(c) The outage plan of hydro generation plants, REGS and ESS and its associated evacuation network shall be prepared with a view to extracting maximum generation from these sources.

Example: Outage of wind generator may be planned during lean wind season. Outage of solar generator, if required, may be planned during the rainy season. Outage of hydro generator may be planned during the lean water season.

(d) Protection relay related outages, auto–re-closure outages and SPS testing outages shall be planned on a monthly basis with the prior permission of the concerned RPC, which shall consult the concerned RLDC & NLDC.

(3) Outage Planning Process shall be as follows:

(a) RPCs shall prepare and finalize the annual outage plan for the next financial year in respect of grid elements of their respective regional grid,

(b) RPCs shall prepare Load Generation Balance Report (LGBR) for the respective region based on the LGBR submitted by SLDCs for their respective states and the data submitted by the regional entity generating stations, inter-State transmission licensees and other entities directly connected to ISTS in such format as may be stipulated by the RPCs and shall prepare annual outage plan for generating units and transmission elements in their respective region after carrying out necessary system studies in order to ensure system security and resource adequacy.

(c) RPCs shall finalize the outage plans in consultation with the NLDC and respective RLDCs. The final outage plan and the final LGBR shall be intimated to NLDC, concerned RLDC, Users, STUs, CTU and the generating stations connected to the ISTS. The final outage plan and the final LGBR shall be made available on the websites of the respective users, RPCs, RLDCs and NLDC.

(d) The timeline for Outage Planning Process shall be as follows:

TABLE 6 : TIMELINE FOR OUTAGE PLANNING PROCESS

Activity	Agency	Cut-off date
Submission of proposed outage plan for the next financial year to RPC with the earliest start date and latest finishing date	STUs, transmission licensees, generating stations and other entities directly connected to ISTS	31st October
Submission of LGBR of the control area to RPC for both peak and off-peak scenarios	SLDC	31st October
Publishing draft LGBR and draft outage plan of regional grid for next financial year on the concerned RPC's website for inviting suggestions, comments, objections of stakeholders.	RPC	30th November
Publishing final LGBR and final outage plan of regional grid for next financial year on the concerned RPC's website	RPC	31st December

(e) The annual outage plan shall be reviewed by RPC on a monthly and quarterly basis in coordination with all the parties concerned, and adjustments or additions of new outages shall be made wherever necessary.

(f) All users, CTU and STUs, licensees shall follow the annual outage plan. If any deviation is required, the same shall be allowed only with the prior permission of the concerned RPC, which shall consult the concerned RLDC and NLDC.

(g) Each user shall obtain the final clearance from NLDC or the concerned RLDC, prior to the planned outage of any grid element. The clearance shall also be obtained from

SLDC for a grid element of the State Control areas. All deviations from the outage plan shall be uploaded on the RPC website.

(h) In case of grid disturbances, system isolation, partial black-out in a State or any other event in the system that may have an adverse impact on the system security due to a proposed outage,

(i) NLDC, RLDC or SLDC, as the case may be, shall have the authority to defer the planned outage;

(ii) SLDC, RLDC or NLDC, as the case may be, before giving clearance of the planned outage may conduct studies again.

(4) To facilitate coordinated planned outages of grid elements, a common outage planning procedure shall be formulated by each RPC in consultation with the NLDC, concerned RLDC and concerned users.

33. OPERATIONAL PLANNING STUDY

(1) Based on the operational planning analysis data, operational planning study shall be carried out by various agencies for time horizons as under:

TABLE 7 : TIME HORIZON FOR OPERATIONAL PLANNING STUDY

Time horizon of operational planning study	Agency	Means for carrying out study
Real time and Intra-day	NLDC, RLDC and SLDC	For various operating conditions using online/offline SCADA/EMS system
Day-ahead	NLDC, RLDC, and SLDC	For various operating conditions using offline tools

Time horizon of operational planning study	Agency	Means for carrying out study
Weekly	NLDC, RLDC, and SLDC	For various operating conditions using offline tools
Monthly/Yearly	RPC	For various operating conditions using offline tools

(2) SLDCs, RLDCs and NLDC shall utilize network estimation tool integrated in their EMS and SCADA systems for the real time operational planning study. All users shall make available at all times real time error free operational data for the successful execution of network analysis using EMS/SCADA. Failure to make available such data shall be immediately reported to the concerned SLDC, the concerned RLDC and NLDC along with a firm timeline for restoration. The performance of online network estimation tools at SLDC and RLDC shall be reviewed in the monthly operational meeting of RPC. Any telemetry related issues impacting the online network estimation tool shall be monitored by RPC for their early resolution.

(3) SLDCs shall perform day-ahead, weekly, monthly and yearly operational studies for the concerned State for:

(a) assessment and declaration of total transfer capability (TTC) and available transfer capability (ATC) for the import or export of electricity by the State. TTC and ATC shall be revised from time to time based on the commissioning of new elements and other grid conditions and shall be published on SLDC website with all the assumptions and limiting constraints;

(b) planned outage assessment;

(c) special scenario assessment;

(d) system protection scheme assessment;

(e) natural disaster assessment; and

(f) any other study relevant in operational scenario.

(4) RLDCs and NLDC shall perform day-ahead, weekly, monthly and yearly operational studies for:

(a) assessment of TTC and ATC at inter-regional, intra-regional, and inter-state levels;

(b) planned outage assessment;

(c) special scenario assessment;

(d) system protection scheme assessment;

(e) natural disaster assessment; and

(f) any other study relevant to operational scenarios

(5) RLDC shall assess intra-regional and inter-state level TTC and ATC and submit them to NLDC. NLDC shall declare TTC and ATC for import or export of electricity between regions including simultaneous import or export capability for a region, and cross-border interconnections 11 (Eleven) months in advance for each month on a rolling basis. TTC and ATC shall be revised from time to time based on the commissioning of new elements and other grid conditions and shall be published on the websites of the NLDC and respective RLDCs with all the assumptions and limiting constraints.

(6) Operational planning study shall be done to assess whether the planned operations shall result in deviations from any of the system operational limits defined under these regulations and applicable CEA Standards. The deviations, if any, shall be reviewed

in the monthly operational meeting of RPC and significant deviations shall be monitored by RPC for early resolution.

(7) NLDC, RLDCs, RPCs and SLDCs shall maintain records of the completed operational planning study, including date specific power flow study results, the operational plan and minutes of meetings on operational study.

(8) NLDC, RLDCs, RPCs and SLDCs shall have operating plans to address potential deviations from system operational limit identified as a result of the operational planning study. These operating plans shall be communicated to users in advance so that they can take corrective measures. In case any user is unable to adhere to such an operating plan, it shall inform the respective SLDC, RLDC and NLDC in advance with detailed reasons and explanations for the non-adherence. These detailed reasons and explanations shall be discussed in the monthly operation sub-committee of the respective region and a quarterly report shall be submitted by the respective RPC to the Commission and CEA.

(9) Each SLDC shall undertake a study on the impact of new elements to be commissioned in the intra-state system in the next six (6) months on the TTC and ATC for the State and share the results of the studies with RLDC.

(10) Each RLDC shall undertake a study on the impact of new elements to be commissioned in the next six (6) months in (a) the ISTS of the region and (b) the intra-state system on the inter-state system and share the results of the studies with NLDC.

(11) NLDC shall undertake study on the impact of new elements to be commissioned in the next six (6) months in (a) inter-regional system, (b) cross-border link and (c) intra-regional system on the inter-regional system.

(12) NLDC, RLDCs and SLDCs shall compare the results of the studies of the impact of new elements on the system and transfer capability addition with those of the interconnection and planning studies by CTU and STUs, and any significant variations observed shall be communicated to CEA, RPCs, CTU and STUs for immediate and long-term mitigation measures.

(13) Defense mechanisms like system protection scheme, load-rejection scheme, generation run-back, islanding scheme or any other scheme for system security shall be proposed by the concerned user or SLDC or RLDC or NLDC and shall be deployed as finalized by the respective RPC.

34. SYSTEM RESTORATION

(1) Based on the template issued by NLDC, SLDC of each State and the RLDC of each region shall prepare restoration procedures for the grid for their respective control areas, which shall be updated every year by the concerned SLDC and RLDC taking into account changes in the configuration of their respective power systems.

(2) Each RLDC, in consultation with the NLDC, CTU, and the concerned STUs, SLDCs, users and RPC, shall prepare detailed procedures for restoration of the regional grid under partial and total blackouts which shall be reviewed and updated annually by the concerned RLDC.

(3) Detailed procedures for restoration post partial and total blackout of each user system within a region shall be prepared by the concerned user in coordination with the concerned SLDC, RLDC or NLDC, as the case may be. The concerned user shall review the procedure every year and update the same. The user shall carry out a mock trial run of the procedure for different sub-systems including black-start of generating

units along with grid forming capability of inverter based generating station and VSC based HVDC black-start support at least once a year under intimation to the concerned SLDC and RLDC. Diesel generator sets and other standalone auxiliary supply source to be used for black start shall be tested on a weekly basis and the user shall send the test reports to the concerned SLDC, RLDC and NLDC on a quarterly basis.

(4) Simulation studies shall be carried out by each user in coordination with RLDC for preparing, reviewing and updating the restoration procedures considering the following:

(a) Black start capability of the generator;

(b) Ability of black start generator to build cranking path and sustain island;

(c) Impact of block load switching in or out;

(d) Line/transformer charging;

(e) Reduced fault levels;

(f) Protection settings under restoration condition.

(5) The thermal and nuclear generating stations shall prepare themselves for house load operation as per design. The concerned user and SLDC shall report the performance of house load operation of a generating station in the event where such operation was required.

(6) NLDC, RLDC and SLDC shall identify the generating stations with black start facility, grid forming capability of inverter based generating stations, house load operation facility, inter-State or inter-regional ties, synchronizing points and essential loads to be restored on priority.

(7) During the restoration process following a blackout, SLDC, RLDC and NLDC are authorized to operate with reduced security standards for voltage and frequency and

may direct the implementation of such operational measures, namely, suspension of secondary or tertiary frequency control, power market activities, defense schemes, reduced governor droop setting as necessary, in order to achieve the fastest possible recovery of the grid.

(8) All communication channels required for restoration process shall be used for the operational communication only till the grid normalcy is restored.

(9) Any entity extending black start support by way of injection of power as identified in clause (6) of this Regulation shall be paid for actual injection @ 110 % of the normal rate of charges for deviation in accordance with DSM Regulations for the last block in which the grid was available. The procedure in this regard shall be prepared by NLDC in consultation with stakeholders and approved by the Commission.

35. REAL TIME OPERATION

(1) System state

Power system shall be categorized under normal, alert, emergency, extreme emergency and restoration state depending on the type of contingencies and value of operational parameters of the power system by RLDC, NLDC or SLDC, as the case may be.

(a) Normal state

Power system shall be categorized under normal state when the power system is operating with operational parameters within their respective operational limits and equipment are within their respective loading limits. Under normal state, the power system is secure and capable of maintaining stability under contingencies defined in the CEA Transmission Planning Criteria.

(b) Alert state

Power system shall be categorized under alert sate when the power system is operating with operational parameters within their respective operational limits, but a single contingency ('N-1') leads to a violation of security criteria. The power system remains intact under such alert state. However, whenever the power system is under alert sate, the system operator shall take corrective measures to bring it back to a normal state.

(c) Emergency state

Power system shall be categorized under emergency state when the power system is operating with operational parameters outside their respective operational limits or equipment are above their respective loading limits. Emergency state can arise out of multiple contingencies or any major grid disturbance in the system. The power system remains intact under such emergency state. However, whenever the power system is under emergency sate, the system operator, to bring back the power system to alert/normal state shall take corrective measures such as:

- extreme measures such as load shedding, generation unit tripping, line tripping or closing,
- emergency control action such as HVDC Control, Excitation Control, HP-LP Bypass, tie line flow rescheduling on critical lines, and
- automated action such as system protection scheme, load curtailment scheme and generation run-back scheme.

(d) Extreme Emergency state

Power system shall be categorized under extreme emergency state if the control actions taken during the emergency state are not able to bring the system either to an alert state or a normal state and operational parameters are outside their respective operational limits or equipments are critically loaded. Extreme emergency state may arise due to high impact low frequency events like natural disasters. The power system may or may not remain intact (splitting may occur) and extreme events like generation plant tripping, bulk load shedding, under frequency load shedding (UFLS) and under voltage load shedding (UVLS) operation may occur.

(e) Restorative State

Power system shall be categorized under restorative state when control action is being taken to reconnect the system elements and restore system load. The power system transits from a restorative state to either an alert state or a normal state, depending on the system conditions.

(2) Each RLDC in consultation with NLDC and SLDCs shall carry out the study for the concerned region and based on historical data and grid incidences evolve detailed criteria to categorise the power system in terms of the above states. The detailed criteria shall be included in the respective Detailed Operating Procedure to be issued by RLDCs and NLDC.

(3) NLDC, RLDCs or SLDCs, as the case may be, shall maintain the grid in the normal state by taking suitable measures. In case the power system moves away from the normal state, appropriate measures shall be taken to bring the system back to the normal state. In case the power system has moved to an extreme emergency state,

appropriate LDCs shall take emergency action and initiate restorative measures immediately.

(4) Procedure to be followed during an event

(a) in the case of an event on the intra-State transmission system that may significantly impact the inter-State transmission system, the concerned SLDC shall immediately inform the RLDC;

(b) in the case of an event on the inter-State transmission system or relating to a regional entity, the concerned entity shall immediately inform the RLDC.

(c) immediately following an event on the regional grid, the RLDC shall inform the concerned users and the concerned SLDC of the necessary action to be taken.

(d) any warning in respect of system security issued by NLDC or RLDC or SLDC shall be taken note of immediately by the concerned users who shall take the necessary action to withstand the said event or to minimize its effect.

(5) Operational coordination

(a) For operational coordination, each inter-State transmission licensee, generating station, QCA and SNA shall have a control centre or coordination centre for round the clock coordination as specified in clauses (7) and (8) of Regulation 28 of these regulations.

(b) Any planned operation activity in the ISTS system [such as generating unit synchronization or de-synchronization, transmission element opening or closing (including breakers), protection system outage, SPS outage and testing etc.] shall be done by taking operational code from RLDC or NLDC, as the case may be. The operational code shall have validity period of sixty (60) minutes from the time of issue. In case such operation activity does not take place within the validity period of the code, the entity shall obtain a fresh operational code from RLDC or NLDC, as the case may be.

36. DEMAND AND LOAD MANAGEMENT

(1) The demand and load shall be managed for ensuring grid security.

(2) SLDC, in coordination with STU and Distribution Licensee (s), shall develop Automatic Demand Management scheme with emergency controls at SLDC.

(3) Whenever the power system is in an alert state or emergency state as assessed by SLDC or advised by RLDC.

(a) the respective distribution licensee or bulk consumer under the regional control area shall abide by the directions of the RLDC to secure the system, and extreme measures like load shedding may be carried out as a last resort.

(b) the respective distribution licensee under state control area shall abide by the directions of SLDC to secure the system, and extreme measures like load shedding may be carried out as a last resort.

(c) SLDC or RLDC through SLDC may direct distribution licensees or bulk consumers directly connected to STU, to restrict drawal from the grid or curtail load to ensure the stability of the grid:

Provided that load shedding shall be resorted to after the demand response option has been exhausted.

(d) The load disconnected, if any, shall be restored as soon as possible on clearance from SLDC, in coordination with RLDC if required, after the system has been normalized.

37. POST DESPATCH ANALYSIS

(1) Operational analysis

(a) NLDC, RLDCs and SLDCs shall analyse the following:

(i) Pattern of demand met, under drawls and over drawls, frequency profile, voltage and tie-line flows, angular spread, area control error, reserve margin, load and RE forecast errors, ancillary services despatched, transmission congestion and (n-1) violations;

(ii) Generation mix in terms of source and station wise generation;

(iii) Irregular pattern in any of the system parameters mentioned in sub-clauses (a)(i) and (a)(ii) of this clause and reasons thereof; and

(iv) Extreme weather events or any other event affecting grid security.

(b) Such analysis shall be disclosed on their respective websites in formats issued by NLDC.

(c) RLDCs shall prepare a quarterly report that shall bring out the system constraints, reasons for not meeting the requirements, if any, of security standards and quality of service, along with details of actions taken, including by those responsible for causing disturbances in the system parameters.

(d) RLDCs shall also provide such a report to the concerned RPC.

(e) For the purpose of analysis and reporting, telemetered data shall be archived with a granularity of not more than five (5) minutes and higher granularity for special events. Such data shall be stored by SLDCs, RLDCs and NLDC for at least fifteen

(15) years and reports shall be stored for twenty-five (25) years for operational analysis.

(2) Event reporting

Event reporting shall make available adequate data to facilitate event analysis.

(a) Immediately following an event (grid disturbance or grid incidence as defined in the CEA Grid Standards) in the system, the concerned user or SLDC shall inform the RLDC through voice message.

(b) Written flash report shall be submitted to RLDC and SLDC by the concerned user within the time line specified in Table 8 below.

(c) Disturbance Recorder (DR), station Event Logger (EL), Data Acquisition System (DAS) shall be submitted within the time line specified in Table 8 below.

(d) RLDC shall report the event (grid disturbance or grid incidence) to CEA, RPC and all regional entities within twenty-four (24) hours of receipt of the flash report.

(e) After a complete analysis of the event, the user shall submit a detailed report in the case of grid disturbance or grid incidence within one (1) week of the occurrence of event to RLDC and RPC.

(f) RLDCs and NLDC (for events involving more than one region) shall prepare a draft report of each grid disturbance or grid incidence including simulation results and analysis which shall be discussed and finalized at the Protection sub-committee of RPC as per the timeline specified in Table-8 below.

TABLE 8 : REPORT SUBMISSION TIMELINE

Sr. No.	Grid Event^ (Classification)	Flash report submission deadline (users/ SLDC)	Disturbance record and station event log submission deadline (users/ SLDC)	Detailed report and data submission deadline (users/ SLDC)	Draft report submission deadline (RLDC/ NLDC)	Discussion in protection committee meeting and final report submission deadline (RPC)
1	GI-1/GI-2	8 hours	24 hours	+7 days	+7 days	+60 days
2	Near miss **event**	8 hours	24 hours	+7 days	+7 days	+60 days
3	GD-1	8 hours	24 hours	+7 days	+7 days	+60 days
4	GD-2/GD-3	8 hours	24 hours	+7 days	+21 days	+60 days
5	GD-4/GD-5	8 hours	24 hours	+7 days	+30 days	+60 days

^*The classification of Grid Disturbance (GD)/Grid Incident (GI) shall be as per the* CEA Grid Standards.

(g) The implementation of the recommendations of the final report shall be monitored by the protection sub-committee of the RPC. NLDC shall disseminate the lessons learnt from each event to all the RPCs for necessary action in the respective regions.

(h) Any additional data such as single line diagram (SLD) of the station, protection relay settings, HVDC transient fault record, switchyard equipment and any other relevant station data required for carrying out analysis of an event by RPC, NLDC, RLDC and SLDC shall be furnished by the users including RLDC and SLDC, as the case may be, within forty- eight (48) hours of the request. All users shall also furnish high-resolution analog data from various instruments including power electronic devices like HVDC, FACTS, renewable generation (inverter level or WTG level) on the request of RPCs, NLDC, RLDCs or SLDCs.

(i) Triggering of STATCOM, TCSC, HVDC run-back, HVDC power oscillation damping, generating station power system stabilizer and any other controller system during any event in the grid shall be reported to the concerned RLDC and RPC if connected to ISTS and to the concerned SLDC if connected to an intra-state system. The transient fault records and event logger data shall be submitted to the concerned RLDC or SLDC within 24 hours of the occurrence of the incident. Generating stations shall submit 1 second resolution active power and reactive power data recorded during oscillations to the concerned RLDC or SLDC within 24 hours of the occurrence of the oscillations.

(j) A monthly report on events of unintended operation or non-operation of the protection system shall be prepared and submitted by each user [owner of important elements as identified at sub-clause (b) of clause (2) of Regulation 29 of these regulations] to the concerned RPC and RLDC within the first week of the subsequent month.

38. PERIODIC REPORTS

(1) Daily and monthly reports covering the performance of the integrated grid shall be prepared by NLDC.

(2) Daily and monthly reports covering the performance of the regional grid shall be prepared by each RLDC based on the inputs received from SLDCs and users.

(3) The reports shall, inter-alia, contain the following:

(i) Frequency profile;

(ii) Source wise generation for each control area;

(iii) Drawal from the grid and area control error;

(iv) Demand met (peak, off-peak and average);

(v) Demand/Energy unserved in MW and MWh;

(vi) Instances and quantum of curtailment of renewable energy;

(vii) Voltage profile of important substations and sub-stations normally having low or high voltage;

(viii) Major generation and transmission outages;

(ix) Constraints and instances of congestion in the transmission system;

(x) Instances of persistent/significant non-compliance with the Grid Code;

(xi) Status of reservoirs.

(4) The NLDC shall prepare a quarterly report providing operational feedback for grid planning and re-optimization and submit it to the CTU and CEA and upload it on its website.

39. REACTIVE POWER MANAGEMENT

(1) All users shall endeavour to maintain the voltage at the interconnection point in the range specified in the Grid Code.

(2) All generating stations shall be capable of supplying reactive power support so as to maintain power factor at the point of interconnection within the limits of 0.95 lagging to 0.95 leading as per the CEA Connectivity Standard Regulations.

(3) All generating stations connected to the grid shall generate or absorb reactive power as per instructions of the concerned RLDC or SLDC, as the case may be, within the capability limits of the respective generating units, where capability limits shall be as specified by the OEM.

(4) The reactive interchange of the users shall be measured and monitored by the SLDC and the RLDC.

(5) NLDC, RLDCs or SLDCs may direct the users about reactive power set-points, voltage set-points and power factor control to maintain the voltage at interconnection points.

(6) NLDC, RLDCs and SLDCs shall assess the dynamic reactive power reserve available at various substations or generating stations under any credible contingency on a regular basis based on technical details and data provided by the users, as per the procedure specified by NLDC.

(7) NLDC, RLDCs and SLDCs shall take appropriate measures to maintain the voltage within limits, inter-alia, using the following facilities, and the facility owner shall abide by the instructions of NLDC, RLDCs and SLDCs:

(i) shunt reactors,

(ii) shunt capacitors (excluding HVDC automatic control),

(iii) TCSC,

(iv) VSC based HVDC,

(v) synchronous/non-synchronous generator voltage control including inverter based reactive power support,

(vi) synchronous condenser,

(vii) static VAR compensators (SVC), STATCOM and other FACTS devices,

(viii) transformer tap change: generator transformer and inter-connecting transformer,

(ix) HVDC power order or HVDC controller selection to optimise filter bank.

(8) Reactive power facility shall be in operation at all times and shall not be taken out without the permission of the concerned RLDC or SLDC.

(9) Periodic or seasonal tap changing of inter-connecting transformers and generator transformers shall be carried out to optimize the voltages, subject to technical feasibility, and where ever necessary, other options such as tap staggering may be carried out in the network.

(10) Hydro and gas generating units having this capability shall operate in synchronous condenser mode operation as per instructions of the RLDC or SLDC of the respective control area. Standalone synchronous condenser units shall operate as per the instructions of RLDC or SLDC, as per the respective control area. The compensation for such synchronous condenser mode operation shall be included in the procedure to be submitted by NLDC and approved by the Commission.

(11) Any commercial settlement for reactive power shall be governed as per the regulatory framework specified in Annexure–4 until the same is separately notified as part of the CERC Ancillary Services Regulations**.**

(12) If voltages are outside the limit as specified in clause (15) of Regulation 29 of these regulations and the means of voltage control set out in clause (7) of this Regulation are exhausted, SLDCs, RLDCs or NLDC shall take all reasonable actions necessary to restore the voltages so as to be within the relevant limits including switching ON or OFF of lines considering the security of the system.

40. PERIODIC TESTING

(1) There shall be periodic tests, as required under clause (3) of this Regulation, carried out on power system elements for ascertaining the correctness of mathematical models used for simulation studies as well as ensuring desired performance during an event in the system.

(2) General provisions

(a) The owner of the power system element shall be responsible for carrying out tests as specified in these regulations and for submitting reports to NLDC, RLDCs, CEA and CTU for all elements and to STUs and SLDCs for intra-State elements.

(b) All equipment owners shall submit a testing plan for the next year to the concerned RPC by 31st October to ensure proper coordination during testing as per the schedule. In case of any change in the schedule, the owners shall inform the concerned RPC in advance.

(c) The tests shall be performed once every five (5) years or whenever major retrofitting is done. If any adverse performance is observed during any grid event, then the tests shall be carried out even earlier, if so advised by SLDC or RLDC or NLDC or RPC, as the case may be.

(d) The owners of the power system elements shall implement the recommendations, if any, suggested in the test reports in consultation with NLDC, RLDC, CEA, RPC and CTU.

(3) Testing requirements

The following tests shall be carried out on the respective power system elements:

TABLE 9 : TESTS REQUIRED FOR POWER SYSTEM ELEMENTS

Power System Elements	Tests	Applicability
Synchronous Generator	(1) Real and Reactive Power Capability assessment. (2) Assessment of Reactive Power Control Capability as per CEA Technical Standards for Connectivity (3) Model Validation and verification test for the complete Generator and Excitation System model including PSS. (4) Model Validation and verification of Turbine/Governor and Load Control or Active Power/ Frequency Control Functions. (5) Testing of Governor performance and Automatic Generation Control.	Individual Unit of rating 100MW and above for Coal/lignite, 50MW and above gas turbine and 25 MW and above for Hydro.
Non synchronous Generator (Solar/Wind)	(1) Real and Reactive Power Capability for Generator (2) Power Plant Controller Function Test (3) Frequency Response Test (4) Active Power Set Point change test. (5) Reactive Power (Voltage / Power Factor / Q) Set Point change test	Applicable as per CEA Technical Standards for Connectivity.
HVDC/FACTS Devices	(1) Reactive Power Controller (RPC) Capability for HVDC/FACTS (2) Filter bank adequacy assessment based on present grid condition, in consultation with NLDC. (3) Validation of response by FACTS devices as per settings.	To all ISTS HVDC as well as Intra-State HVDC/FACTS, as applicable

41. CAPACITY BUILDING AND CERTIFICATION

Capacity building, skill upgradation, and certification of the personnel deployed in load despatch centres shall be done periodically under an institutional framework through accredited certifying agency (ies).

CHAPTER 7

SCHEDULING AND DESPATCH CODE

42. INTRODUCTION

This chapter deals with the procedure for scheduling injection and drawal of power by the regional entities and the modalities for exchange of information, including scheduling for intra-state and cross-border entities transacting power through the Inter-State Transmission System. This chapter also covers provisions with respect to control area jurisdiction.

43. CONTROL AREA JURISDICTION OF LOAD DESPATCH CENTER

(1) The national grid shall be demarcated into Regional and State control areas and each control area shall be under the jurisdiction of RLDC or SLDC, as the case may be.

(2) The RLDCs shall be responsible for optimum scheduling and despatch of electricity, monitoring of real time grid operations and management of the reserves, including energy storage systems and demand response within their control area, supervision and control over the inter-state transmission systems, processing of interface energy meter data and coordinating the accounting and settlement of regional pool account.

(3) The SLDCs shall be responsible for optimum scheduling and despatch of electricity, monitoring of real time grid operations and management of the reserves including energy storage systems and demand response within its State control area, supervision and control over the intra-State transmission system, processing of interface energy meter data and coordinating the accounting and the settlement of State pool account, as may be specified by the appropriate State Commission.

(4) The entities connected exclusively to the inter-State transmission system shall be under the control area jurisdiction of RLDCs for scheduling and despatch of electricity for such entities.

(5) The entities connected exclusively to the intra-State transmission systems shall be under the control area jurisdiction of SLDCs for scheduling and despatch of electricity.

(6) Entities connected to both inter-State transmission systems and intra-State transmission systems shall be under the control area jurisdiction of RLDC, if more than or equal to 50% of the quantum of connectivity is with ISTS, and if more than 50% of the quantum of connectivity is with intra-State transmission system, it shall be under the control area jurisdiction of SLDC.

(7) In case an entity is connected to both inter-State transmission systems and intra-State transmission systems, the load despatch centre responsible for scheduling such entities shall coordinate with the concerned RLDC or SLDC, as the case may be, for ensuring grid security.

(8) Unless otherwise decided by the Commission, the entities that have already declared COD as on the date of coming into force of these regulations, shall continue to remain under the control area of the SLDC or the RLDC, as the case may be, as existing before the date of coming into force of these regulations:

Provided that the control area jurisdiction of generating stations of DVC that have already achieved COD as on coming into force of these regulations shall be as per Clause (9) of this regulation.

(9) Control Area jurisdiction of the generating station of DVC and other entities connected to the DVC system

(i) The control area of the generating stations of DVC which are connected to the transmission lines of inter-State transmission licensees including those owned and operated by DVC which are included in monthly transmission charges under the Sharing Regulations shall be under control area jurisdiction of RLDC;

(ii) The control area of the generating stations which are exclusively connected to the transmission system owned and controlled by DVC but are not included in monthly transmission charges under Sharing Regulations shall be under control area jurisdiction of DVC LDC;

(iii) The control area of the generating stations which are connected to transmission system covered under both sub-clause (i) and (ii), shall be within the jurisdiction of RLDC if more than or equal to 50% of the quantum of connectivity is with transmission system covered under sub-clause (i) of this clause and in other cases will be under the control area of jurisdiction of DVC LDC.

(iv) The control area of entities other than generating stations connected to the DVC system shall be governed in terms of sub-clauses (i) to (iii) of this clause.

(10) Notwithstanding anything contained in clauses (1) to (8) of this Regulation, the Commission may, on its own motion or on the application made by a grid connected entity, grant approval for a change in the control area jurisdiction of such an entity.

44. RESPONSIBILITIES OF LOAD DESPATCH CENTRES

(1) The Regional Load Despatch Centre, in discharge of its functions under the Act, shall be responsible for the following, within its regional control area:

(a) Forecasting of demand based on the inputs from SLDCs (under clause 2 of Regulation 31 of these regulations) and other regional entities for each time block on a day-ahead and intraday basis.

(b) Forecasting of generation from wind and solar generating stations, which are regional entities, for each time block on day-ahead and intraday basis:

Provided that such forecasts may be used by the wind and solar generating stations at their own risk and discretion, along with all commercial liabilities arising out of them. .

(c) Scheduling of electricity within the region which includes:

(i) Injection and drawal schedules for regional entities, cross-border entities, in accordance with the contracts~~;~~

(ii) Incorporation of schedules for regional entities under collective transactions;

(iii) Incorporation of schedules under the Ancillary Services Regulations.

(iv) optimisation of scheduling inter-alia through Security Constrained Economic Despatch (SCED);

(d) Secure operation of the grid by:

(i) Balancing demand and supply to minimize Area Control Error (ACE);

(ii) Maintaining and despatching reserves in accordance with these regulations and Ancillary Services Regulations.

(e) Assessment of transmission capability for inter-State transmission system for secure operation of the grid including but not limited to:

(i) Assessment of TTC and ATC for inter-regional, intra-regional and inter-State levels for its region and submit it to the NLDC.

(ii) Assessment of TTC and ATC for import or export of electricity for a State in coordination with the concerned SLDC and submit to NLDC.

(iii) Assessment of TTC and ATC shall be done on a continuous basis at least three(3) months in advance and revised based on contingencies from time to time.

(f) Publication of TTC and ATC, as finalised by NLDC, with all the assumptions and constraints on its website.

(g) Running a Security Constraint Unit Commitment (SCUC) for regional entity generating stations.

(2) The National Load Despatch Centre, in discharge of its functions under the Act, shall be responsible for the following:

(a) Optimum scheduling and despatch of electricity over inter-regional links amongst Regional Load Despatch Centres;

(b) Coordination with Regional Load Despatch Centres for the energy accounting of inter-regional exchange of power;

(c) Coordination and scheduling of cross-border exchange of power;

(d) Coordination of the set-points of all HVDCs within the country and cross-border HVDC interconnections;

(e) Finalising the TTC and ATC with all assumptions and limitations based on inputs received from RLDCs and publishing the same on its website, at least three (3) months in advance, and revising them based on contingencies from time to time.

(f) Finalising SCED and SCUC through RLDCs, and publishing the same on its website;

(g) Furnishing availability of transmission corridors to the Power Exchange(s) for day ahead and real time collective transactions and, in case of congestion, allocating available transmission corridors among the Power Exchange(s) in the ratio of initial unconstrained market clearing volume in the respective Power Exchange(s) or as specified by the Commission from time to time.

(3) The State Load Despatch Centre in discharge of its functions under the Act and for stable, smooth and secure operation of the integrated grid, shall be responsible for the following in its control area:

(a) Forecasting demand for its control area under clause 2 of Regulation 31 of these regulations for each time block on day-ahead and intra-day basis;

(b) Forecasting of generation from wind and solar generating stations under its jurisdiction for each time block on day-ahead and intra-day basis:

Provided that such forecasts may be used by the wind and solar generating stations at their own risk and discretion along with all commercial liabilities arising out of it;

(c) Scheduling and despatch for the entities in the State control area in accordance with contracts;

(d) Balancing demand and supply to minimize Area Control Error (ACE) for the State;

(e) Maintaining and despatching reserves.

(f) Declaring Total Transfer Capability and Available Transfer Capability in respect of import and export of electricity of its control area with inter-State transmission systems in coordination with the Central Transmission Utility, State Transmission Utility, and concerned RLDC and revising the same from time to time based on grid conditions. Assessment of TTC and ATC shall be done on a continuous basis at least three (3) months in advance and revised based on contingencies from time to time.

(4) Damodar Valley Corporation shall carry out the responsibilities in their respective control area, in accordance with clause 3 of this Regulation, for the stable, smooth, and secure operation of the integrated grid.

(5) Bhakra Beas Management Board and Narmada Control Authority shall coordinate with the concerned RLDC for scheduling and despatch of their generating stations.

(6) Settlement Nodal Agency shall coordinate with the concerned RLDC and NLDC for scheduling, despatch, and settlement for its control area.

45. GENERAL PROVISIONS

(1) Details of regional entity generating stations to be published by RLDC

(a) RLDCs shall publish a list of all regional entity generating stations within their control area, which shall be updated quarterly on their website along with details such as station capacity, allocated share of beneficiaries, contracted quantum by buyers, and balance available capacity.

(b) RLDCs shall also publish details, as applicable, for regional entity generating stations other than renewable generating stations, as submitted by such generating stations in accordance with Regulation 20 of these regulations.

(c) RLDC shall publish the details, as applicable, for all regional entity renewable generating stations as submitted by such generating stations in accordance with Annexure-6.

(2) The regional entity generating stations and the entities participating in Ancillary Services must be capable of receiving the load set point signals from the RLDCs or the NLDC as per CEA Technical Standards for Connectivity, or in terms of Ancillary Service Regulations, as applicable.

(3) List of Drawee Regional Entities:

RLDCs shall update on a quarterly basis the list of all drawee regional entities within their respective control area and post the same on their websites along with the allocated or contracted quantum from all entities, excluding the intra-State entities within their control area.

(4) Entitlement of a buyer and beneficiary:

(a) In cases of allocation of power from a central generating station by the Central Government, each beneficiary shall be entitled to MW despatch out of the declared capacity of such a generating station, in proportion to its share allocation.

(b) For all other cases not covered under sub-clause (a) of this Clause, the buyer shall be entitled to MW despatch out of the declared capacity of regional entity generating station as per its contracts.

(c) The entitlement from the regional entity generating station shall be rounded off up to two (2) decimal points for the purposes of scheduling and accounting.

(5) Requirement for Commencement of Scheduling:

(a) The following documents shall be submitted to the respective RLDC by the seller or the buyer, as the case may be, before commencement of the scheduling of transactions under GNA or T-GNA, as the case may be:

(i) Document in support of the grant of GNA or Connectivity, by the sellers and the buyers, as applicable;

(ii) Document in support of the effective date of GNA by the sellers and the buyers

(iii) Request for consideration under Regulation 22.4 of the GNA Regulations, if applicable.

(iv) Grant of T-GNA with an effective date, by the buyers;

(v) Declaration by the sellers and the buyers about the existence of valid contracts for the transactions.

(vi) Copies of the valid contracts signed by the sellers and the buyers, for transactions other than collective transactions.

(b) In case of allocation of power from the central generating stations by the Central Government, the concerned RLDC shall obtain the share allocation of each beneficiary issued by RPC.

(c) The copy of contracts once submitted by sellers and buyers need not be submitted again before every scheduling request and the copy of the contract can be linked with a unique ID by RLDC for reference before scheduling request:

Provided that in case of any change in terms of the contract or termination of contract, the seller as well as the buyer shall inform the same, along with a copy of the modified contract, as applicable, within a day, to the respective RLDC

(6) Adherence to Schedule:

Each regional entity shall regulate its generation or demand or both, as the case may be, so as to adhere to the schedule of net injection into or net drawal from the inter-State transmission system.

(7) Area Control Error:

The concerned Load Despatch Centre and other drawee regional entities shall keep their Area Control Error close to zero (0) by rescheduling, deploying reserves and automatic demand management scheme.

(8) Declaration of Declared Capacity by Regional entity generating stations

(a) The regional entity generating station other than the WS seller shall declare ex-bus Declared Capacity limited to 100% MCR less auxiliary power consumption, on day ahead basis as per the provisions of Regulation 49 of these regulations:

Provided that the hydro generating stations may declare ex-bus Declared Capacity more than 100% MCR less auxiliary power consumption limited to overload capability in terms of sub-clause (a) of clause (10) of this Regulation during high inflow periods:

Provide further that a high inflow period for this purpose shall be notified by the respective RPC.

(b) Regional entity WS Seller shall declare the available capacity on day ahead basis, as per the provisions of Regulations 49 of these regulations. The regional entity with generating stations other than WS sellers may be required to demonstrate the declared capacity of their generating stations as and when directed by the concerned RLDC. For this purpose, RLDC, in coordination with SLDC and the beneficiaries, shall schedule the regional entity generating station up to its declared capacity as declared on day ahead basis.

(c) The schedule issued by the RLDC shall be binding on the beneficiaries for such testing of the declared capacity of the regional entity generating station. In case the generating station fails to demonstrate the declared capacity, it shall be treated as a mis-declaration for which charges shall be levied on the generating station by RPC as follows:

The charges for the first mis-declaration for a block or multiple blocks in a day shall be the charges corresponding to two days' fixed charges at normative availability. For the second mis-declaration, the charges shall correspond to four days' fixed charges at normative availability, and for subsequent mis-declarations, the charges shall increase in a geometric progression over a period of a month.

(9) Ramping Rate to be Declared for Scheduling:

(a) The regional entity generating station shall declare the ramping rate along with the declaration of day-ahead declared capacity in the following manner, which shall be accounted for in the preparation of generation schedules:

(i) Coal or lignite fired plants shall declare a ramp up or ramp down rate of not less than 1% of ex-bus capacity corresponding to MCR on bar per minute;

(ii) Gas power plants shall declare a ramp up or ramp down rate of not less than 3% of ex-bus capacity corresponding to MCR on bar per minute;

(iii) Hydro power plants shall declare a ramp up or ramp down rate of not less than 10% of ex-bus capacity corresponding to MCR on bar per minute;

(iv) Renewable Energy generating stations shall declare a ramp up or ramp down rate as per CEA Connectivity Standards.

(10) Optimum Utilization of Hydro Energy:

(a) During high inflow and water spillage conditions, for Storage type generating station and Run–of-River Generating Stations with or without Pondage, the declared capacity for the day may be up to the installed capacity plus overload capability (up to 10% or such other limit as certified by the OEM and approved by CEA) minus auxiliary consumption, corrected for the reservoir level. In case, the overload capability of such a station is more than 10% as approved, such a station shall declare the overload capability in advance.

(b) During high inflow and water spillage conditions, the concerned RLDC shall allow scheduling of power from hydro generating stations for overload capability up to 10% of Installed Capacity or any other limit as per sub-clause (a) of this clause without the requirement of additional GNA for such overload capacity, subject to the availability of margins in the transmission system.

(11) Scheduling of WS seller and ESS by QCA:

(a) The regional entity renewable energy generating station(s) or Projects based on energy storage system(s) connected at a particular ISTS substation or at multiple ISTS substations located in a State may appoint a QCA on their behalf to coordinate and facilitate scheduling for such generating stations or energy storage system(s). The responsibility of QCA is listed at Annexure-6 to these regulations.

(b) NLDC shall submit a procedure for aggregation of pooling stations for the purpose of combined scheduling and deviation settlement for wind or solar or renewable hybrid generating stations that are regional entities, within six (6) months of notification of these regulations for approval of the Commission.

(c) The QCA shall be registered with the concerned RLDC.

(d) QCA registered with the concerned RLDC shall, on behalf of wind, solar or renewable hybrid generating stations or Energy Storage System shall:

(i) Coordinate and facilitate scheduling of power with the concerned RLDC; and;

(ii) Undertake commercial settlement of deviations with the concerned RLDC in accordance with the DSM Regulations.

(iii) Submit a copy of the consent to the concerned RLDC certifying that QCA shall undertake all operational and commercial responsibilities on behalf of generating stations as per the CERC Regulations.

(e) The concerned wind, solar or renewable hybrid generating stations including energy storage systems shall indemnify the RLDC for any act of commission or omission on the part of QCA including compliance with the Grid Code and settlement of its financial liability in the pooled account.

(f) Contract between the generating stations and QCA shall invariably contain provisions for internal dispute resolution, and any disputes arising between the generating stations and QCA shall be settled in accordance with the said mechanism.

(12) Minimum turndown level for regional entity thermal generating stations:

The minimum turndown level for operation in respect of a unit of a regional entity thermal generating station shall be 55% of the MCR of the said unit or such other minimum power level as specified in the CEA (Flexible Operation of coal based Thermal Generating Units) Regulations, 2023, as amended from time to time, whichever is lower:

Provided that the Commission may fix through an order a different minimum turndown level of operation in respect of specific unit(s) of a regional entity thermal generating station:

Provided further that such generating station on its own option may declare a minimum turndown level below the minimum turndown level specified in this clause:

Provided also that the regional entity thermal generating stations whose tariffs are determined under Section 62 or Section 63 of the Act, shall be compensated for part load operation, that is, for generation below the normative level of operation, in terms of the provisions of the contract entered into by such generating stations with the beneficiaries or buyers, or in the absence of such provision in the contract, as per the mechanism to be specified by the Commission through separate regulations or through Order**:**

Provided also that till the mechanism of part load compensation is notified by the Commission, the mechanism in this regard already in force under the Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010 shall continue to be in operation.

(13) Scheduling of Inter-Regional and Cross-Border Transactions

(a) NLDC shall prepare a schedule for cross-border exchange of power, which shall be on a net of the country basis;

(b) NLDC shall coordinate scheduling and despatch of electricity over inter-regional links with concerned RLDCs.

(14) A generating station or ESS or a drawee entity shall be allowed to schedule injection or drawal only up to its effective GNA quantum and T-GNA quantum, as applicable, in accordance with the GNA Regulations.

(15) For meeting its power requirements during non-generation hours, whether before or after COD, a generating station, including renewable energy generating station, shall enter into a valid contract with a seller or distribution licensee or through power exchange:

Provided that where the generating station including a renewable energy generating station is unable to enter into a contract for the drawal of power during non-generation hours, it may draw power from ISTS on payment of deviation charges as per the DSM Regulations.

46. SECURITY CONSTRAINED UNIT COMMITMENT (SCUC)

(1) The objective of Security Constrained Unit Commitment (SCUC) is to commit a generating station or unit thereof, for the maximisation of reserves in the interest of grid security, without altering the entitlements and schedule of the buyers of the said generating station in the day ahead time horizon.

(2) Reserves shall be procured and deployed in accordance with the Ancillary Services Regulations, and SCUC shall supplement such procurement of reserves under certain conditions, as specified in this Regulation.

(3) SCUC shall be undertaken if the NLDC, in coordination with RLDCs and based on an assessment of the power system condition, anticipates that there is likely to be a shortage

of reserves despite efforts made to procure such reserves in accordance with the Ancillary Services Regulations.

(4) The SCUC may be undertaken on day ahead basis, in respect of the regional entity generating stations or units thereof, for which tariffs are determined under section 62 of the Act, as per the following process:

(a) By 1400 Hrs of D-1 day, 'D' being the day of delivery, NLDC in coordination with RLDCs shall publish a tentative list of generating stations or units thereof, which are likely to be scheduled below the minimum turndown level of the respective stations for some or all the time blocks of the D day, based on beneficiary requisitions and initial unconstrained bid results of DAM in the power exchanges, received till 1300 Hrs of the D-1 day.

(b) Beneficiaries of such stations, whose units are likely to be scheduled below minimum turndown level for some or all time blocks of the D day, shall be permitted to revise their requisitions from such stations by 1430 Hrs of D-1 day, in order to enable such units to be on bar. The revised requisition from the said generating stations, once confirmed by the beneficiaries by 1430 Hrs of D-1 day, shall be final and binding after 1430 Hrs of D-1 day and further reduction in drawal schedule shall not be allowed from such stations except in cases when the generating stations remain above minimum turn-down level.

(c) After 1430 Hrs, the NLDC in coordination with RLDCs shall prepare the final list of such generating units that are likely to go below their minimum turndown level and such generating units shall be stacked as per merit order, that is, in the order of the lowest energy charge to the highest energy charge. The generating units so identified shall be considered for undertaking SCUC.

(d) If the NLDC in coordination with the RLDCs, after considering the bid results as finalized and available from DAM-AS, anticipates shortfall of reserves in D day due to (i) extreme variation in weather conditions; (ii) high load forecast; (iii) the requirement of maintaining reserves on regional or all India basis for grid security; (iv) network congestion, NLDC may schedule incremental energy from the generating units in the list referred to in sub-clause (c) of this clause , so as to bring such units to their minimum turndown level in order to maximize availability of on-bar units, by 1500 Hrs. of D-1 day and update the list on the respective RLDC website:

Provided that in respect of such generating station or unit thereof which has been brought to its minimum turndown level by the NLDC under this clause, downward revision by the beneficiary shall not be allowed.

(e) The NLDC shall indicate the quantum of URS power to be kept as reserves, in the generation station or unit thereof brought under SCUC, and such quantum of power identified as reserves shall not be available for scheduling by the beneficiary or for sale by the generating station through the energy market. The quantum of power over and above the identified quantum of reserves may be rescheduled by the beneficiary(ies) or scheduled by way of selling in the market.

(f) In order to maintain load generation balance consequent to scheduling of incremental generation as per sub-clause (d) of this clause, the NLDC in coordination with RLDCs, shall make commensurate reduction in generation from the on-bar generating station(s), subject to technical constraints, starting with the highest energy charge and SCED compensation charge in the stack of generating stations maintained for the purpose of SCED in accordance with these regulations.

(g) The generating station from which incremental energy has been scheduled as per sub-clause (d) of this clause shall be paid from the Deviation and Ancillary Services Pool Account, for the energy charge equivalent to the incremental energy scheduled, and the generating station from which reduction in generation has been directed as per sub-clause (f) of this clause shall pay back to the Deviation and Ancillary Services Pool Account, the energy charge equivalent to the decremental energy. Compensation for part load operation of a generating station or unit thereof brought on bar under SCUC shall be paid from the Deviation and Ancillary Services Pool Account.

(h) The URS power over and above the minimum turn down level, available after declaration of RTM results, in the generating station or unit thereof, brought on-bar under sub-clause (d) of this clause shall be deemed to be available for use as SRAS or TRAS or both in terms of the Ancillary Services Regulations

(i) All the generating stations identified under SCUC shall be available on bar, and in the event of such stations or units thereof being on Unit Shut Down (USD), the time to start a unit under different conditions such as HOT, WARM and COLD and minimum time for which it shall be brought on bar, shall be as specified in the Detailed Procedure to be prepared by NLDC and approved the Commission.

(j) The generating stations other than those whose tariffs are determined under Section 62 of the Act may opt to participate in SCUC as per the Detailed Procedure to be prepared by NLDC and approved by the Commission.

(5) SCUC three days in advance under certain circumstances:

(a) In case NLDC anticipates based on assessment that adequate reserves may not be available on D-1 Day or D-day either under day ahead SCUC or under Ancillary Services Regulations, it may also carry out SCUC three (3) days in advance of the actual day of scheduling for the regional entity generating stations. NLDC, through RLDC shall advise the regional entity generating station or unit(s) thereof to commit the unit by 1000 Hrs of D-2 day under cold start condition. The criteria for assessment of adequacy or inadequacy of reserves and identification of the generating stations or units thereof for SCUC three days in advance, shall be stipulated in the Detailed Procedure by NLDC after obtaining approval of the Commission.

(b) NLDC shall announce the requirement of SCUC three days in advance on its website by specified time on "D-3 " day as per the Detailed Procedure.

(c) All regional entity generating stations shall declare DC for 'D' day within 2 hours of announcement by NLDC, for consideration under three-day ahead SCUC.

(d) The results of SCUC along with time to commit unit (s) on bar shall be informed by NLDC to RLDCs for onward information to the generating stations. RLDC shall ensure that intimation is sent to the generating station sufficiently in advance keeping in view its start-up time.

(e) The generating stations shall bring unit (s) accordingly.

(f) The generating stations or units committed through such SCUC shall be provided the schedule above or up to minimum turn down level. Corresponding schedule for drawal shall be adjusted against requisition from the beneficiaries and the balance through security constrained economic dispatch (SCED) on the D day.

(g) The provisions of sub-clauses (e) to (j) of clause (4) of this Regulation shall also apply for the generating stations or units thereof committed under SCUC three days in advance.

47. UNIT SHUT DOWN (USD)

(1) The generating stations or units thereof, identified by NLDC in co-ordination with RLDCs, as per sub-clause (c) of clause (4) of Regulation 46 of these regulations, but not brought on bar under SCUC, shall have the option to operate at a level below the minimum turn down level or to go under Unit Shut Down (USD).

(2) In case a generating station, or unit thereof, opts to go under unit shut down (USD), the generating company owning such generating station or unit thereof shall fulfil its obligation to supply electricity to its beneficiaries who had made requisition from the said generating station prior to it going under USD, by arranging supply either (a) by entering into a contract(s) covered under the Power Market Regulation; or (b) by arranging supply from any other generating station or unit thereof owned by such generating company subject to honouring of rights of the original beneficiaries of the said generating station or unit thereof from which supply is arranged; or (c) through SCED subject to the stipulation under sub-clause (a)(vi) of clause (2) of Regulation 49 of these regulations, the details of which shall be provided in the Detailed Procedure to be specified by NLDC in this regard.

(3) In case of emergency conditions, for reasons of grid security, a generating station or unit thereof, which is under USD may be directed by NLDC to come on bar, and in such event the generating station or unit thereof shall come on bar under hot, warm and cold conditions as per the time period to be specified in the detailed procedure under sub-clause (i) of clause (4) of Regulation 46 of these regulations.

(4) Once a generating station is brought on bar as per clause (3) of this Regulation, it shall be treated as a unit under SCUC and scheduled and compensated as per Regulation 46 of these regulations.

48. SCHEDULING FROM ALTERNATE SOURCE OF POWER BY A GENERATING STATION

(1) A generating station may supply power from alternate source in case of (i) USD in terms of clause (1) of Regulation 47 of these regulations or (ii) forced outage of unit(s) or (iii) a generating station other than REGS replacing its scheduled generation by power supplied from REGS irrespective of whether such identified sources are located within or outside the premises of the generating station or at a different location.

(2) The methodology for scheduling of power from alternate sources covered under sub - clauses (i) and (ii) of clause (1) of this regulation shall be as per the following steps:

(a) The generating station may enter into contract with alternate supplier under bilateral transaction or collective transaction.

(b) In case of bilateral transaction, the generating station shall request RLDC to schedule power from such alternate supplier to its beneficiaries which shall become effective from 7th or 8th time blocks, as the case may be, in terms of clause (4) of Regulation 49 of these regulations.

(c) The power scheduled from alternate supplier shall be reduced from the schedule of the generating station.

(d) In case of alternate supply is arranged through collective transactions, the transacted quantum shall be reduced from the scheduled generation of the generating station.

(e) The generating station may also request the concerned RLDC to arrange alternate supply through SCED, in accordance with provisions contained under sub-clause (a)(vi) of clause (2) of Regulation 49 of these regulations.

(f) The generating station shall not be required to pay the transmission charges and losses for such purchase of power to supply to the buyer from alternate sources.

(3) The methodology for scheduling of power from alternate sources covered under sub - clause (iii) of clause (1) of this regulation, shall be as per the following steps:

(a) The generating station shall enter into contract with REGS for supply of power from alternate sources.

(b) The generating station shall request RLDC to schedule power from such alternate source to its beneficiaries which shall become effective from 7th or 8th time blocks, as the case may be, in terms of clause (4) of Regulation 49 of these regulations.

(c) The power scheduled from alternate source shall be reduced from the schedule of the generating station.

(d) The generating station shall not be required to pay the transmission charges and losses for such purchase and supply from alternate sources to the buyer.

(e) In case of a generating station whose tariff is determined by the Commission under Section 62 of the Act, supply of power by such generating station to its buyer from an alternate source, in terms of sub-clauses (a) to (d) of this clause, shall be subject to sharing of net savings as specified in the Tariff Regulations:

Provided that until a provision is made in the Tariff Regulations, sharing of net savings shall be in accordance with the detailed procedure to be prepared by NLDC and approved by the Commission.

(f) In case of a generating station other than whose tariff is determined by the Commission under Section 62 of the Act, supply of power by such generating station to its buyer from an alternate source in terms of sub-clauses (a) to (d) of this clause shall be in accordance with the contract with the buyer and in the absence of a specific provision in the contract, in terms of mutual consent including on sharing of net savings between the generating station and the buyer.

49. PROCEDURE FOR SCHEDULING AND DESPATCH FOR INTER-STATE TRANSACTIONS

(1) The following scheduling related activities shall be carried out daily for regional entities, on day ahead basis, 'D-1' day, for supply of power on 'D' day, as follows:

(a) Declaration of Declared Capacity by generating stations:

(i) The generating station based on coal and lignite shall submit the following information for 0000 hours to 2400 hours of the 'D' day, by 6 AM on 'D-1' day:

(a) Time block-wise On-bar Declared Capacity (MW) for on-bar units;

(b) Time block-wise Off-bar Declared Capacity (MW) for off-bar units;

(c) Time block-wise Ramp up rate (MW/min) for on-bar capacity;

(d) Time block-wise Ramp down rate (MW/min) for on-bar capacity;

(e) MWh capability for the day;

(f) Minimum turndown level (MW) and in percentage (%) of ex-bus capacity on-bar;

(ii) The generating station based on hydro energy shall submit the following information for 0000 hours to 2400 hours of the 'D' day, by 6 AM on 'D-1' day:

(a) Time block-wise ex-bus declared capacity;

(b) MWh capability for the day;

(c) Ex-bus peaking capability in MW and MWh;

(d) Time block-wise Ramp up rate (MW/min) for on-bar capacity;

(e) Time block-wise Ramp down rate (MW/min) for on-bar capacity;

(f) Unit-wise forbidden zones in MW and percentage (%) of ex-bus installed capacity;

(g) Minimum MW and duration corresponding to requirement of water release for irrigation, drinking water and other considerations.

(h) Unit wise maximum MW along with probable combination of unit maximum in case adequate water is not available.

(iii) The generating station based on gas or combined cycle generating station shall submit the following for 0000 hours to 2400 hours of the 'D' day, by 6 AM on 'D-1' day:

(a) Time block-wise On-bar Declared Capacity (DC) for the station in MW separately for each fuel such as domestic gas, RLNG or liquid fuel and On-bar units;

(b) Time block wise Off-bar Declared Capacity (MW) and off-bar units;

(c) MWh capability (fuel-wise) for the next day;

(d) Time block wise Ramp up rate (MW/min) for on-bar capacity;

(e) Time block wise Ramp down rate (MW/min) for on-bar capacity;

(f) Minimum turndown level (MW) and in percentage (%) of ex-bus capacity on-bar.

(iv) The regional entity renewable energy generating station, individually or represented by a lead generator or QCA, shall submit aggregate available capacity of the pooled generation and aggregate schedule along with contract-wise breakup for each time block for 0000 hours to 2400 hours of the 'D' day, by

6 AM on ‘D-1’ day. The source wise breakup of aggregate available capacity of the pooled generation shall also be furnished.

(v) ESS including pumped storage plant, individually or represented by the lead ESS or QCA on their behalf, shall submit aggregate available capacity of the pooled generation and aggregate schedule along with contract-wise breakup for each time-block for 0000 hours to 2400 hours of the ‘D’ day, by 6 AM on ‘D-1’ day.

(vi) The availability declaration by regional entity generating station shall have a resolution of two decimal (0.01) MW and three decimal (0.001) MWh.

(b) Entitlement of each beneficiary or buyer:

(i) For generating station, where the Central Government has allocated power, each State shall be entitled to a MW despatch up to the State’s Share in the station’s declared capacity (including On-bar Declared Capacity and Off-bar Declared Capacity) for the day. Accordingly, based on declared capacity of such generating station, RLDC shall declare entitled share of each beneficiary or buyer for 0000 hours to 2400 hours of the ‘D’ day, by 7 AM on ‘D-1’ day.

(ii) The generating station other than those having allocation of power by the Central Government shall indicate the declared capacity along with respective share of the beneficiary(ies) or buyers in accordance with the contracts entered with them. Based on the declared capacity of such generating station and share of the beneficiaries or buyers as indicated by such generating station, RLDC shall declare share of each beneficiary or buyer for 0000 hours to 2400 hours of the ‘D’ day, by 7 AM on ‘D-1’ day.

(c) The mutually agreed requisition for scheduling of intra-State entities shall be as submitted by the regional entity buyers or regional entity sellers in accordance with the contracts entered between them by 7 AM on 'D-1' day.

(d) The requisition for cross-border schedule along with its breakup from various sources shall be submitted by the Settlement Nodal Agency (SNA) for 0000 hours to 2400 hours of the 'D' day, by 8 AM on 'D-1' day;

(e) Each SLDC shall intimate the quantum of secondary and tertiary reserves in the State control area for the 'D' day by 8 AM of 'D-1' day.

(f) Requisition of schedule by the buyers which are GNA grantees:

(i) Based on the entitlement declared in accordance with sub-clause (b) of clause (1) of this Regulation, SLDC on behalf of the intra-State entities which are drawee GNA grantees, shall furnish time block-wise requisition for drawal to the concerned RLDC in accordance with the contracts, by 8 AM of 'D-1' day.

(ii) Other drawee GNA grantees which are regional entities shall furnish time block-wise requisition for drawal to the concerned RLDC in accordance with contracts, by 8 AM of 'D-1' day.

(iii) The SLDC on behalf of the intra-State entities which are drawee GNA grantees, as well as other drawee GNA grantees while furnishing time block-wise requisition under this Regulation shall subject to technical constraints, duly factor in merit order of the generating stations with which it has entered into contract(s):

Provided that the renewable energy generating stations shall not be subjected to merit order despatch, and subject to technical constraints shall be requisitioned first followed by requisition from other generating stations in merit order.

(g) Allocation of corridors by RLDC for GNA grantees

(i) RLDC shall check if drawl schedules as requisitioned by drawee GNA grantees can be allowed based on available transmission capability:

Provided that in case of constraint in transmission system, the available transmission corridor shall be allocated to the drawee GNA grantees in proportion to their GNA within the region or from outside region, depending upon the transmission constraint, whether it is within the region or from outside the region, as the case may be. The same shall be intimated to drawee GNA grantees by 8.15 AM on 'D-1' day.

(ii) Drawee GNA grantees shall revise their requisition for drawl schedule based on availability of transmission corridors for such grantee by 8.30 AM on 'D-1' day.

(iii) RLDC shall issue final drawl schedules and injection schedules for drawee and injecting GNA grantees by 9 AM on 'D-1' day.

(iv) For the purpose of "Use of GNA by other GNA grantees" as specified in the GNA Regulations, the GNA shared with other entity shall considered as GNA of the new entity.

(h) In case a generating station other than REGS intends to replace its schedule by power supplied from REGS, it shall intimate the quantum and source of power by which it intends to replace the power already scheduled under this Regulation by 9.15 am on 'D-1' day.

(i) RLDC shall incorporate by 9.45 am of 'D-1' day, the request from such generating station, in the injection schedule of the REGS and the said generating station, and the drawal schedule of the buyer.

(j) Requisition of schedule by T-GNA grantees

(i) Based on the entitlement or otherwise, SLDC on behalf of intra-State entities which are T-GNA grantees, shall furnish time block-wise requisition for drawl, to the concerned RLDC in accordance with contracts by 9.15 AM of 'D-1' day.

(ii) Other drawee T-GNA grantees who are regional entities, shall furnish time block-wise requisition for drawl to concerned RLDC in accordance with contracts by 9 AM of 'D-1' day.

(iii) Allocation of corridors by RLDC for T-GNA grantees: RLDC shall check if drawl schedules as requisitioned by T-GNA grantees can be granted based on available transmission capability after allocating corridors to the GNA grantees.

Provided that in case of constraint in transmission system, the available transmission corridor shall be allocated to the T-GNA grantees in proportion to their T-GNA.

(iv) RLDC shall issue final drawl schedules for T-GNA grantees by 9.45 AM of 'D-1' day.

(k) RLDC shall release the balance corridors after finalisation of schedules for GNA and T-GNA grantees for day ahead collective transactions.

(l) The generating station whose tariff is determined under Section 62 of the Act, may sell its un-requisitioned surplus as available at 9.45 AM in the day ahead market, unless the consent is withheld by the beneficiary or buyer in writing. The sharing of net savings shall be as per provisions of Tariff Regulations and until a provision is made in the Tariff Regulations, in accordance with the detailed procedure to be prepared by NLDC and approved by the Commission.

(m) Scheduling of collective transactions:

(i) Power Exchange(s) shall open bidding window for day ahead collective transactions and TRAS from 10.00 AM to 11AM of ‘D-1’ day.

(ii) The power exchange shall submit the day-ahead provisional trade schedules along with net power interchange of each bid area and region to NLDC by 11.45 AM of ‘D-1’ day.

(iii) NLDC shall validate the same from system security angle and inform the power exchange with revisions required, if any, due to transmission congestion or any other system constraint by 12.15 PM of ‘D-1’ day.

(iv) The power exchange shall submit the final trade schedules to NLDC for regional entities and to SLDC for intra-State entities by 1.00 PM of ‘D-1’ day.

(n) RLDC shall release balance corridors after finalisation of schedules under day ahead collective transactions by 1.00 PM of ‘D-1’ day.

(o) RLDC shall process exigency applications received till 1 PM of ‘D-1’ day for the ‘D’ day by 2 PM of ‘D-1’ day.

(p) RLDC shall update the availability of balance transmission corridors, if any, after finalisation of schedules for exigency applications by 2.00 PM of ‘D-1’ day on its website. The balance transmission corridor may be utilised by GNA grantees by way of revision of schedule, under any contract within its GNA or for exigency applications or in real time market on first cum first serve basis.

(q) Procedure for scheduling of transaction in Real-time market (RTM):

(i) All the entities participating in the real-time market including TRAS may place their bids and offers on the Power Exchange(s) for purchase and sale of power.

(ii) The window for trade in real-time market for day (D) shall open from 22.45 hrs to 23.00 hrs of (D-1) for the delivery of power for the first two time-blocks of 1st hour of day (D) i.e., 00.00 hrs to 00.30 hrs, and will be repeated every half an hour thereafter.

(iii) NLDC shall indicate to the Power Exchange(s) the available margin on each of the transmission corridors before the gate closure.

(iv) The power exchanges shall clear the real-time bids from 23.00 hrs till 23.15 hrs of 'D-1' day based on the available transmission corridor and the buy and sell bids for the real time market (RTM) for the specified duration and intimate the cleared bids to NLDC by 23.15 hrs, for scheduling.

(r) NLDC shall finalise schedules under RTM, SCED and Ancillary Services by 23.30 hrs. of 'D-1' day and RLDC shall publish the final schedules for dispatch by 23.35 hrs. of 'D-1'day.

(s) TRAS shall be procured in accordance with Ancillary services Regulations along with bidding for collective transactions, RTM or any other mechanism as per these regulations or Ancillary services Regulations.

(t) Issuance of day-ahead schedule:

RLDC shall convey the following for the next day to all regional and other entities involved in inter-state transactions after each step of finalisation of schedules for GNA grantees and T-GNA grantees:

(i) The ex-power plant schedule to each of the regional entity generating station, in MW for different time blocks along with breakup of schedule for each beneficiary or buyer.

(ii) The “net drawal schedule” for each regional entity in MW for each time block, along with break-up of (a) schedule from each of the sellers, (b) schedule of injection to ISTS and (c) injection or drawal schedule under collective transaction

(iii) All requisitions and schedules shall be rounded off to the nearest two decimals at each control area boundary for each of the transaction and shall have a resolution of 0.01 MW.

(u) Issue of schedules by SLDC:

(i) SLDCs shall take into account the schedule released by the concerned RLDC for their intra-State entities and finalise the intra-State schedule.

(ii) Power Exchange(s) shall furnish the detailed break up of each point of injection and each point of drawal within each State to respective SLDCs after receipt of acceptance from NLDC. Power Exchange(s) shall ensure necessary coordination with SLDCs for scheduling of the transactions.

(2) Additional factors to be considered while finalising schedule

(a) **Security Constrained Economic Despatch (SCED)**

(i) The objective of Security Constrained Economic Despatch (SCED) is to optimise generation despatch after gate closure in the real time market and after finalisation of schedules under RTM, by incrementing generation from the generating stations with cheaper charge and decrementing commensurate generation from the generating station with higher charge, after considering the operational and technical constraints of generation and transmission facilities.

(ii) NLDC shall be the nodal agency for implementing Security Constrained Economic Despatch (SCED) through RLDCs for the generating stations connected to inter-State transmission system which are willing to participate under SCED.

(iii) The generating stations which are willing to participate in SCED shall declare the energy charge, or the SCED Compensation Charge (after factoring in the likely changes in fuel cost and part load compensation, if any), as applicable, to NLDC on weekly basis.

(iv) NLDC shall prepare a consolidated stack of URS available in such generating stations from the lowest energy charge and SCED Compensation Charge to the highest energy charge and SCED Compensation Charge in each time block. After gate closure in the real time market, the generating stations so identified shall be instructed and despatched for SCED Up in the order of the lowest charge and to the highest charge, after taking into account ramp up or ramp down rate, response time, transmission congestion and such other parameters as stipulated in the Detailed Procedure. Corresponding to the incremental generation under SCED Up, instruction and despatch for SCED Down shall be given to the generating stations in the order of the highest charge to the lowest charge, subject to ramp up or ramp down rate, response time, transmission congestion and such other parameters as stipulated in the Detailed Procedure.

(v) Part load compensation for reduction in schedule on account of SCED, in respect of a generating station or unit thereof whose tariff is determined under Section 62 of the Act shall be paid from the savings in the SCED Account. Part load compensation for reduction in schedule of a generating station or unit thereof other than those whose tariffs are determined under Section 62 of the Act shall be factored in by such generating station while declaring the SCED Compensation Charge and shall not be paid separately.

(vi) Arrangement of power by a regional entity generating station participating in SCED to meet schedules below minimum turndown level:

a. In case a regional entity generating station gets schedule below minimum turndown level and wishes to arrange power scheduled by its buyers through SCED, it shall submit consent to NLDC before gate closure for arranging the scheduled power for such generating station through SCED.

b. NLDC shall consider the drawal schedules in respect of such generating station, under SCED subject to availability of scope of optimisation, that is, if the energy charge or SCED Compensation Charge, as applicable, of such generating station is higher than that of the marginal generating station in the stack prepared under and after completion of step at sub-clause (iv) of this clause, and also subject to the condition the entire drawal schedule against such generating station can be accommodated under SCED.

c. The settlement of energy charge and SCED Compensation Charges shall be in accordance with sub-clauses (viii) to (x) of this clause.

(vii) The deviation in respect of such generating stations shall be settled with reference to their revised schedule. The increment or decrement of generation under SCED shall not form part of schedule considered under ancillary services for such generating stations.

(viii) The schedule of beneficiaries shall not be changed on account of SCED. Buyers or beneficiaries shall continue to pay the charges for the scheduled energy directly to the generating station(s) participating in the SCED.

(ix) NLDC shall open a separate bank account called 'SCED Account'. All payments to and from the generating station(s) on account of SCED schedules shall flow from and to the said 'SCED Account'.

(x) For any increment in the generation schedule on account of SCED, the participating generator shall be paid from the 'SCED Account' at the rate of its energy charge or SCED Compensation Chargedeclared upfront by the generator. For any decrement in the generation schedule on account of SCED, the participating generator shall pay to the 'SCED Account' at the rate of energy charge or SCED Compensation Charge, as applicable.

The net saving to the generating stations shall be shared between the beneficiaries or buyers and the generating stations as per the detailed Procedure to be prepared by NLDC within two months of the notification of these regulations after stakeholder consultation and seeking approval of the Commission.

(xi) In case of reduction in generation under SCED on account of SCUC as per Regulation 46 of these regulations, the generating station from which reduction in generation has been directed shall pay back to the Deviation and Ancillary Service Pool Account at the energy charge or SCED Compensation

Charge, as the case may be, equivalent to the decremented energy due to SCUC. The compensation for such case for a generating station whose tariff is determined under Section 62 of the Act, shall also be adjusted from Deviation and Ancillary Service Pool Account.

(b) Margins for primary response:

For the purpose of ensuring primary response, RLDCs and SLDCs, as the case may be, shall not schedule the generating station or unit(s) thereof beyond ex-bus generation corresponding to 100% of the Installed capacity of the generating station or unit(s) thereof. The generating station shall not resort to Valve Wide Open (VWO) operation of units, whether running on full load or part load, and shall ensure that there is margin available for providing governor action as primary response.

In case of gas or liquid fuel-based units, suitable adjustment in Installed Capacity shall be made by RLDCs and SLDCs, as the case may be, for scheduling in due consideration the prevailing ambient conditions of temperature and pressure vis-à-vis site ambient conditions on which installed capacity of the generating station or unit(s) thereof have been specified:

Provided that the hydro generating stations shall be permitted to schedule ex-bus generation corresponding to 110% of the installed capacity or any other overload capability as allowed under sub-clause (a) of clause (10) of Regulation 45 of these regulations, during high inflow periods to avoid spillage:

(3) Power to revise schedules:

(a) Curtailment of scheduled transactions for grid security:

(A) When for the reason of transmission constraints or in the interest of grid security, it becomes inevitable to curtail power flow on a transmission corridor, the transactions already scheduled may be curtailed with immediate effect by the Regional Load Despatch Centre (keeping in view the transaction which is likely to relieve the threat to grid security) as follows:

(i) Transactions under T-GNA shall be curtailed first followed by transactions under GNA.

(ii) Transactions under T- GNA shall be curtailed in the following order:

(I) Within transactions under T-GNA, bilateral transactions shall be curtailed first followed by collective transactions under day ahead market followed by collective transactions under real time market;

(II) Within bilateral transactions under T-GNA, curtailment shall be done first from generation sources other than wind, solar, wind-solar hybrid and run of the river hydro plants with up to three hours pondage (in case of excess water leading to spillage), pro rata based on their T-GNA quantum;

(III) The generation from wind, solar, wind-solar hybrid and run of the river hydro plants with up to three hours pondage (in case of excess water leading to spillage) shall be curtailed pro rata based on T-GNA, after curtailment of generation from other sources, within T-GNA.

(IV) Collective transactions under day ahead market shall be curtailed after curtailment of bilateral transactions under T-GNA.

(V) Collective transactions under real time market shall be curtailed after curtailment of collective transactions under day ahead market.

(iii) Transactions under GNA shall be curtailed in the following order:

(I) Within transactions under GNA, curtailment shall be done first from generation sources other than wind, solar, wind-solar hybrid and run of the river hydro plants with up to three hours pondage (in case of excess water leading to spillage), on pro rata basis based on their GNA quantum.

(II) The generation from wind, solar, wind-solar hybrid and run of the river hydro plants with up to three hours pondage (in case of excess water leading to spillage) shall be curtailed pro rata based on their GNA quantum, after curtailment of generation from other sources, within GNA.

(iv) RLDC or SLDC, as the case may be, shall publish a report of such incidents on its website.

(B) NLDC shall publish, from time to time on its website, the operational limits of parameters for maintenance of grid security for the information and compliance of users of the grid. The curtailment of schedule shall be carried out only in case violation of the operational limits.

(b) In the event of bottleneck in evacuation of power due to outage, failure or limitation in the transmission system or any other constraint necessitating reduction in generation, the RLDC shall revise the schedules:

Provided that generation and drawal schedules revised by the Regional Load Despatch Centre shall become effective from 7th block or 8th block depending on time block in which schedule has been revised as first time block.

(c) In case of contingencies such as critical loading of lines, transformers, abnormal voltages or threat to system security, the following steps as considered necessary, may be taken by RLDC:

(i) Issue directions to concerned entities to adhere to the schedules;

(ii) Deployment of ancillary services;

(iii) Switching on/off pump storage plants operating in pumping mode;

(iv) Despatching emergency demand response measures;

(v) Direct the SLDCs or other regional entities to increase or decrease their drawal or injection by revising their schedules and such directions shall be immediately acted upon.

(d) Whenever RLDC revises final schedules due to reasons of grid security or contingency, brief reasons shall be informed immediately to the concerned entity followed by a detailed explanation to be posted on RLDC website within 24 hours.

(e) Any verbal directions by RLDC shall be confirmed in writing as soon as possible latest within twenty four hours.

(4) Revision of schedules on request of buyers which are GNA grantees:

(a) SLDCs on behalf of intra-state entities, regional entity ESSs as drawee entities, beneficiaries, regional entity buyers or cross-border buying entities may revise their schedules under GNA as per sub-clauses (b) and (c) of this clause in accordance with their respective contracts:

Provided that scheduled transactions under T-GNA once scheduled cannot be revised other than in case of forced outage as per clause (7) of this Regulation.

(b) The request for revision of scheduled transaction for 'D' day, shall be allowed subject to the following:

(i) Request of buyers for upward revision of schedule from the generating station whose tariff is determined under Section 62 of the Act shall be allowed starting 2 PM on 'D-1' day, only in respect of the remaining available quantum of un-requisitioned surplus in such generating stations, after finalization of schedules under day ahead market.

(ii) Request of buyers for downward revision of schedule from the generating stations, whose tariff is determined under Section 62 of the Act shall be allowed in any time block subject to the provision relating to SCUC under Regulation 46 of these regulations.

(iii) Request of buyers for upward or downward revision of schedule in respect of the generating stations other than those whose tariff is determined under Section 62 of the Act, shall be allowed in terms of provisions of the respective contracts between the generating stations and beneficiaries or buyers.

(c) Based on the request for revision in schedule made as per sub-clauses (a) and (b) of this clause, any revision in schedule made in odd time blocks shall become effective from 7th time block and any revision in schedule made in even time blocks shall become effective from 8th time block, counting the time block in which the request for revision has been received by the RLDCs to be the first one.

(d) While finalizing the drawal and despatch schedules, in case any congestion is foreseen in the inter-State transmission system or technical constraints of a generating station, the concerned RLDC shall moderate the schedules as required, under intimation to the concerned regional entities.

(5) Grid disturbance of category GD-5:

(a) GD-5 occurs when forty per cent or more of the antecedent generation or load in a regional grid is lost as defined in the CEA Grid Standards.

(b) Certification of such grid disturbance and its duration shall be done by the RLDC.

(c) Scheduled generation of all the affected regional entity generating stations supplying power under bilateral transactions shall be deemed to have been revised to be equal to their actual generation for all the time blocks affected by the grid disturbance. Such regional entity generating station shall pay back the energy charges received by it for the scheduled generation revised as actual generation to the Deviation and Ancillary Service Pool Account:

Provided that, in case the beneficiaries or buyers of such regional entity generating station are also affected by such grid disturbance, the scheduled drawals of such beneficiaries or buyers shall be deemed to have been revised to corresponding actual generation schedule of regional entity generating stations:

Provided further that in case the beneficiaries or buyers of such regional entity generating station are not affected by such grid disturbance and they continue to draw power, the scheduled drawals of such beneficiaries or buyers shall not be revised.

(d) The scheduled generation of all the affected regional entity generating stations supplying power under collective transactions shall be deemed to have been revised to be equal to their actual generation. Such regional entity generating stations shall refund the charges received towards such scheduled energy to the Deviation and Ancillary Service Pool Account.

(e) The declaration of grid disturbance shall be done by the concerned RLDC at the earliest. A notice to this effect shall be posted at its website by the RLDC of the region in which the grid disturbance has occurred which shall be considered as declaration of the grid disturbance by RLDC. All regional entities shall take note of the grid disturbance and take appropriate action at their end.

(f) Energy and deviation settlement for the period of such grid disturbance causing disruption in injection or drawal of power shall be done by the concerned RPC(s) in consultation with the concerned RLDC(s):

Provided that generation and drawal schedules revised by the Regional Load Despatch Centre shall become effective from 7th block or 8thblock depending on block in which schedule has been revised as first block.

(6) The generation schedules and drawl schedules shall be accessible to the regional entities though user credentials controlled access. After the operating day is over at 2400 hours, the schedule finally implemented during the day (taking into account all before-the-fact changes in despatch schedule of regional entity generating stations and drawal schedule of the States) shall be issued by the concerned RLDC. These schedules shall be the basis for commercial accounting.

(7) Revision of Declared Capacity and schedule, shall be allowed on account of forced outage of a unit of a generating station or ESS (as an injecting entity) only in case of bilateral transactions and not in case of collective transaction. Such generating station or ESS (as injecting entity) or the electricity trader or any other agency selling power from the unit of the generating station or ESS shall immediately intimate the outage of the unit along with the requisition for revision of Declared Capacity and schedule and the estimated time of restoration of the unit, to SLDC or RLDC, as the case may be. The schedule of beneficiaries, sellers and buyers of power from this generating unit shall be revised on pro-rata basis for all bilateral transactions. The revised Declared

Capacity and schedules shall become effective from the time block and in the manner as specified in clause (4) of this Regulation:

Provided that the generating station or ESS (as injecting entity) or trading licensee or any other agency selling power from a generating station or unit(s) thereof or ESS may revise its estimated restoration time once in a day and the revised schedule shall become effective from the 7th time block or 8th time block as per clause (4) of this Regulation, counting the time block in which the revision is informed by the generator or ESS to be the first one:

Provided further that the SLDC or the RLDC as the case may be, shall inform the revised schedule to the seller and the buyer. The original schedule shall become effective from the estimated time of restoration of the unit.

(8) In case of requirement of revision of schedule due to forecasting error, a WS seller may revise its schedule only in case of bilateral transactions and not in case of collective transaction. Such revision of schedule shall become effective from the time block and in the manner as specified in sub-clause (c) of clause (4) of this Regulation.

(9) In case of requirement of revision of Declared Capacity due to forecasting error, a RoR generating station may request for revision of its Declared Capacity and schedule only in case of bilateral transactions and not in case of collective transaction. Such revision shall become effective from the time block and in the manner as specified in sub-clause (c) of clause (4) of this Regulation.

(10) In the event of forced outage of a generating station or unit thereof, the generating company owning the generating station or unit thereof shall fulfil its supply obligation to the beneficiaries which made requisition from such generating station or unit thereof, (i) by entering into contract(s) covered under Power Market Regulations or (ii)

by arranging supply from any other generating station or unit thereof owned by such generating company subject to honouring of rights of the original beneficiaries of the said generating station or unit thereof from which the supply is arranged or (iii) through SCED, as applicable.

(11) Discrepancy in schedule

(a) All regional entities, open access customers, injecting entities and drawee consumers shall closely check their transaction Schedule and point out errors, if any, to the concerned LDC.

(b) The final schedules issued by RLDC shall be open to all regional entities and other regional open access entities for any checking and verification, for a period of 5 days. In case any mistake or omission is detected, the RLDC shall make a complete check and rectify the same.

(12) Energy Metering and Accounting:

(a) The CTU shall be responsible for procurement and installation of Interface Energy Meters (IEMs), at the cost of respective entity, at all the ISTS interface points, points of connections between the regional entities, cross border entities and other identified points for recording of actual active and reactive energy interchanged in each time-block through those points, and its operation and periodic calibration shall be done by the respective entity. CTU shall be responsible for replacement of faulty meters.

(b) The installation, operation, calibration and maintenance of Interface Energy Meters (IEMs) with automatic remote meter reading (AMR) facility shall be in accordance with the CEA Metering Regulations 2006.

(c) The installation, operation, and maintenance of additional communication links, if any, required for the purpose of AMR facility shall be in accordance with CEA Communications Regulations.

(d) Access to such metering data to the concerned RLDC and SLDC(s) shall be in accordance with the CEA Metering Regulations 2006.

(e) Entities in whose premises the IEMs are installed shall be responsible for (i) monitoring the healthiness of the CT and PT inputs to the meters, (ii) taking weekly meter readings for the seven day period ending on the preceding Sunday 2400 hrs and transmitting them to the RLDC by Tuesday noon, in case such readings have not been transmitted through automatic remote meter reading (AMR) facility (iii) monitoring and ensuring that the time drift of IEM is within the limits as specified in CEA Metering Regulations 2006 and (iv) promptly intimating the changes in CT and PT ratio to RLDC.

(f) RLDC shall, based on the IEM readings, compute time block wise actual net injection and drawal of regional entities and cross border entities within their control area:

Provided that the computations done by RLDCs shall be open to all regional entities and cross border entities for a period of fifteen (15) days for checking and verification.

(g) In case any error or omission is detected by self-analysis or brought to notice by an entity, the RLDC or RPC or NLDC, as the case may be, shall make a complete check and rectify the error within a period of a month from date of such detection.

(h) RLDC shall forward the IEM readings and the implemented schedule to the concerned RPC on a weekly basis by each Thursday for the preceding seven days period ending on the preceding Sunday mid-night, to enable the latter to prepare and issue the various accounts such as Deviation Settlement Mechanism (DSM), reactive charges, congestion charges, ancillary services, SCED, heat rate compensation charges, and regional transmission deviation in accordance with relevant regulations and Annexure 7 of these regulations.

(13) Inspection of Records:

The operational logs and records of the regional entity generating stations and inter-State transmission licensees shall be available for inspection and review by the RLDCs and RPCs.

(14) Oversight of Injection and Drawal:

NLDC or RLDC, as the case may be, shall periodically review the over drawal from or under injection into the grid. In case of persistent over drawal or under injection, the matter shall be reported to the RPC and the Commission for necessary action.

CHAPTER 8

CYBER SECURITY

50. GENERAL

(1) This chapter deals with measures to be taken to safeguard the national grid from spyware, malware, cyber-attacks, network hacking, procedure for security audit from time to time, upgradation of system requirements and keeping abreast of latest developments in the area of cyber-attacks and cyber security requirements.

(2) All users, NLDC, RLDCs, SLDCs, CTU and STUs, power exchanges, QCAs, SNAs, shall have in place, a cyber security framework in accordance with Information Technology Act, 2000; CEA (Technical Standards for Connectivity) Regulations, 2007; CEA (Cyber Security in Power Sector) Guidelines, 2021 and any such regulations issued from time to time, by an appropriate authority, so as to support reliable operation of the grid.

51. CYBER SECURITY AUDIT

All users, NLDC, RLDCs, SLDCs, CTU and STUs, power exchanges, QCAs, SNAs, shall conduct Cyber Security Audit as per the guidelines mentioned in the CEA (Cyber Security in Power Sector) Guidelines, 2021 and any other guidelines issued by an appropriate Authority.

52. MECHANISM OF REPORTING

(1) All entities shall immediately report to the appropriate government agencies in accordance with the Information Technology Act, 2000, as amended from time to time,

and CEA (Cyber Security in Power Sector) Guidelines, 2021, in case of any cyber-attack.

(2) NLDC, RLDCs, SLDCs, RPCs and the Commission shall also be informed by such entities in case of any instance of cyber-attack.

53. CYBER SECURITY COORDINATION FORUM

(1) The sectoral CERT (Computer Emergency Response Team) for wings of power sector, as notified by Government of India, from time to time, shall form a Cyber Security Coordination Forum with members from all concerned utilities and other statutory agencies to coordinate and deliberate on the cyber security challenges and gaps at appropriate level. A sub-committee of the same shall be formed at the regional level.

(2) The sectoral CERT shall lay down rules of procedure for carrying out their activities.

CHAPTER 9

MONITORING AND COMPLIANCE CODE

54. GENERAL

This chapter deals with (a) monitoring of compliance of these regulations by various entities in the grid by RLDCs, RPCs or any other person, (b) manner of reporting the instances of violations of these regulations and (c) taking remedial steps or initiating appropriate action.

55. ASSESSMENT OF COMPLIANCES

The performance of all users, CTU, STUs, NLDC, RLDCs, SLDCs and RPCs, power exchanges, QCAs, SNAs with respect to compliance of these regulations shall be assessed periodically.

56. MONITORING OF COMPLIANCE

(1) In order to ensure compliance, two methodologies shall be followed:

(a) Self-Audit

(b) Compliance Audit

(2) Self –Audit:

(a) All users, CTU, STUs, NLDC, RLDCs, RPCs and SLDCs, power exchanges, QCAs, SNAs shall conduct annual self-audits to review compliance of these regulations and submit the reports by 31st July of every year.

(b) The self-audit report shall inter alia contain the following information with respect to non-compliance:

(i) Sufficient information to understand how and why the non-compliance occurred;

(ii) Extent of damage caused by such non-compliance;

(iii) Steps and timeline planned to rectify the same;

(iv) Steps taken to mitigate any future recurrence;

(c) The self-audit reports by users, QCAs, SNAs shall be submitted to the concerned RLDC or SLDC, as the case may be.

(d) The self-audit reports by power exchanges shall also be submitted to the NLDC.

(e) The self-audit reports of NLDC, RLDCs, CTU, and RPCs shall be submitted to the Commission. The self-audit report of SLDC and STUs shall be submitted to the concerned SERC.

(f) The deficiencies shall be rectified in a time bound manner within a reasonable time.

(g) The monitoring agency for users shall be the concerned RLDC or SLDC on the basis of their respective control area. The monitoring agency shall track the progress of compliances of users, and exceptional reporting for non-compliance shall be submitted to the appropriate Commission.

(h) The monitoring agency for RLDC, NLDC, CTU and RPC shall be the Commission, and for STUs and SLDCs, shall be the concerned SERC.

(i) The Regional Power Committee (RPC) in the region shall also continuously monitor the instances of non-compliance of the provisions of these regulations and endeavor to sort out all operational issues and deliberate on the ways in which such cases of non-compliance shall be prevented in future. The Member Secretary of respective RPCs may also report any unresolved issues to the Commission.

(j) The Commission may initiate appropriate proceedings upon receipt of report under sub-clauses (f) and (h) of this clause.

(k) In case of non-compliance of any provisions of these regulations by NLDC, RLDCs, SLDCs, RPCs and any other person, the matter may be reported by any person to the Commission through filing of a petition.

(3) Independent Third-Party Compliance Audit:

The Commission may order independent third-party compliance audit for any user, power exchange, QCA, SNA, CTU, NLDC, RLDC and RPC as deemed necessary based on the facts brought to the knowledge of the Commission.

CHAPTER 10
MISCELLANEOUS

57. POWER TO RELAX

The Commission, for reasons to be recorded in writing, may relax any of the provisions of these regulations on its own motion or on an application made before it by an affected person to remove the hardship arising out of the operation of any of these regulations, applicable to a class of persons.

58. POWER TO REMOVE DIFFICULTY

If any difficulty arises in giving effect to the provisions of these regulations, the Commission may, on its own motion or on an application made before it by the nodal agency, by order, make such provisions not inconsistent with the provisions of the Act or provisions of other regulations specified by the Commission, as may appear to be necessary for removing the difficulty in giving effect to the objectives of these regulations.

59. REPEAL AND SAVINGS

(1) Save as otherwise provided in these regulations, the Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2010 and all subsequent amendments thereof shall stand repealed from the date of commencement of these Regulations.

(2) Regulation 6.3B of Central Electricity Regulatory Commission (Indian Electricity Grid Code) (Fourth Amendment) Regulations, 2016 along with Appendix-II "Mechanism for Compensation for Degradation of Heat Rate, Aux Consumption and Secondary Fuel Oil Consumption, due to Part Load Operation and Multiple Start/Stop of Units" as issued by CERC

dated 5th May 2017 vide No. L-1/219/2017-CERC shall continue to be in force till the regulations or Order under clause (12) of Regulation 45 of these regulations are issued.

(3) The mechanism of computing and sharing of net savings under SCED in accordance with the Order dated 31.3.2022 vide Petition No. 3/SM/2022 and other related Orders shall continue to be applicable till the Detailed Procedure under sub-clause (a)(x) of clause (2) of Regulation 49 of these regulations is issued.

(4) Notwithstanding such repeal, anything done or any action taken or purported to have been done or taken including any procedure, minutes, reports, confirmation or declaration of any instrument executed under the repealed regulations shall be deemed to have been done or taken under the relevant provisions of these regulations.

60. ISSUE OF SUO MOTO ORDERS AND DIRECTIONS

The Commission may from time to time issue suo motu orders and practice directions with regard to implementation of these regulations and matters incidental or ancillary thereto, as the case may be.

61. TREATMENT OF THESE REGULATIONS IN CONTRACT

The provisions of these regulations or any amendments thereof shall not be treated under 'Change in law' in any of the agreements entered into by any of the Users covered under these regulations.

Sd/-
(Harpreet Singh Pruthi)
Secretary

ANNEXURE - 1

THIRD PARTY PROTECTION SYSTEM CHECKING & VALIDATION TEMPLATE FOR A SUBSTATION

1. INTRODUCTION

(1) The audit reports, along with action plan for rectification of deficiencies found, if any, shall be submitted to RPC or RLDC within a month of submission of report by auditor.

(2) The third-party protection system checking shall be carried at site by the designated agency. The agency shall furnish two reports:

(a) Preliminary Report: This report shall be prepared on the site and shall be signed by all the parties present.

(b) Detailed Report: This report shall be furnished by agency within one month after carrying out detailed analysis.

2. CHECKLIST

(1) The protection system checklist shall contain information as per this Regulation.

(a) General Information (to be provided prior to the checking as well as to be included in final report):

(i) Substation name

(ii) Name of Owner Utility

(iii) Voltage Level (s) or highest voltage level?

(iv) Short circuit current rating of all equipment (for all voltage level)

(v) Date of commissioning of the substation

(vi) Checking and validation date

(vii) Record of previous tripping’s (in last one year) and details of protection operation

(viii) Previous Relay Test Reports

(ix) Overall single line diagram (SLD)

(x) AC aux SLD

(xi) DC aux SLD

(xii) SAS architecture diagram

(xiii) SPS scheme implemented (if any)

(b) The preliminary report shall inter-alia contain the following:

TABLE A: FORMAT OF PRELIMINARY REPORT

S. No.	Issues	Remarks
1	Recommendation of last protection checking and validation	Status of works and pending issues if any
2	Review of existing settings at substation	Recommended Action
3	Disturbance Recorder out available for last 6 tripping's (Y/N)	Recommended Action
4	Chronic reason of tripping, if any	Recommended Action
5	Major non-conformity/deficiency observed	Recommended Action

(c) The relay configuration checklist for available power system elements at station:

(i) Transmission Line

(ii) Bus Reactor/Line Reactor

(iii) Inter-connecting Transformer

(iv) Busbar Protection Relay

(v) AC auxiliary system

(vi) DC auxiliary system

(vii) Communication system

(viii) Circuit Breaker Details

(ix) Current Transformer Details

(x) Capacitive Voltage Transformers Details

(xi) Any other equipment/system relevant for protection system operation

(d) The minimum set of points on which checking and validation shall be carried out is covered in this clause. The detailed list shall be prepared by checking and validation team in consultation with concerned entity, RLDC and RPC.

(i) Transmission Line Distance Protection/Differential Protection

a. Name and Length of Line
b. Whether series compensated or not
c. Mode of communication used (PLCC/OPGW)
d. Relay Make and Model for Main-I and Main-II
e. List of all active protections & settings
f. Carrier aided scheme if any
g. Status of Power Swing/Out of Step/SOTF/Breaker Failure/Broken Conductor/STUB/Fault Locator/DR/VT fuse fail/Overvoltage Protection/Trip Circuit supervision/Auto-reclose/Load encroachment etc.
h. Relay connected to Trip Coil-1 or 2 or both
i. CT ratio and PT ratio
j. Feed from DC supply-1 or 2
k. Connected to dedicated CT core (mention name)
l. Other requirements for protection checking and validation

(ii) Shunt Reactor & Inter-connecting Transformer Protection

a. Whether two groups of protections used (Group A and Group B)
b. Do the groups have separate DC sources

c. Relay Make and Model

d. List of all active protections along with settings

e. Status of Differential Protection/Restricted Earth Fault Protection/Back-up Directional Overcurrent/Backup Earth fault/ Breaker Failure

f. Status of Oil Temperature Indicator/Winding Temperature Indicator/Bucholz/Pressure Release Device etc.

g. Relay connected to Trip Coil-1 or 2 or both

h. CT ratio and PT ratio

i. Feed from DC supply-1 or 2

j. Connected to dedicated CT core (mention name)

k. Other requirements for protection checking and validation

(iii) Busbar Protection Relay

a. Busbar and redundant relay make and model

b. Type of Busbar arrangement

c. Zones

d. Dedicated CT core for each busbar protection (Yes/No)

e. Breaker Failure relay included (Yes/No), if additional then furnish make and model

f. Trip issued to both Busbar protection in case of enabling

g. Isolator indication and check relays

h. Other requirements for protection checking and validation

(iv) AC auxiliary system

a. Source of AC auxiliary system

b. Supply changeover between sources (Auto/Manual)

c. Diesel generator (DG) details

d. Maintenance plan and supply changeover periodicity in DG

e. Single Line Diagram

f. Other requirements for protection checking and validation

(v) DC auxiliary system

a. Type of Batteries (Make, vintage, model)

b. Status of battery Charger

c. Measured voltage (positive to earth and negative to earth)

d. Availability of ground fault detectors

e. Protection relays and trip circuits with independent DC sources

f. Other requirements for protection checking and validation

g. Communication system

i. Mode of communication for Main-1 and Main-2 protection

ii. Mode of communication for data and speech communication

iii. Status of PLCC channels

iv. Time synchronization equipment details

v. 7OPGW on geographically diversified paths for Main-1 and main-2 relay

vi. Other requirements for protection checking and validation

(vi) Circuit Breaker Details

a. Details and Status

b. Healthiness of Tripping Coil and Trip circuit supervision relay

c. Single Pole/Multi pole operation

d. Pole Discrepancy Relay available(Y/N)

e. Monitoring Devices for checking the dielectric medium

f. Other requirements for protection checking and validation

(vii) Current Transformer (CT)/Capacitive Voltage Transformer (CVT) Details

a. CT/CVT ID name and voltage level

b. CT/CVT core connection details

c. Accuracy Class

d. Whether Protection/Metering

e. CT/CVT ratio available and ratio adopted

f. Details of last checking and validation of CT/CVT healthiness

g. Other requirements for protection checking and validation

h. Other protections: Direction earth fault, negative sequence, over current, over voltage, over frequency, under voltage, under frequency, forward power, reverse power, out of step/power swing, HVDC protection etc.

3. SUMMARY OF CHECKING:

The summary shall specifically mention minimum following points:

(1) The settings and scheme adopted are in line with agreed protection philosophy or any accepted guidelines (e.g. Ramakrishna guidelines or CBIP manual based).

(2) The deviations from the RPC protection philosophy, if any and reasons for taking the deviations shall be recorded.

(3) All the major general deficiency shall be listed in detail along with remedial recommendations.

(4) The relay settings to be adopted shall be validated with simulation based or EMTP studies and details shall be enclosed in report.

(5) The cases of protection maloperation shall be analysed from protection indices report furnished by concerned utility, the causes of failure along with corrective actions and recommendations based on the findings shall be noted in the report.

ANNEXURE - 2

GENERATION RESERVE ESTIMATION AND FREQUENCY CONTROL

4. INTRODUCTION

This procedure is in line with the sub-clause (f) of clause (10) of Regulation 30 of these regulations which requires methodology for the following as detailed in subsequent paragraphs:

(1) Assessment of reference contingency,

(2) All India minimum target frequency response characteristics,

(3) Calculation of frequency response obligation of each control area,

(4) Criteria for reportable event,

(5) Calculation of actual frequency response characteristics of control area and

(6) Calculation of frequency response performance

5. ASSESSMENT OF REFERENCE CONTINGENCY

The reference contingency is the quantum of sudden generation or demand outage in an event. The reference contingency shall consider quantum of generation outage based on outage of largest power plant, group of power plants, a generation complex, or a generation pooling station, or the actual generation outage occurred in an event during last two years, or a credible outage scenario. Similarly reference contingency shall also consider outage of single largest load center or actual outage of load occurred in an event during last two years. To start with reference contingency shall be considered as outage of 4500 MW which shall be revised by NLDC from time to time. The primary reserve at All India level shall be more than the reference contingency quantum. Therefore, minimum quantum of primary reserve shall be currently 4500 MW.

6. ALL INDIA MINIMUM TARGET FREQUENCY RESPONSE CHARACTERISTICS

(a) The all India minimum target frequency response characteristic (MW/Hz) shall be reference contingency quantum (MW) divided by maximum steady frequency deviation (Hz) allowable for the reference contingency event.

(b) The primary reserves shall be activated immediately (within few seconds) when the frequency deviates from 50 Hz. The safe, secure and reliable operation of grid requires that the nadir frequency should be at least 0.1 Hz above the first stage of under frequency load shedding scheme. This implies that the nadir frequency shall be above or 49.5 Hz (considering first stage of under frequency loading shedding setting as 49.4 Hz) for the reference contingency event and the maximum steady state frequency deviation should not cross 0.30 Hz for the reference contingency event.

(c) Therefore, the minimum All India target Frequency Response Characteristic currently shall be quantum of load or generation loss in reference contingency (as defined in Section (1) above divided by frequency deviation value of 0.3 Hz i.e. 15000 MW/Hz (4500 MW/0.3 Hz).

7. CALCULATION OF FREQUENCY RESPONSE OBLIGATION (FRO) OF EACH CONTROL AREA:

The minimum Frequency Response Obligation (FRO) of each control area in MW/Hz shall be calculated as:

FRO = (Control Area average Demand + Control Area average Generation) * minimum all India Target Frequency Response Characteristic/ (Sum of peak or average demand of all control areas + Sum of average generation of all control areas)

Provided FRO shall be nil in case of a control area not having any generation resources, such as Goa, DD, DNH etc.

8. CRITERIA FOR REPORTABLE EVENT:

The frequency response characteristic (FRC) calculation shall be carried out by each control area for any load or generation loss incident involving net change of more than 1000 MW of load or generation or a frequency change involving 0.1 Hz or more. The event shall be notified by the NLDC.

9. CALCULATION OF ACTUAL FREQUENCY RESPONSE CHARACTERISTICS OF CONTROL AREA

(a) Frequency Response Characteristics (FRC) computations:

Frequency Response Characteristics (FRC) will be computed for all events involving a sudden 1000 MW or more load or generation loss or a step change in frequency by 0.10 Hz i.e. for all reportable events as notified by NLDC. The FRC shall be worked out by NLDC, RLDCs and SLDCs to for each interconnection/region/control area (including for each generating station). Each generating station shall also compute it's FRC. The following steps shall be followed for computation of FRC

(i) After every event involving a sudden 1000 MW or more load or generation loss or a step change in frequency by 0.1 Hz, NLDC would get the PMUs frequency data. NLDC would also get the exact quantum of load/generation lost from the RLDC of the affected region.

(ii) NLDC shall plot the frequency graph and determine the initial frequency, minimum/maximum frequency, settling frequency and time points (points A, C and

B of the Figure-A). Accordingly, frequency difference points & corresponding time to be used for FRC calculations would be informed to all RLDCs.

(iii) NLDC shall also work out region wise and neighboring countries (Bhutan and Nepal) FRC (Format as per Table - B) based on 10 second Historical Data Recording (HDR) data available at NLDC and inform all RLDCs within three (3) working days. RLDCs shall inform the SLDCs/regional entities in their region.

(iv) RLDCs shall also work out each control area wise FRC (Format as per Table -B) based on HDR data available at RLDCs within six (6) working days after the event.

(v) All the SLDCs shall work out FRC for all the intra-state entities (for events indicated by the Regional Load Despatch Centres) based on the HDR available at their respective SLDCs and submit the same to respective RLDC within six (6) working days after the event. (Format as per Table-B).

(vi) All regional entity generating stations shall also assess the FRC for their respective stations and submit the same to respective RLDC within six (6) working days. (Format as per Table-B). The high resolution data (1 second or better resolution) of active power generation and frequency shall also be shared with RLDC.

(b) Input data for FRC:

(i) The data for frequency response characteristic Calculations may be taken from the real time telemetered data recorded by the SCADA systems installed at Control Areas / Regional Load Despatch Centres / National Load Despatch Centre.

(ii) Bad quality of data could be flagged / mentioned by the control centre(s) and reasonable assumptions made for FRC computation. Details of these may be mentioned.

(c) Instructions for computation of FRC:

A sample frequency chart given at Figure-A with points A, B, and C labeled, depicts a typical frequency excursion caused by a loss of a large generator in Indian power system. Point A denotes the interconnection frequency immediately before the disturbance. Point B represents the Interconnection frequency at the point immediately after the frequency stabilizes due to governor action but before the contingent area takes any corrective actions, automatic or manual. Point C represents the interconnection frequency at its maximum deviation due to the loss of generation.

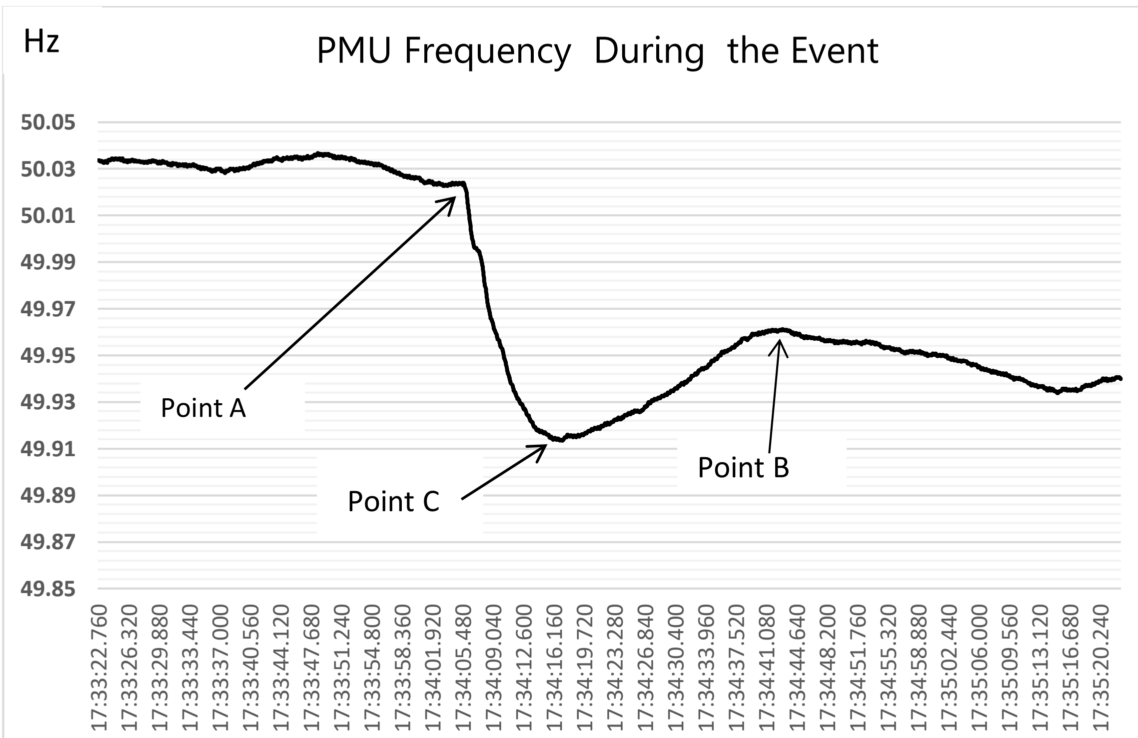


FIGURE A: SAMPLE PMU FREQUENCY PLOT SHOWING RELEVANT POINTS FOR FRC CALCULATION

(d) Steps to work out frequency response characteristics of control area are as follows: -

Step-1: Actual net interchange of the control area immediately before the disturbance (Point – A in the figure-A), say P_A. Sign convention for net power imported into a Control Area is positive (+) and net power exported out of a control area is negative (-).

Step-2: Actual net interchange of the control area immediately after the disturbance (Point – B in the figure-A), say P_B. Use the same sign convention as Step-1.

Step-3: The change in net interchange of the Control Area = (P_B -P_A). [For a disturbance that causes the frequency to decrease, this value should ideally be negative. The net interchange of a control area may be positive, if the drop in generation has occurred in that control area. Similarly, for load throw off or frequency rise cases in a control area, the net interchange shall normally be positive except for the Control Area, where the load throw off has taken place.]

Step-4: If the control area has suffered the loss, then Load or generation lost by the control area = PL. Otherwise, the loss (PL) is zero. Sign convention for Load Loss is negative (-) and Generation Loss positive (+).

Step-5: The Control Area Response Δ P = (PB-PA) - PL

Step-6: The Frequency immediately before the disturbance = fA.

Step-7: The Frequency immediately after the disturbance = fB.

Step-8: Change in Interconnection Frequency from Point A to Point B = Δf = (fB - fA)

Step-9: Frequency Response Characteristic (FRC) of the Control Area = Δ P/ Δf

Step-10: Frequency Response Obligation (FRO) of each control area calculated in advance as per clause 3 of this Annexure

Step 11: Frequency Response Performance (FRP) = Actual Frequency Response Characteristic (AFRC)/ Frequency Response Obligation (FRO)

TABLE B: FRC CALCULATION SHEET TO BE USED BY ALL SLDC/RLDC/NLDC/CONTROL AREA

S. No	Particulars	Dimension	Control Area-1 /Region
1	Actual Net Interchange before the Event (Time= hh:mm:ss)	MW	
2	Actual Net Interchange after the Event (Time= hh:mm:ss)	MW	
3	Change in Net Interchange (2 - 1)	MW	
4	Generation Loss (+) / Load Throw off (-) during the Event	MW	
5	Control Area Response (3-4)	MW	
6	Frequency before the Event	Hz	
7	Frequency after the Event	Hz	
8	Change in Frequency (7-6)	Hz	
9	Frequency Response Characteristic (5 / 8)	MW/Hz	
10	Frequency Response Obligation (FRO) of control area	MW/Hz	
11	Frequency Response Performance (FRP)(9/10)	Numeric value (up to two decimal places)	

10. CALCULATION OF FREQUENCY RESPONSE PERFORMANCE

(a) The performance of each control area in providing frequency response characteristic shall be calculated for each reportable event. Each control area shall separately assess their frequency response characteristic and share with RLDC along with high resolution data of at least one (1) second for regional entity generating stations and ten (10) second for state control area.

Frequency Response Performance (FRP) = Actual Frequency Response Characteristic (AFRC)/ Frequency Response Obligation (FRO)

Each control area shall be graded based on median Frequency Response Performance annually (at least 10 events) as per following criteria:

TABLE C: FREQUENCY RESPONSE CRITERIA

S. N	Performance*	Grading
i.	FRP≥ 1	Excellent
ii.	0.85 ≤ FRP < 1	Good
iii.	0.75 ≤ FRP <0.85	Average
iv.	0.5≤ FRP < 0.75	Below Average
v.	FRP <0.5	Poor

**Provided that for wind/solar generating stations and state control areas with internal generation less than 100 MW or annual peak demand less than 1000 MW, the FRP grading shall be indicative only.*

ANNEXURE-3

ASSESSMENT OF SECONDARY AND TERTIARY GENERATION RESERVES AT REGIONAL/STATE LEVEL

1. Area control error (ACE) for each Control Area shall be calculated using sub-clause (d) of clause (11) of Regulation 30 of these regulations, time block wise for the last financial year.
2. The positive ACE and negative ACE shall be separately tabulated.
3. The positive ACE shall be arranged in ascending order and 99 percentile of such ACE shall be captured. Similarly, negative ACE shall be arranged in ascending order and 99 percentile of such ACE shall be captured.
4. Such 99 percentile of positive and negative ACE respectively of a control area for previous financial year, is the desired positive and negative secondary reserve capacity for such control area for next financial year. Desired quantum of tertiary reserve of the control area shall also be equal to such estimated secondary reserve.
5. The total reserves in a region shall be algebraic sum of reserves in each state control area. However, due to diversity within the region, the Region as a whole might need lesser reserves of secondary and tertiary reserves. The reserve requirement shall be based on regional ACE which shall further be divided to identify the share of each state based on 99 percentile ACE of such State control area. The All -India Total of Positive (and Negative) secondary reserve capacity requirement on regional basis shall be equal to the reference contingency or secondary reserve capacity requirement based on regional ACE, whichever is higher, subject to the economic utilization of the resource available in the system while ensuring grid security.
6. The amount of reserve to be kept with each State control area as per clause (5) of this Annexure shall be validated against the maximum unit size of the intra-state generator of

that control area such that reserve requirement is not more than unit size of maximum intra-state generator.

7. The secondary reserves for each control area obtained as per clause (5) of this Annexure shall be further apportioned among the reserve to be kept at intra-state generation and at inter-state generation as per the following considerations:
   (1) The maximum demand and maximum internal generation for each control area.
   (2) The ratio of demand met through internal generation and inter-state generation (drawl from the grid) is calculated.
   (3) The above ratio is used to apportion the secondary reserve obtained as per clause (5) of this Annexure among the reserves to be maintained by each control area at intra-state generators and inter-state generators.

   Illustration: The maximum demand met of Punjab is 13602 MW and internal generation is 6932 MW. The drawl from the grid is therefore 13602-6932= 6670 MW. Suppose the reserve capacity calculated for Punjab in step-5 is 91 MW. The ratio of demand met by internal generation is 0.51(6932/13602) and by ISGS generation is 0.49 (6670/13602). Thus reserve to be kept by Punjab in intra-state generation is 46 MW(0.51*91) and in ISGS generation is 44 MW (0.49*91).

8. For control areas having no generation or very small generation, the entire reserves capacity calculated as per clause (5) of this Annexure for the state, shall be kept at inter-state generation.

ANNEXURE - 4

1. Reactive Power Compensation

(a) Reactive power compensation should ideally be provided locally, by generating reactive power as close to the reactive power consumption as possible. The regional entities are therefore expected to provide local VAr compensation or generation such that they do not draw VARs from the EHV grid, particularly under low-voltage condition. To discourage VAr drawals by regional entities, VAr exchanges with ISTS shall be priced as follows:

(a) The regional entity pays for VAr drawal when voltage is below 97%

(b) The regional entity gets paid for VAr return when voltage is below 97%.

(c) The regional entity gets paid for VAr drawal when voltage is above103%.

(d) The regional entity pays for VAr return when voltage is above 103%.

Where all voltage measurements are at the interface point with ISTS.

(b) The charge for VArh shall be at the rate of 5 paise/kVArh w.e.f. the date of effect of these regulations. This rate shall be escalated at 0.5paise/kVArh per year thereafter, unless otherwise revised.

(c) All the Inverter Based Resources (IBRs) covering wind, solar and energy storage shall ensure that they have the necessary capability, as per CEA Connectivity Standards, all the time including non-operating hours and night hours for solar. The active power consumed by these devices for purpose of providing reactive power support, when operating under synchronous condenser/night-mode, shall not be charged under deviations and shall be treated as transmission losses in the ISTS.

(d) For IBRs of capacity 50 MW and below not coming directly to the point of interconnection but through the pooling at the Power Park Developer end, the Power Park Developer shall act as aggregator for the Reactive Energy Charges for payments to and from the Pool Account at RLDC level. The de-pooling of Reactive Energy charges amongst the individual wind and solar shall be done by the Power Park Developer.

(e) For any interconnecting line between two states, owned by the States, the interface points shall be treated in terms of this Regulation for the purpose of reactive power charges.

2. ACCOUNTING AND PAYMENT FOR REACTIVE ENERGY EXCHANGES

(a) RPC Secretariat shall also issue the weekly statement for VAR charges, to all regional entities.

(b) The concerned regional entities shall pay the amounts into regional Pool Account operated by the RLDC within 10 (ten) days of issue of statement.

(c) The regional entities who have to receive the money on account of VAR charges would then be paid out from the regional Pool Account, within two (2) working days from the receipt of payment in the Pool Account.

(d) If payments against the above VAr charges are delayed by more than two days, i.e., beyond twelve (12) days from issue of the statement by RPC Secretariat, the defaulting regional entity shall pay simple interest @ 0.04% for each day of delay. The interest so collected shall be paid to the regional entities who had to receive the amount, payment of which got delayed.

(e) Persistent payment defaults, if any, shall be reported by the RLDC to the Member Secretary, RPC, for initiating remedial action.

ANNEXURE- 5

1. REPORTING REQUIREMENTS

S. No.	Entity Responsible	Reporting / Study Requirement and Frequency	Reference Regulation of these regulations
1.	RPC	Exception report of UFR (monthly)	Operating Code: Regulation No. 29(13)(e)
		Annual Outage Plan(annual)	Operating Code: Regulation No. 32(2)(a)
		All India LGBR (annual)	Operating Code: Regulation No. 32 (3)(b)
		Feedback Report to address potential violation of system operational limit (quarterly)	Operating Code Regulation No. 33(8)
		Final report on grid disturbance (post grid disturbance)	Operating Code Regulation No. 37(2)(f)
		Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code Regulation No. 56(2)(a)
2.	CTU	Transmission resource adequacy assessment	Resource Planning Code Regulation No. 5(4)(a)
		Self-audit Report (By 31st July of every year)	Monitoring and Compliance Code Regulation No. 56(2)(a)
3.	NLDC	Assessment of frequency response obligation of each control area (By 15th of March every year)	Operating Code Regulation 30(10)(f)
		Operational planning (monthly/ yearly)	Operating Code Regulation 31(1)(a)
		Operational planning (Intra-day, Day Ahead, Weekly)	Operating Code Regulation 31(1)(b)
		Forecast error (intra-day / day-ahead / weekly / monthly and	Operating Code Regulation 31(2)(i)

S. No.	Entity Responsible	Reporting / Study Requirement and Frequency	Reference Regulation of these regulations
		yearly)	
		Operational analysis (post despatch)	Operating Code: Regulation No. 37(1)
		Draft report of each grid disturbance or grid incidence (post such event)	Operating Code: Regulation No. 37(2)(f)
		Daily and monthly report of integrated grid performance (daily and monthly)	Operating Code: Regulation 38(1)
		Self-audit Report (By 31st July of every year)	Monitoring and Compliance Code: Regulation No. 56(2)(a)
4.	RLDC	Operational planning (monthly / yearly)	Operating Code Regulation 31(1)(a)
		Operational planning (Intra-day, Day Ahead, Weekly)	Operating Code Regulation31(1)(b)
		Forecast error (intra-day / day-ahead / weekly / monthly and yearly)	Operating Code Regulation 31(2)(i)
		Operational analysis (post despatch)	Operating Code: Regulation No. 37(1)
		Draft report of each grid disturbance (post grid disturbance)	Operating Code: Regulation No. 37(2)(f)
		Regional grid performance (daily and monthly)	Operating Code: Regulation 38(2)
		Details of regional entity generating stations (quarterly)	Scheduling and Despatch Code: Regulation No. 45(1)(a)
		Self-audit Report (By 31st July of every year)	Monitoring and Compliance Code: Regulation No. 56(2)(a)
5.	SLDC	Exception report of UFR (monthly)	Operating Code: Regulation No. 29(13)(d)
		Operational planning (monthly / yearly)	Operating Code: Regulation 31(1)(a)

S. No.	Entity Responsible	Reporting / Study Requirement and Frequency	Reference Regulation of these regulations
		Operational planning (Intra-day, Day Ahead, Weekly)	Operating Code: Regulation 31(1)(b)
		Forecast error (intra-day/ day-ahead /weekly/monthly and yearly)	Operating Code: Regulation 31(2)(i)
		Operational analysis (post despatch)	Operating Code: Regulation No. 37(1)
		Flash report and detailed report on any grid disturbance (post grid disturbance)	Operating Code: Regulation No. 37(2)
		Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code: Regulation No. 56(2)(a)
	STU	Transmission resource adequacy assessment	Resource Planning Code: Regulation No. 5(4)(b)
		Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code: Regulation No. 56(2)(a)
6.	User	Tuning of AVR, PSS, Voltage Controllers (PPC) including for low and high voltage ride through capability	Operating Code: Regulation No. 29(7)
		Flash report and detailed report on any grid disturbance (post grid disturbance)	Operating Code: Regulation No. 37(2)
		Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code: Regulation No. 56(2)(a)
7.	Power Exchange	Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code: Regulation No. 56(2)(a)
8.	QCA	Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code: Regulation No. 56(2)(a)

S. No.	Entity Responsible	Reporting / Study Requirement and Frequency	Reference Regulation of these regulations
9.	SNA	Self-audit Report (By 31st July of every year))	Monitoring and Compliance Code: Regulation No. 56(2)(a)

2. Procedure to be submitted for approval of the Central Commission, after preparation and due stakeholder consultation

S. No.	Entity Responsible	Drafting Responsibilities	Timeline to submit to Commission from date of notification of these regulations	Reference Regulation Number
1.	NLDC	Detailed procedure covering modalities for first time energization and integration of new or modified power system elements	60 days	Connection Code: Regulation No. 8(2)
		Compensation of quick start synchronous generation	60 days	Operating Code: Regulation No. 30(9)
		Assessment of quantum of secondary reserve capacity	60 days	Operating Code: Regulation No. 30(11)(k)
		Methodology for allocation of cost of procurement of Secondary/Tertiary reserve capacity in case of shortfall of reserve capacity by the State	60 days	Operating Code: Regulation No. 30(11)(t),30(12)(h)

S. No.	Entity Responsible	Drafting Responsibilities	Timeline to submit to Commission from date of notification of these regulations	Reference Regulation Number
		Procedure for payment for Black start support	60 days	Operating Code: Regulation No. 34 (9)
		Compensation for synchronous condenser mode operation	60 days	Operating Code: Regulation No. 39 (10)
		Procedure for aggregation of pooling stations for the purpose of combined scheduling and deviation settlement for wind or solar or renewable hybrid generating stations	60 days	Scheduling and Despatch Code: Regulation No. 45 (11)(b)
		Detailed procedure to start a unit under different conditions such as HOT, WARM and COLD	60 days	Scheduling and Despatch Code: Regulation No. 46 (4)(i)
		Detailed procedure for participation of the generating stations other than those whose tariffs are determined under Section 62 of the Act opting to participate in SCUC	60 days	Scheduling and Despatch Code: Regulation No. 46 (4)(j)
		Assessment of adequacy or inadequacy of reserves and identification of the generating stations/units for SCUC	60 days	Scheduling and Despatch Code: Regulation No. 46 (5)(a), 46 (5)(b)
		Supply from alternate REGS source: sharing of	60 days	Scheduling and Despatch Code:

S. No.	Entity Responsible	Drafting Responsibilities	Timeline to submit to Commission from date of notification of these regulations	Reference Regulation Number
		net savings for generating stations whose tariff is determined under Section 62 of the Act.		Regulation No. 48(3)(e)
		Sharing of net savings from sale in day ahead collective market, for generating stations whose tariff is determined under Section 62 of the Act.		Scheduling and Despatch Code: Regulation No. 49(1)(l)
		Detailed procedure for SCED: sharing of net savings	60 days	Scheduling and Despatch Code: 49(2)(a)(x)

3. PROCEDURE TO BE SUBMITTED FOR INFORMATION OF THE CENTRAL COMMISSION, AFTER PREPARATION AND DUE STAKEHOLDER CONSULTATION

S. No.	Entity Responsible	Drafting Responsibilities	Timeline to submit to Commission from date of notification of these regulations	Regulation No.
1.	RPC	Tuning procedure for Power System Stabilizers, AVRs of generating units and reactive power controllers	60 days	Operating Code: Regulation No. 29(8)
		Common outage planning	60 days	Operating Code:

S. No.	Entity Responsible	Drafting Responsibilities	Timeline to submit to Commission from date of notification of these regulations	Regulation No.
		procedure		Regulation No. 32(4)
2.	NLDC	Detailed Procedure covering modalities for carrying out interconnection studies	60 days	Connection Code: Regulation No. 10(3)
		Operating procedure	60 days	Operating Code: Regulation No. 28(3)
		Information exchange and timelines in respect of Secondary/Tertiary reserves	60 days	Operating Code: Regulation No. 30 (11)(q), 30(12)(d), 30(12)(l)
		Detailed Procedure for evaluating control area wise performance of SRAS, TRAS providers	60 days	Operating Code: Regulation No. 30(13)
		Dynamic reactive power reserve assessment	60 days	Operating Code: Regulation No. 39 (6)
		Detailed procedure for SCED	60 days	Scheduling and Despatch Code: 49(2)(a)(iv)
3.	RLDC	Operating procedure	60 days	Operating Code: Regulation No. 28(4)
		Procedure for operational planning analysis, real-time monitoring, real-time assessments and format for data submission and updating	60 days	Operating Code: Regulation No. 31 (1)(c)
		Restoration Procedure	To be updated every year	Operating Code: Regulation No. 34 (1), 34(2)

S. No.	Entity Responsible	Drafting Responsibilities	Timeline to submit to Commission from date of notification of these regulations	Regulation No.
4.	SLDC	Detailed procedure covering modalities for first time energization and integration of new or modified power system elements	6 months	Connection Code Regulation No. 8(4)
		Operating procedure	6 months	Operating Code: Regulation No. 28(5)
		Procedure for operational planning analysis, real-time monitoring, real-time assessments and format for data submission and updating	6 months	Operating Code: Regulation No. 31 (1)(d)
		Restoration Procedure	To be updated every year	Operating Code: Regulation No. 34 (1)
5.	User	Detailed procedures for restoration post partial and total blackout of user system	To be reviewed and updated every year	Operating Code: Regulation No. 34 (3)

ANNEXURE-6

PROCEDURE SPECIFYING DATA, FORECASTING AND SCHEDULING FOR RENEWABLE ENERGY GENERATING STATIONS (REGS) AT INTER-STATE LEVEL

1. INTRODUCTION

(a) This Procedure contains requirements of data submission by Renewable Energy Generating Station or QCA on behalf of Renewable Energy Generating Station(s), prior to COD and real time and scheduling methodology to be followed for multiple renewable energy generating station(s) connected at a pooling station.

(b) The responsibility to provide forecast and other data and to coordinate with RLDC under this Procedure shall be that of Qualified Coordinating Agency on behalf of all generating stations it is representing.

Provided that where Qualified Coordinating Agency is not identified, individual renewable energy generating station or lead generator, as the case may be, shall be responsible for the same.

2. ROLE OF ENTITIES

(1) **QCA or Renewable Energy Generating Station or Lead Generator**

(a) The individual generating station or Lead Generator shall submit one time details to concerned RLDC as per Appendix-I to this Annexure. Further, if there is any change in the information furnished, then the updated information shall be shared with the concerned RLDC not later than 7 working days of such change.

(b) QCA (for the REGSs it is representing) or REGS (who are not represented through QCA) or Lead Generator shall undertake the following activities:

(i) QCA or Lead Generator (for generating stations it is representing) shall undertake technical coordination amongst the generators it is representing, connected at a pooling station.

(ii) Provide Available Capacity, Day ahead forecast (based on their own forecast or on the forecast done by RLDC) and Schedule as per Appendix-II to this Annexure, through web-based application maintained by RLDCs.

(iii) Provide real time data at turbine/inverter level and generation data at pooling station level as per Appendix-III to this Annexure.

(iv) Provide monthly data:

a. For wind plants- average wind speed, average power generation for 15-min time block for each turbine

b. For solar plants - average solar irradiation, average power generation at 15-min time block level for all inverters* >=1 MW

* if a solar plant uses only smaller string inverters, then data may be provided at the plant level

(v) Be responsible for metering and data collection, transmission and co-ordination with RLDC, SLDC, RPC, CTU and other agencies as per IEGC and extant CERC Regulations.

(vi) Undertake commercial settlement for deviation as per applicable CERC Regulations.

(vii) Submit a copy of the consent to the concerned RLDC wherein it is mentioned that QCA shall undertake all operational and commercial responsibilities on behalf of generating stations as per the CERC Regulations.

(viii) Use Automatic meter reading technologies for transfer, analysis and processing of interface meter data.

(ix) Shall furnish the contract rate(s) along with a copy of the contract(s), for the purpose of Deviation charge account preparation, to respective RPC.

(x) Shall comply the instruction of respective RLDCs in normal operation as well as emergency condition.

(xi) Shall establish protocol for communication with individual generators to implement the instructions of RLDCs effectively.

(xii) Shall maintain records and accounts of the time-block wise Schedules, the Actual generation injected and the deviation, for the polling station and individual generator(s) separately.

(xiii) Shall ensure availability of data telemetry at the turbine/inverter level to the concerned RLDC and shall ensure the correctness of the real-time data and undertake the corrective actions, if required. The suggested data telemetry requirement is enclosed at Appendix-III to this Annexure.

(xiv) Keep each of the RLDCs indemnified at all times and shall undertake to indemnify, defend and save the SLDCs/RLDCs harmless from any and all damages, losses including commercial losses due to forecasting error, claims and actions including those relating to injury to or death of any person or damage to property, demands, suits, recoveries, costs and expenses, court costs, attorney fees, and all other obligations by or to third parties, arising out of or resulting from the transactions undertaken by the Generators.

(2) **RLDC**

(a) The concerned RLDC shall be responsible for scheduling, communication, coordination with QCA or generating station or Lead Generator.

(b) The concerned RLDC will be responsible for processing the interface meter data and computing the net injections at pooling station represented by each QCA or REGS or Lead Generator, as the case may be, as specified in Appendix- IV to this Annexure.

3. FORECASTING

(1) QCA or generating station or Lead Generator shall provide the forecast to the concerned RLDC which may be based on their own forecast or RLDC's forecast as per Appendix-II to this Annexure.

(2) QCA or generating station or Lead Generator may prepare their schedule based on the forecast done by RLDC or their own forecast. Any commercial impact on account of deviation from schedule based on the forecast chosen by the QCA shall be borne by the respective QCA.

4. SCHEDULING AND DESPATCH

(1) Following alternatives exist for Scheduling and Despatch for Generators within Solar / Wind /Hybrid Power parks due to multiple generation developers within the Park injecting at various points with in the park and ultimately injecting at interface with ISTS:

Case-1 QCA has been identified for all generating stations connected at a pooling station.

Case-2 Where QCA at a pooling station is identified for some of the generating stations but not all of generating stations at such pooling station

Case-3 Where QCA at a pooling station is not identified following situations may arise

Case-A: The concerned RLDC shall be responsible for the scheduling, communication, coordination with RE Generators of 50 MW and above and connected to Inter State Transmission System (ISTS).

Case-B: Lead generator shall be responsible for the coordination and communication with RLDC, SLDC, RPC and other agencies for scheduling of RE Generators individually having less than 50 MW, but collectively having an aggregate installed capacity of 50 MW and above and connected within the solar park.

(2) For Case-1, QCA shall be responsible for doing de-pooling of DSM charges as per the mutual agreement between generators and QCA.

(3) For Case- 2 and Case- 3, where scheduling and accounting is to be coordinated by RLDC, a representative sketch showing the scheduling is at Appendix-IV.

(4) The change of QCA would need a notice period of fifteen (15) days and the changeover shall take place with effect from 0000 hours of a Monday, the first day of weekly settlement cycle.

(5) In case of any payment default by the QCA, the generators shall be liable to pay the DSM charges in proportion to their MW capacity.

Appendix-I

Details to be submitted by the Wind/Solar generating stations which are regional entities/ lead generator, principal generator	
Type: Wind/Solar Generator	
Individual / on Behalf of Group of generators	
If on Behalf of Group of generators group of then details of agreement to be attached	
Total Installed Capacity of Generating Station	
Total Number of Units with details	
Physical Address of the RE Generating Station	
Whether any PPA has been signed: (Y/N)	If yes ,then attach details
Connectivity Details	Location/Voltage Level
Metering Details	Meter No. 1. Main 2. Check
Connectivity Diagram	(Please Enclose)
Static data	As per attached sheet
Contact Details of the Nodal Person	Name : Designation : Number: Landline Number, Mobile Number, Fax Number
Contact Details of the Alternate Nodal Person	Name : Designation : Number: Landline Number, Mobile Number, Fax Number

Data to be submitted by the RE Generator / lead generator, principal generator for Wind turbine generating plants

S No	Particulars
1	**Type**
2	Manufacturer
3	Make /Model
4	Capacity
5	COD
6	Hub height
7	Total height
8	RPM range
9	Rated wind speed
Performance Parameters	
11	Rated electrical power at rated wind speed
12	Cut in speed
13	Cut out speed
14	Survival speed (Max wind speed)
15	Ambient temperature for out of operation
16	Ambient temperature for in operation
17	Survival temperature
18	Low Voltage Ride Through (LVRT) setting
19	High Voltage Ride Through (HVRT) setting
20	Lightning strength (KA & in coulombs)
21	Noise power level (db)
22	Rotor

23	Hub type
24	Rotor diameter
25	Number of blades
26	Area swept by blades
27	Rated rotational speed
28	Rotational Direction
29	Coning angle
30	Tilting angle
31	Design tip speed ratio
Blade	
32	Length
33	Diameter
34	Material
35	Twist angle
Generator	
36	Generator Type
37	Generator no of poles
38	Generator speed
39	Winding type
40	Rated Gen.Voltage
41	Rated Gen. frequency
42	Generator current
43	Rated Temperature of generator
44	Generator cooling
45	Generator power factor
46	KW/MW @ Rated Wind speed
47	KW/MW @ peak continuous

48	Frequency Converter
49	Filter generator side
50	Filter grid side
Transformer	
51	Transformer capacity
52	Transformer cooling type
53	Voltage
54	Winding configuration
Weight	
55	Rotor weight
56	Nacelle weight
57	Tower weight
58	**Over speed Protection**
59	**Design Life**
60	**Design Standard**
61	Latitude
62	Longitude
63	COD Details
64	Past Generation History from the COD to the date on which DAS facility provided at RLDC, if applicable
65	Distance above mean sea level

For Solar generating Plants: Static data points:

1. Latitude
2. Longitude
3. Power Curve
4. Elevation and orientation angles of arrays or concentrators
5. The generation capacity of the Generating Facility

6. Distance above mean sea level etc.
7. COD details
8. Rated voltage
9. Details of Type of Mounting: (Tracking Technology If used, single axis or dual axis, auto or manual)
10. Manufacturer and Model (of Important Components, Such as Concentrators, Inverter, Cable, PV Module, Transformer, Cables)
11. DC installed Capacity
12. Module Cell Technology
13. I-V Characteristic of the Module
14. Inverter Rating at different temperature
15. Inverter Efficiency Curve
16. Transformer Capacity & Rating, evacuation voltage, distance form injection point

Appendix-II

Forecast and Schedule Data to be submitted by QCA, generator-wise

FORMAT: A (to be submitted a day in advance)

15 Min time block (96 Block in a day)	TIME	Available Capacity (MW) - Day Ahead	Day Ahead Forecast (MW)	Day Ahead Schedule (MW)
1	00:00-00:15			
2	00:15-00:30			
3	00:30-00:45			
4	00:45-01:00			
.				
94				
95				
96				

Note: The forecast should ideally factor forecasting errors. As such schedule should ordinarily be same as forecast.

FORMAT: B (to be submitted on the day of actual generation, revision of availability and schedule, if any, shall be done as per this Grid Code.

15 Min time block (96 Block in a day)	TIME	Day ahead schedule (MW)	Current Available Capacity (MW)	Revised Schedule (MW)
1	00:00-00:15			
2	00:15-00:30			
3	00:30-00:45			
4	00:45-01:00			
.				
94				
95				
96				

Appendix-III

Real-time Data Telemetry requirement (Suggested List)

Wind turbine generating plants

1. Turbine Generation (MW/MVAR)
2. Wind Speed(meter/second)
3. Generator Status (on/off-line)- this is required for calculation of availability of the WTG
4. Wind Direction (degrees from true north)
5. Voltage(Volt)
6. Ambient air temperature (^{o} C)
7. Barometric pressure (Pascal)
8. Relative humidity(in percent)
9. Air Density (kg/m^3)

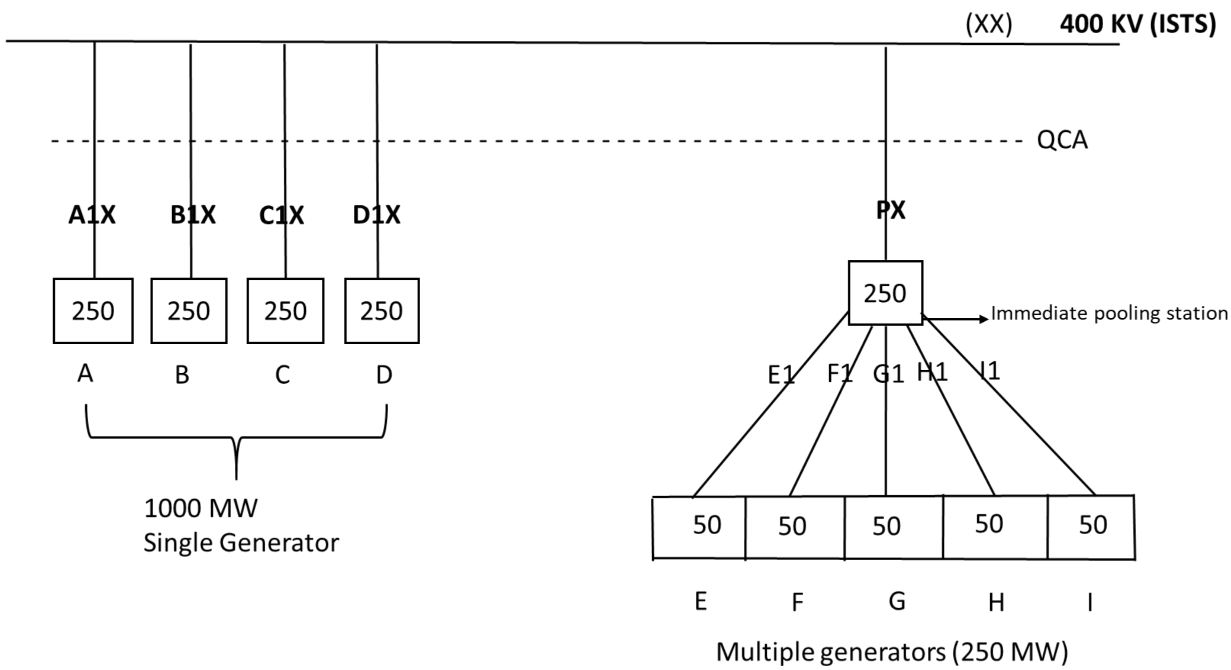
For Solar generating Plant s

1. Solar Generation unit/ Inverter-wise (MW and MVAR)
2. Voltage at interconnection point (Volt)
3. Generator/Inverter Status (on/off-line)
4. Global horizontal irradiance (GHI)- Watt per meter square
5. Ambient temperature (^{o}C)
6. Diffuse Irradiance- Watt per meter square
7. Direct Irradiance- Watt per meter square
8. Sun-rise and sunset timings
9. Cloud cover-(Okta)
10. Rainfall (mm)
11. Relative humidity (%)
12. Performance Ratio

Appendix-IV

Block Diagram showing the case wise Scheduling and Forecasting considering a sample case

Case-I (QCA responsible for all generators):

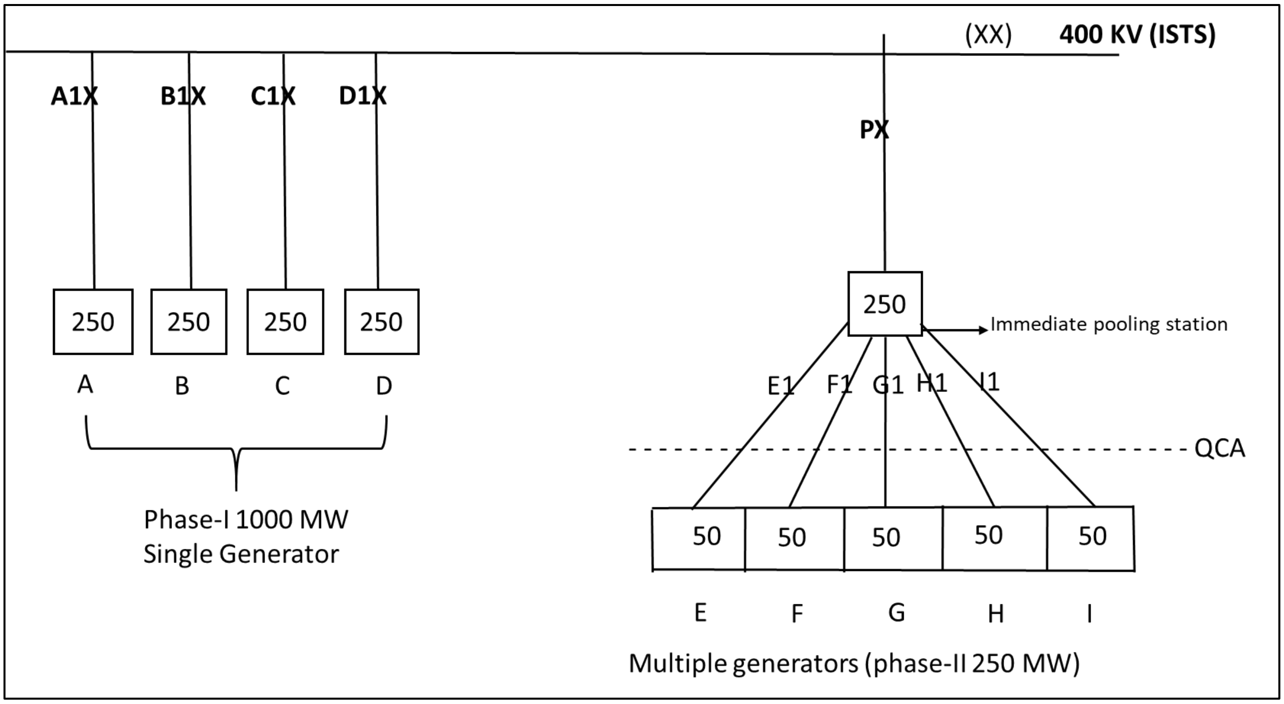


(a) Suppose an REGS of 1000 MW capacity is developed in four blocks namely A,B,C & D of 250 MW capacity each and is directly connected to point A1,B1,C1& D1 respectively at ISTS. Let REGSs of 50 MW each aggregating to 250 MW (5 Nos. namely E, F, G, H & I) be connected to intermediate pooling station. REGSs are connected to interface point E1, F1, G1, H1& I1 and thereby connected to ISTS at XX point.

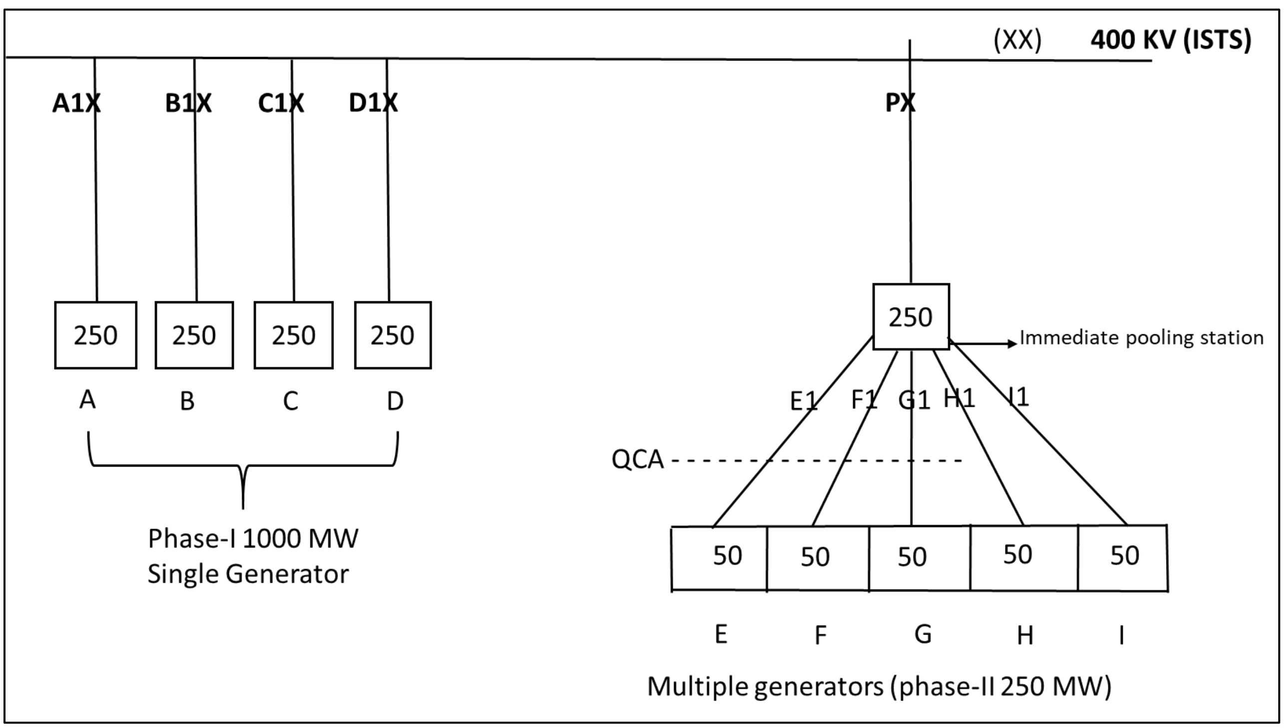
(b) Suppose all the REGSs have mutually agreed to appoint a QCA for all scheduling and forecasting activities, such QCA, shall be responsible for carrying out activities as assigned under this Code.

Case-2 (QCA responsible for some of the generators):

A. QCA is responsible for all REGS connected at Intermediate pooling station

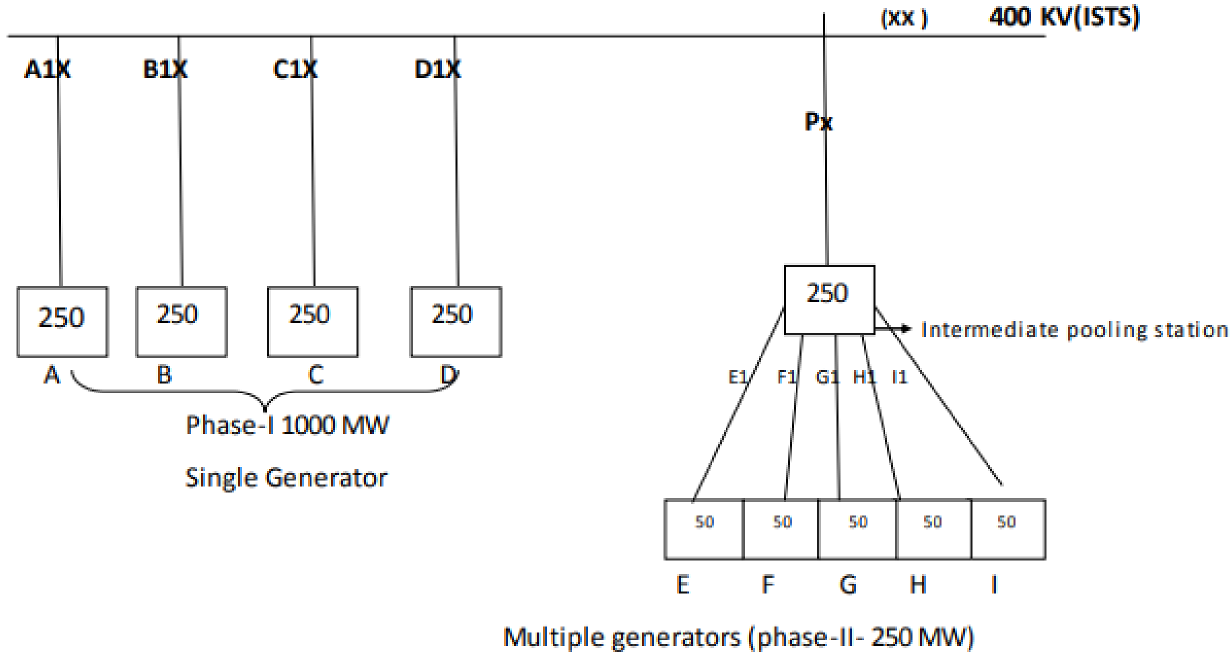


B. QCA responsible for some REGS connected at Intermediate pooling station



In each of the above scenarios, the QCA shall be responsible for coordination of scheduling and de-pooling of DSM charges for all those REGS that mutually agreed to appoint a QCA. The other REGS shall be required to submit their schedule as well as be liable to pay their DSM charges.

Case-3: 50 MW and above (Phase-I &II)



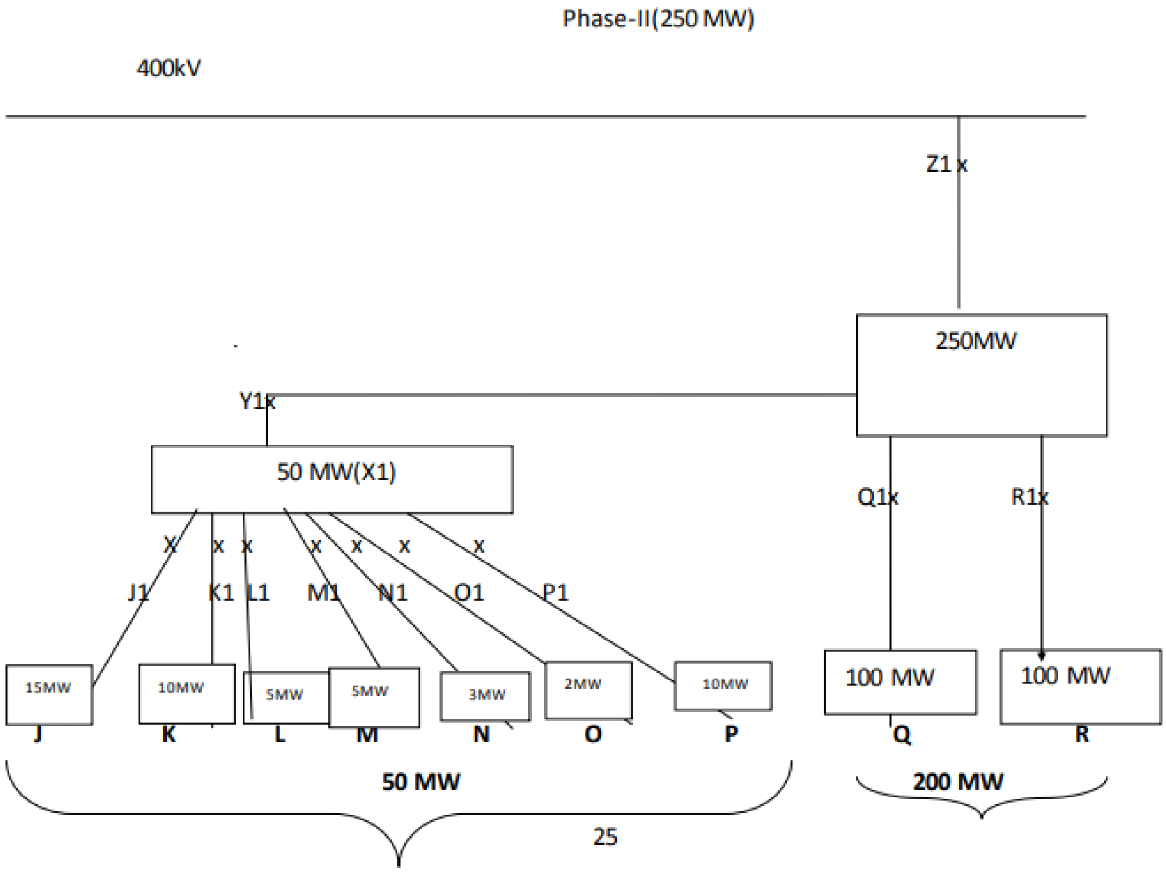
Phase-I – 1000 MW,

A single generator of 1000 MW capacity is developing the generating station in phase-1 in four blocks namely A,B,C & D of 250 MW capacity each and is directly connected to point A1,B1,C1& D1 respectively at ISTS. At the interface point scheduling and forecasting shall be done by RLDC.

Phase-II- 500 MW (Separate Generator/Entities)

(a) Let multiple REGS of 50 MW each aggregating to 250 MW (5 Nos. Multiple Generator of 50 Mw each (as separate entities), be connected to inter mediate pooling stations.
(b) REGS namely E, F, G, H & I each having the capacity of 50 MW each are connected to interface point E1, F1, G1, H1& I1 and thereby connected to ISTS at XX point.
(c) In such a case, scheduling, accounting, forecasting for these generators needs to be segregated at point E1, F1,G1, H1, I1. Scheduling shall be done at point P and shall be segregated at E1,F1,G1,H1,I1 by RLDC.
(d) Further there may be case where multiple generators less than 50MW (<50MW) capacity are connected to the intermediate pooling station are stated as under:-

Case-II Below 50 MW



(e) Let us consider, multiple REGS (namely J,K,L,M,N,O&P) collectively having an aggregate installed capacity of 50 MW or more and are represented through a Lead Generator. Further REGS Q & R each of 100 MW are connected at Q1 & R1. All these REGS are connected to ISTS at point Z1.

(f) Scheduling and forecasting for the REGSs J,K,L,M,N,O& P shall be done at Point Z1, but need to segregated at Point J1, K1,L1, M1, N1,O1& P1 and for REGSs Q & R needs to be segregated at Q1 and R1. In this case, RLDC shall schedule at point Z1 and segregate at Y1,Q1& R1 . The lead generator shall provide aggregated schedule to RLDC at Y1. Further the lead generator shall do segregation of schedules and other operational & commercial activities for generators J,K,L,M,N,O,P at points J1, K1,L1, M1, N1,O1& P1.

ANNEXURE- 7

ACCOUNTING AND POOL SETTLEMENT SYSTEM

(1) METERING, ACCOUNTING AND SETTLEMENT SYSTEM:

(a) At the Inter State Transmission System (ISTS) level, the basic principle followed is that all settlements for the energy scheduled before the fact are done directly between the sellers and the buyers , with the Regional Power Committee issuing the Accounts specifying the quantum of energy scheduled. All deviations from the schedule are settled through a regulatory Pool Account maintained by RLDCs where only the deviation payments are handled.

(b) The settlement system shall be transparent, robust, scale-able (multi buyer/seller, inter connection with lower and upper pool systems) and dispute-free with integrity and probity and usage of state of the art techniques. The settlement computation details, applicable charges and operation of different regulatory Pool Accounts shall be in accordance with various regulations of the Commission. RPCs shall standardise the formats of various accounts.

(c) The Implemented Schedule incorporating all before-the-fact changes in schedule shall be used as a reference for energy accounting.

(d) Energy Accounts inter-alia shall indicate Declared Capability of generating stations, Entitlements, Requisitions, Scheduled loss, Scheduled transactions GNA and T-GNA and actual Interchange, Reactive Power Accounts, SCED scheduled energy and any other accounts to be issued under CERC Regulations.

(e) Assumptions, if any, in the accounts shall be clearly stated in Notes to the Accounts.

(f) Each regional entity (whether generator, RE Generator, QCA (on behalf of generators), captive Power Plant, OA customer connected at ISTS) in a region shall be a member of the regional pool and separately accountable for deviations. For cross border transactions, the Settlement Nodal Agency (SNA) as appointed by the Government of India would be a member of the regional pool.

NSC REPORT

Basic Information

Ref Number	NSC/REP/2024/APR/33	**Report Date**	02.05.2024
Customer	Steag Energy services India Ptv Ltd	**Region**	Kolkata
End User	ONGC Tripura Power		
Product	Flow	**Commercial**	Chargeable
Order Code	83F1F-AACSAACABDBRZ1	**Serial Number**	D8032E20000
Remarks:	-		

Testing:

1 While performing visual inspection , observed flowmeter unclean condition , dark spot on display module.

2 Flowmeter found to be Powering ON with rated Power supply

3 TUBE NOT OSC. Errors observed on display module . (spare display used for checking purpose)

OPERATION

Parameter	Value
ACTUAL SYS.COND	TUBE NOT OSC.
PREV.SYS.COND	TUBE NOT OSC.

4 Further testing , opened sensor compartment to measure the pickup & excitation coil resistance found sensor **pickupTT (PT1000 carrier tube) is open**

Testpoints Measuring values

S1+S1-	8.6 ohms
S2+S2-	8.5 ohms
Tm+Tt-	1.1 Kohms
Tc+Tt	1.1 Kohms
E Excitation coil	**Open**

Reference to above test points sensor found defective

Conclusion

E Excitation coil found open of the flowmeter , sensor is defective

Sensor not available as spare ,Complete Flowmeter needs to be replaced .

Promass 83 Model is currently phase out . Succesor model quote will be provided from our E+H Kolkata office.

Service charges :

	Work Description	SAC Code	Description	Qty
1	XD99WS	998717	Daignosis Charges : INR:20,000 + 18% GST	1 No.

Tested by Kunal Nanaware

E+H NSC Engineer: Sarthak Patil

ONGC-Tripura Power Company (P) Ltd.

ONGC TRIPURA POWER COMPANY LIMITED
Palatana, Tripura

RCA# 157
Unit-2 Tripping due to UPS -1 & 2 failure on 25-07-2024

O&M by: Steag

00	20-12-2023	IFI	Issued for Implementation	Steag	Bharat N Vegda Plant Manager STEAG	Prabhat Chandra HEAD(O&M) OTPC
REV	DATE	STATUS	REVISION LIST	PREPARED BY	REVIEWED & APPROVED BY	VERIFIED BY

IR/24-25/25-07-2024/157

RCA COMMITTEE MEMBERS/CONCERNED DEPARTMENTS	
OTPC	STEAG

DEPARTMENT	NAME	SIGNATURE	DEPARTMENT	NAME	SIGNATURE
OPERATION	S. Choudhury		OPERATION	G.T. Rao	
MECHANICAL	B. SARKAR		MECHANICAL	R. Bhadra	
ELECTRICAL	N. K. Gupta		ELECTRICAL	DARSHIT	
C & I	M. MUSA	25/9/24	C & I	D.DEBBARMA	
TECH. CELL	for Arindam Mondal	07/10/24	TECH. CELL	KRISHNA	

Incident No	IR/2024-25//**25-07-2024/157**
Date of incident	25-07-2024

Incident:
Unit-2 UPS-1 & UPS-2 output supply failed which has resulted in Unit-2 trip and Unit-1 run back.

Time Of occurrence	**14:38 Hrs(25/07/2024)**
Time Of Restoration	**21:26 Hrs (27/07/2024)**
Generation Loss	3.3969 MU
GT-2 Coasting Down Time	Not available due to unavailability of data
ST-2 Coasting Down Time	Not available due to unavailability of data

Status before Incident:
GTG-1: 130 MW and STG-1 94MW.
GTG-2: 130 MW and STG-2 94MW.
GBC-1 and GBC-3 were in service with control system in auto.
Unit-2 UPS status:
UPS-1 input voltage/input current: 427 V/38A; Output voltage/output current: 240V /62A and frequency: 50.02 Hz.
UPS-2 input voltage/input current: 425 V/37A; Output voltage/output current: 240V /64A and frequency: 50.02 Hz.

Incident Description:

- **14:00:01 hrs**: UPS-2 system failed. (as per UPS-2 voltage trend showing bad value).
- **14:38:36 hrs**: UPS-1 system failed . (as per UPS-1 voltage trend showing bad value).
- Due to the failure of both UPS-1&2, ACDB panel got dead, leading to failure of mark-VIe and max-DNA DCS panel power supply and more-over all HMIs of unit-2 CCR workstation PC got OFF.
- **14:39:20 hrs**.: Both GTG-2 and STG-2 400KV main & tie circuit breakers tripped. EPB pressed as Unit-2 all screens were black & status of Unit-2 was completely unknown due to complete control supply failure. (GTG GR1 HVCB Open time 14:37:23 hrs and STG GR1 HVCB open time 14:37:34 hrs, Relay time synchronization to be done as found discrepancy)

Unit-1 Side: -

- As Unit-2 DMCW pump got trip, both IAC-1 and IAC-2 tripped due to low cooling water supply pressure. Later cooling water supply to IAC was lined up from Unit-1 DMCW system and both IACs taken into service at **14:56 hrs**. Instrument air pressure was found dropped up to 2.98 ksc.
- As GBC PMCC control supply power was lined up from Unit-2 UPS -ACDB (F141 MCB), GBC PMCC all auxiliary drives got tripped & both running GBCs also tripped on lube oil pressure low.
- GT-1 run back started on gas pressure low protection.
- GT-1 UAT to ST Fast bus transfer was done manually @ GT-1 Load of 40 MW. GT-1 Load was gradually dropped due to insufficient gas header pressure as both GBC got trip.
- GTG-1 load came down to **1 MW &** STG-1 at 46 MW.
- GBC PMCC control supply charged from unit-1 GT PMCC and GBC-3 started at **15:03 hrs,** unit-1

load increased gradually up to base Load.

Unit-2 Side: -

- After unit-2 Trip, UAT to ST fast bus transfer was not successful and hence 6.6 KV bus power supply failed.
- Both GT PMCC and ST PMCC sections become dead.
- EDG-2 came in service in auto, but GTG PMCC and STG PMCC emergency section did not charge in auto due to failure of Max DNA. GT & ST PMCC emergency breaker charged with EDG-2.
- Unit-2 all HT and LT drives got trip, including AC lube oil and jacking oil drives.
- In local, GT-2 DC JOP 88JE-2 not came in service due to lube oil discharge pressure feed back not received at motor feeder from mark vie panel as power supply to Mark-VIe got OFF, later by looping at motor feeder same was started from local push button.
- As CW pump and vacuum pump got tripped, LP turbine rupture disc got damaged on high pressure.
- In 2CA & 2CB board, both UAT breakers were found in closed condition & same were tripped manually by emergency pull lever at breaker end.
- **16:04 hrs:** Unit-2 6.6 KV bus 2CA & 2CB board tie breakers charged by looping and restored all AC system. Later STGPMCC and GTPMCC power system restored.
- As Mark-VIe power supply was not available, GT AC lube oil pump-1 (QA) & Turning gear motor (88TG) started by looping, HQ pump-2, JA-1 pump started manually from Feeder end.
- At **16:30 hrs:** Mark-VIe panel power supply charged from 125 V DCDB and external AC supply provided to lift oil 20QB solenoid valve.
- At **17:49 hrs:** GT-2 turning gear established.
- And STG-2 turning gear was stopped same was made normal with DC drives, later AC lube oil and jacking oil started after MAX-DNA power system got normal and stopped DC drives.
- At **17:10 hrs**. UPS-1 & 2 manual bypass switch taken into service by hard looping and ACDB board charged.
- At **17:50 hrs**: MAX-DNA DCS panel power system charged.
- After the normalization of MAX-DNA DCS, cooling water system, DMCW water system, CEP, HPBFP, AC lube oil system etc. were started one by one.
- Permit issued to EMD for UPS-1 and UPS-2 inspection in presence of UPS service engineers.

Note: As there was no power supply, in Unit-2 Work stations, MAX-DNA and Mark-VIe panel, no trends and SOEs are available till ACDB power restoration.

Action Taken:

- Hirel UPS service engineer was immediately called by M/s Steag to restore UPS as early as possible.

• Both UPS were checked by service engineer and following observations were reported by him. UPS-1 having failure of electronic cards mainly name as User I/F Card HRD-255 "H11", System Control Card (inverter control card) HRD-253 "H7", Control SMPS card HRD-238 "H8" and Display mimic card HRD 326. • UPS-2 having failure of electronic component cards mainly name as User I/F Card HRD-255 "H11", System Control Card (inverter control card)HRD-253 "H7", SSW(Static Switch) Driver Card HRD-334 "H17", RJ45 LAN Cable, 14 Pin FRC Ribbon cable with connector and 26 Pin FRC Ribbon cable with connector.
Relays flagged : • UPS-1 front HMI display was not working, hence defect was not known at the time of incident. • UPS-2 front HMI display static switch indication was not glowing and following alarms were appeared on display. a)NO:01 SC CAN1 FAIL {System control card communication fail}. b)NO:02 PRC CAN FAIL {Parallel communication to control card Fail} c)NO:03 ALT SSW ERROR {Alternate Supply Static Switch Error} d)NO:04 INV SSW ERROR { Inverter Supply Static Switch Error} First Active alarm is SC Can1 Fail and then other alarms appeared.
Nil
Alarms Annunciated: As per attachment from Mark VIe & MAX DNA SOE.
Reference to Incident & repetition if any

Detailed Incident Information, Observation & Rectification:

Following rectification activities carried out by Hirel:

1) UPS-2 Display card removed and installed at UPS-1 to check defect for UPS-1 (as UPS-1 display card was not working and problem could not be identified)

2) Old Spare SMPS power card replaced in UPS1 as found defective.

3) New Spare control card from store taken and replaced in UPS-1 but it was not working due to older version (7.0) instead of required version (17.0). Unit-1 UPS card version was also checked for its suitability but Unit-1 UPS-1 and UPS-2 having version of 7.0 and were not suitable for Unit-2 UPS. (Unit-1 was in running condition and its UPS system was healthy)

4) Various combinations were checked by OEM service engineer to make One of UPS available but could not succeeded.

5) At OTPC store, one inverter control card spare (Version 7.0) was available in store but it was not suitable for unit-2 UPS system, suitable cards version 17.0 spares are not available for further rectification

work. Rectifications of UPS were not possible due to non availability of System Control card (Inverter control card) and Display cards, hence, OTPC placed verbal order to Hirel to supply these cards from Gandhinagar (Gujarat) as well as from Dibrugarh (Assam) on 27 and 26 July 24 on urgent basis.

6) M/s Hitachi (Hi-rel) is OEM and both UPS is under AMC of OEM and the issue of difference in inverter control card version was never pointed out by OEM Service Engineer nor recommended to keep important card as spare. Upon failure of UPS on 25.07.2024 the service engineer pointed out regarding difference in version of inverter control card in U -1 and 2 UPS. Also at the same time, service engineer and senior officials of OEM informed about obsolescence of existing series 17 cards and need for upgradation of UPS of Unit-1&2. To restore Unit-2 as soon as possible OTPC placed verbal order to Hirel to supply these cards from Gandhinagar (Gujarat) as well as from Dibrugarh (Assam) on 27 and 26 august 24 on urgent basis.

7) On 26th July 2024: At 22:00 Hrs, 02 set of control card and Display card were received from Dibrugarh. Out of 02 main control card, only one control card was working, but PRC can Fail alarm was persisting and could not be rectified. Hence they suggested to try with other cards which are supposed to come on next day morning from Gandhinagar.

8) On 27th July 2024: At 10:00 hrs, another 02 set of control card and display cards were received at site.

9) After replacement of following cards for UPS-1 and UPS-2 respectively, system made available at 18:30 hrs (27/07/2024). (Service Report attached herewith for reference)

UPS-1 Cards Replaced:

1) HRD-255 User I/F Card "H11" (Display Card)

2) HRD-253 System Control Card (inverter control card) "H7"

3) HRD-238 SMPS for Control card "H8" faulty (Reason of UPS fail)

4) HRD 326 Display mimic card.

UPS-2 Cards Replaced:

1) HRD-255 User I/F Card "H11" (Display Card)

2) HRD-253System Control Card (inverter control card) "H7"

3) HRD-334 SSW Driver Card ""H17" card faulty (Reason for UPS fail)

4) RJ45 LAN Cable

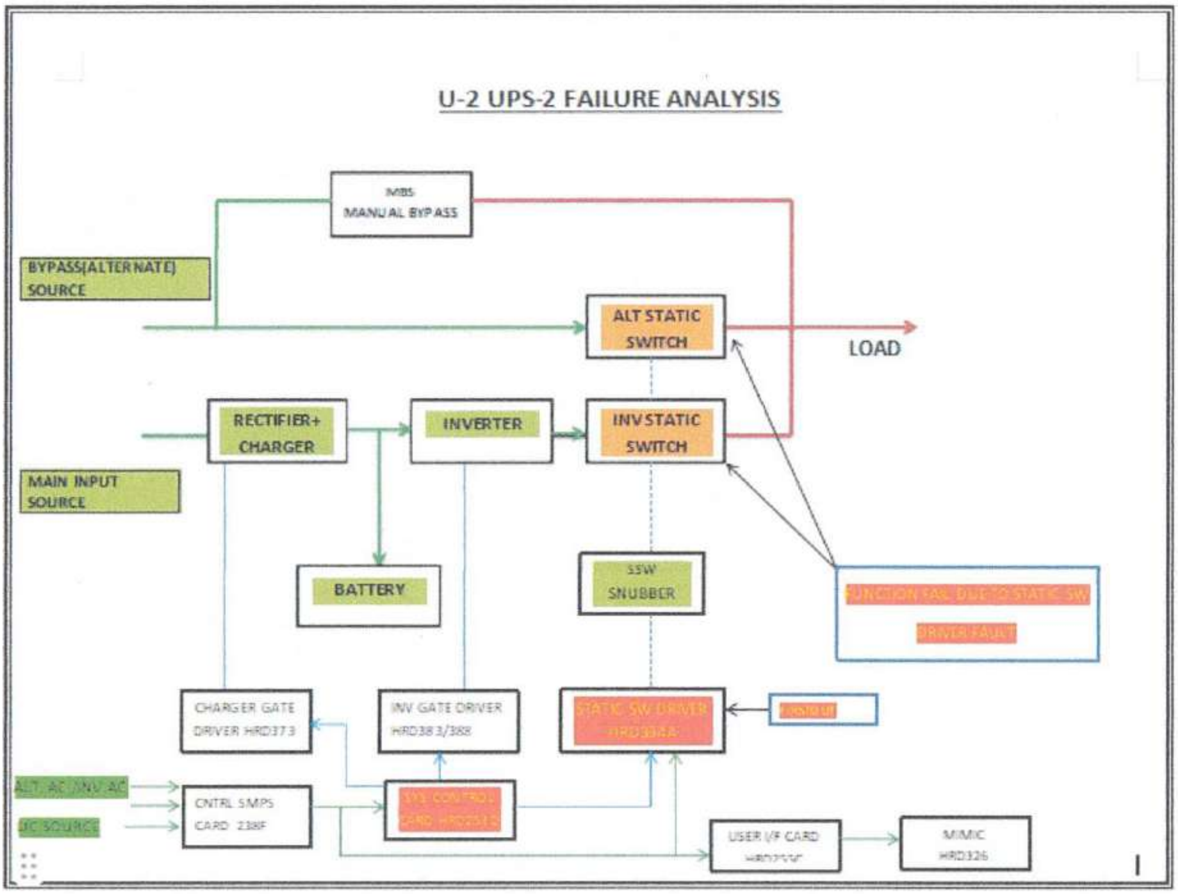
5) 14Pin FRC Ribbon cable with connector

6) 26Pin FRC Ribbon cable with connector.

Note: All defectives cards have been send to OEM for failure analysis.

ROOT CAUSE ANALYSIS:

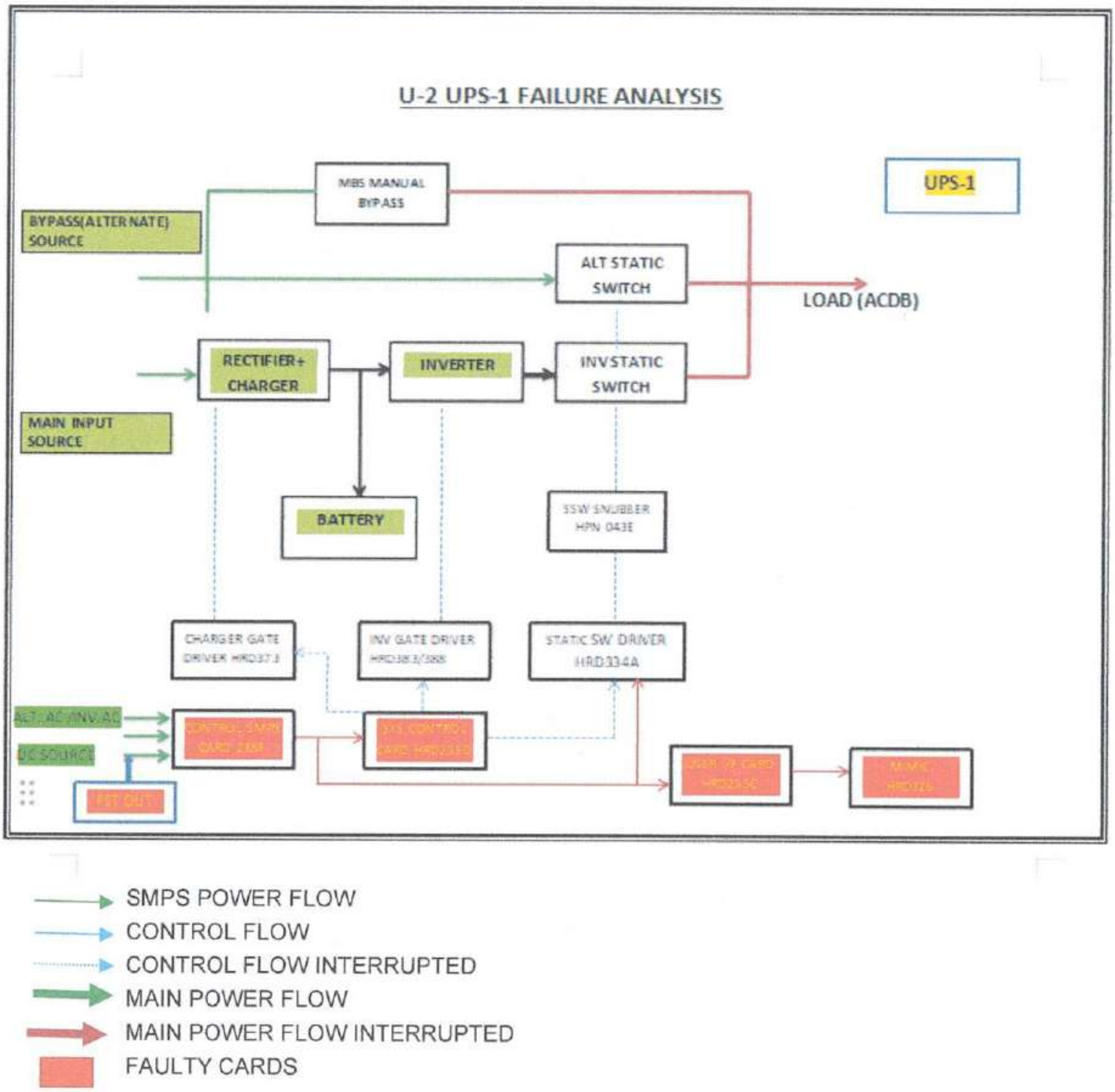
Analysis 1st phase: "Why" possibilities considered, improbable options eliminated, and probable options identified



SMPS POWER FLOW
CONTROL FLOW
CONTROL FLOW INTERRUPTED
MAIN POWER FLOW
MAIN POWER FLOW INTERRUPTED
FAULTY CARDS

ROOT CAUSE ANALYSIS:

1. UPS-2 SSW (Static Switch) Driver card (HRD334A) first failed causes functional failure of alternate source and inverter source.
2. Failure of Static Switch Driver cards leads to UPS-2 output failure. Though inverter section of UPS-2 was healthy, automatic bypass supply and battery back up did not came in service due to failure of static switch driver card hence UPS-2 output became zero.
3. Hence UPS-2 Load was shifted to UPS-1.



1. UPS-1 SMPS Card was failed which is supplying auxiliary power to system control card (inverter driver card), Display mimic card , User interface card and Static switch driver card resulting failure of UPS-1.
2. UPS-1&2 failures leads to power loss at ACDB-1 & 2 and hence Mark VIe, MAX DNA DCS, ECP, and all GBC auxiliary control supply interrupted.
3. As all 6.6 KV Breakers signals and commands passes through DCS & ECP, Unit-2 UAT-1 & 2 down stream switch boards (2CA & 2CB), Breakers (6.6 KV and 415V) were not operated after GT-2 & STG-2 Trip.

UPS IMPORTANT CARDS FUNCTIONAL DETAILS:

SL. NO.	CARD NAME	CARD CODE	FUNCTION
1	SMPS FOR CONTROL CARD	HRD 238F	CONTROL SUPPLY TO SYS.CONTROL CARD (HRD253D), USER I/F) CARD (HRD255C)., INVERTER GATE DRIVER CARD (HRD388)
2	SYSTEM. CONTROL CARD	HRD253D	MAIN SYSTEM CONTROL CARD WHICH INTERFACES WITH INVERTER GATE DRIVER (HRD383 & HRD388), STATIC SWITCH DRIVER CARD (HRD334A), USER I/F CARD (HRD255C),
3	USER INTERFACE CARD	HRD255C	USER INTERFACE
4	MIMIC DISPLAY	HRD326	DISPLAY
5	STATIC SWITCH DRIVER CARD	HRD334A	STATIC SW CONTROL FOR SSW OF INV. & ALT) AND SSW SNUBBER (HPN043E).
6	INV GATE DRIVER CARD	HRD 383/388	INV. GATE CONTROL
7	INV PSFB (INVERTER POWER SUPPLY FEEDBACK)	HRD-260B	INVERTER POWER SUPPLY FEEDBACK TO SYSTEM CONTROL CARD (HRD253D).
8	INV. GATE DRIVER SMPS CARD	HRD 319D	POWER SUPPLY FOR INVERTER GATE DRIVER CARD (HRD 383/388)
9	SWITCHER CARD	HRD 290B	ALT SUPPLY FEEDBACK TO SYSTEM CONTROL CARD HRD 253D
10	SNUBBER CARD	HPN 043E	SNUBBER TO INVERTER. INTERFACE BETWEEN STATIC SWITCHES AND STATIC SWITCH DRIVER CARD (HRD 334A)
11	CHARGER CONTROL CARD	HRD 371	MAIN CHARGER CONTROL CARD INTERFACE WITH CHARGER GATE DRIVER (HRD 373), UPS-2 CHARGER CONTROL CARD AND CHARGER PSFB (HRD 372A) CARD
12	CHARGER GATE DRIVER CARD	HRD 373	RECTIFIER GATE CONTROL
13	CHARGER PSFB	HRD 372A	CHARGER POWER SUPPLY FEEDBACK TO CHARGER CONTROL CARD HRD 371
14	CHARGER POWER SUPPLY CARD	HRD 290B	POWER SUPPLY FOR MAIN CHARGER CONTROL CARD (HRD 371)
15	I/O CARD	HRD 256A	POTENTIAL FREE CONTACTS FOR ALARMS

Dealing With Alarms:

Alarms are messages indicating an abnormal functioning of the UPS. These messages are displayed on the front panel LCD screen both visually and with an audio buzzer. These alarms are alerted to the user in the following three modes, simultaneously:

- Text readout on the front panel LCD screen
- By a red flashing visual LED
- By an audio buzzer (which has an auto reset of 10 SECONDS)

Following is the list of alarms along with the cause that has triggered the alarm:

ALARMS LIST

Sr. No.	Alarm Name	Probable Cause	Action
1	SC SUPPLY FAIL	1. SC Power supply failed 2. SC Power supply output shorted/overloaded 3. SC Power supply input is not present 4. SC Power supply fuse is blown	1. Call for service support if problem persist
2	INV OVER LD T SC	1. Inverter tripped due to overload	1. Remove excess load. 2. After 20 minutes inverter will start automatically if unsuccessful – Call for service support.
3	INV CL ACTIVE	1. The inverter output is overloaded by 150% of nominal full load current.	1. Remove excess load IMMEDIATELY or the inverter may trip.
4	INV SAT TRIP	1. The inverter output was severely overloaded. 2. SMPS for gate drive is faulty or fail. 3. Cooling FAN failure	1. Check load side for overload /short circuit – Remove fault. 2. Press Reset Key to clear the SAT TRIP alarm. After clearing the SAT TRIP alarm, try to start inverter. 3. Try starting the inverter & if unsuccessful – Call for service support.
5	LOW BATTERY	1. Reserve (battery) power has been nearly exhausted.	1. You only have few minutes of battery backup left.
	LOW BATTERY TRIP	1. Reserve (battery) power has been exhausted	1. Wait till mains resume and 2. Battery to charge.
7	INV OVER TEMP	1. Cooling fan failure. 2. Excess load. 3. Ambient temperature above specified limits.	1. Reduce load & try to start the unit – if unsuccessful – Call for service support. 2. Measure the ambient temperature at approximately 1mt from the unit – if found in excess of specified limits – take actions to reduce it (room ventilation, a/c, etc.) – wait for approximately 20 min. to allow

			cooling & try to start the unit – if unsuccessful – Call for service support.
8	PRC SUPPLY FAIL	1. PRC Power supply failed 2. PRC Power supply output shorted/overloaded 3. PRC Power supply input is not present 4. PRC Power supply fuse is blown	1. Call for service support if problem persist
9	SC CAN1 FAIL	1. CAN communication between SC-PRC is fail	1. Call for service support if problem persist
10	STOP COMMAND	1. Stop command is Activated to inverter	***
11	INV LOW	1. Inverter is stop or trip 2. Adjustment/Calibration Error	1. Check the trip conditions if inverter is trip. 2. Check the adjustment for Inverter low & inverter voltage reference. 3. Call for service support if condition persists.
12	INV HIGH	1. Inverter control problem 2. Adjustment/Calibration Error	1. Check the adjustment for Inverter high & inverter voltage reference. 2. Call for service support if condition persists.
13	ALT LOW	1. Alternate supply low/absent. 2. Adjustment/Calibration Error	1. Check the Alt low adjustment 2. Measure actual value with a MULTIMETER & if found to be in specified limits – Call for service support.
14	ALT HIGH	1. Alternate supply High. 2. Adjustment/Calibration Error.	1. 1. Check the Alt high adjustment 2. Measure actual value with a MULTIMETER & if found to be in specified limits – Call for service support
15	ALT FO	1. Alternate supply problem. 2. Adjustment error	1. Check the alternate supply. 2. Check the adjustment for the frequency tolerance if alternate supply is found OK. 3. Call for the service support if problem persists.
16	MIS OFF	1. MIS switch is Off 2. MIS contact not sensed by the SC/PRC card.	1. Check the MIS contact connections if alarm is present even after MIS is ON. 2. Call for the service support if problem persists.
17	MANUAL TRANSFER	1. Manual transfer command is ON.	1. When it is not required make it OFF otherwise if bypass source is not present or unhealthy there will be no output supply available.
18	NO SYNC	1. Inverter o/p is not synchronized	1. If bypass is present then after some

		with alternate or bypass source	time this alarm will be removed.
9	SC SUPPLY FAIL	1. SC Power supply failed 2. SC Power supply output shorted/overloaded 3. SC Power supply input is not present 4. SC Power supply fuse is blown	1. Call for service support if problem persist
20	OUTPUT UNDER V	1. Static switch i1.11. Inverter/Alternate supply not available 2. Fault in static switch 3. Adjustment/ Calibration error	1. Check the trip conditions for inverter. 2. Check the adjustment value for Output Low. 3. Call for service supports. If condition persist.
21	OUTPUT OVER V	1. Inverter/Alterna11. Inverter/Alternate problem output high voltage 2. Adjustment/ Calibration error	1. Check the trip conditions for inverter. 2. Check the adjustment value for Output Low. 3. Call for service supports. If condition persist.
22	OVER LOAD	1. The inverter output is overloaded.	1. Remove excess load IMMEDIATELY. If Alt source is not healthy and load is on inverter then inverter will trip after predefine time and output will also trip.
22	INV OVER LD TRIP	1. The inverter tripped due to overload.	1. Remove excess load. 2. After 20 minutes inverter will start automatically if unsuccessful – Call for service support.
23	LOAD ON BYPASS	1. Inverter is stopped or tripped. 2. Manual transfer to bypass.	1. Check the conditions for inverter trip. 2. Call for the service support if problem persists.
24	ALT SSW ERROR	1. Alternate static switch is faulty.	1. If problem persist call for service support
25	INV SSW ERROR	1. Inverter static switch is faulty.	1. If problem persist call for service support
26	PRC SUPPLY FAIL	1. PRC Power supply failed 2. PRC Power supply output shorted/overloaded 3. PRC Power supply input is not present 4. PRC Power supply fuse is blown	1. Call for service support if problem persist
27	MAINS HIGH	1. Mains supply problem 2. Adjustment /Calibration parameter error	1. Measure actual value of mains input supply with a multi-meter & if found to be in specified limits. 2. Check the mains high adjustment. 3. Call for service support if both of above points found OK.
28	MAINS LOW	1. Mains supply problem	1. Measure actual value of mains input

		2. Adjustment /Calibration parameter error	supply with a multi-meter & if found to be in specified limits. 2. Check the mains high adjustment. 3. Call for service support if both of above points found OK.
29	MANUAL BOOST	1. Manual boost mode is present.	***
30	HIGH DC SHUTDOWN	1. Charger control problem.	1. If condition persist call for service support. 2.
31	BAT MCCB OFF CHG	1. Battery MCCB is OFF. 2. Failure in sensing the contact of Battery MCCB by the charger control card.	1. Check the Battery MCCB contact connections to charger control card if alarm is present even after Battery MCCB is ON. 2. Call for service support if problem persists.
32	CHG OVER TEMP	1. Cooling fan failure. 2. Excess load. 3. Ambient temperature above specified limits	1. Call for service support. 2. Reduce load & try to start the unit – if unsuccessful – Call for service support. 3. Measure the ambient temperature at approx 1mt from the unit – if found in excess of specified limits – take actions to reduce it (room ventilation, a/c, etc.) – wait for approximately 20 min. to allow cooling & try to start the unit – if unsuccessful – Call for service support.
33	SC COMM FAIL	1. Serial communication between UI & SC is failed. 2. Loose connections in RS485 communication bus.	1. Check the RS485 bus Connections 2. Call for the service support if problem persists.
34	PRC COM M FAIL	1. Serial communication between UI & PRC is failed. 2. Loose connections in RS485 communication bus.	1. Check the RS485 bus Connections 2. Call for the service support if problem persists.
35	CHG COMM FAIL	1. Serial communication between UI & Charger is failed. 2. Loose connections in RS485 communication bus.	1. Check the RS485 bus Connections 2. Call for the service support if problem persists.
36	MAINS FAIL	1. Mains input supply is not present 2. Failure of Logic supply of UI	1. Check mains input supply. 2. If alarm is present even after mains supply is present check logic supply of UI.
37	BAT DISCHARGE	1. Battery is discharging due to absence of mains input supply or charger trip.	1. Check mains input supply. 2. Check the charger trip condition if mains input supply is available.
38	DC GROUND	1. Earth fault on DC BUS	1. Call for the service support if Problem persists.

39	BATT MCCB OFF UI	1. Battery MCCB is OFF. 2. Failure in sensing the contact of Battery MCCB by the UI card.	1. Check the Battery MCCB contact connections to UI card if alarm is present even after Battery MCCB is ON. 2. Call for service support if problem persists.
40	INV HIGH DC	1. Inverter trip due to inverter input DC voltage > Predefined reference.	1. Monitor the charger DC voltage in LCD. Try to restart the inverter through RESET and ON keys if DC Voltage < Predefined reference. 2. Call for the service support if problem persists.
41	STANDBY UPS FO	1. Reference frequency from the SC/PRC card of another UPS is not received in PR mode.	1. Check the fiber connections between SC/PRC cards of two UPS. 2. Call for the service support if problem persists.
42	OUTPUT FO	1. Output frequency out of tolerance band.	1. Check the bypass frequency is within tolerance band or not. 2. Call for the service support if bypass frequency is within range.
43	UPS IS STANDALONE	1. Failure in receiving the PMI signal from the SC/PRC card of another UPS in PR mode.	1. Check the PMI connections between SC/PRC cards of two UPS. 2. Call for the service support if problem persists.
44	PRC CAN FAIL	1. Failure in receiving data on CAN bus from PRC section of SC/PRC card of another UPS in PR mode.	1. Check the CAN connections between SC/PRC cards of two UPS. 2. Call for the service support if problem persists.
45	I/P PHASE OUT	1. Failure of input phase. 2. Failure of input sensing control fuse.	1. Check the mains supply. 2. Call for the service support if problem persists.
46	CHG PMI FAIL	1. Failure in receiving the PMI signal from the charger card of another UPS in PR mode only.	1. Check the PMI connections between charger cards of two UPS. 2. Call for the service support if problem persists.
47	MAINS FREQ O TOL	1. Mains frequency is out of tolerance.	1. Check the mains supply. 2. Call for the service support if problem persists.
48	SC CAN2 FAIL	1. CAN communication failure generated during PR mode.	1. Call for the service support if problem persists.
49	SSW OT	1. Cooling fan failure. 2. Excess load. 3. Ambient temperature above specified limits.	1. Reduce load & try to start the unit – if unsuccessful – Call for service support. 2. Measure the ambient temperature at approximately 1mt from the unit – if found in excess of specified limits – take actions to reduce it (room ventilation, a/c, etc.) – wait for

			approximately 20 min. to allow cooling & try to start the unit – if unsuccessful – Call for service support.
50	MBS ON	1. Manual Bypass Switch operated	***
51	CHG CAN FAIL	1. CAN communication failure between charger control cards, generated in PR mode only.	1. Call for the service support if problem persists.
52	SYS ON BATT	1. Battery in discharging mode	1. Battery discharging due to charger off
53	POWER DEMAND		
54	BAT LIQ LOW LEVL		
55	ABNORM ROOM TEMP		
56	EQUALIZE CHG DIS		
57	ABNOR BAT TEMP		
58	GENERATOR OP		
59	DISABLE		
60	REMOTE START		
61	REMOTE STOP		
62	REMOTE MUTE		
63	ASYNC COMMAND		
64	RETRANSFER		

No	Event	WHY possibilities considered	Discussion	Probable causes (Y/N)
1	GT-2 trip	As UPS-2 & UPS-1 failed at 14:00& 14:38 hrs respectively	UPS system failed	Yes
2	UPS system failed			
2A	AC Power supply (including alternate supply) / DC (battery) input fail.	As input source failed to UPS, it leads UPS output failure	No input power supply interruption was observed.	Not the cause
2B	Overloading	Connecting device that draw more power than UPS capacity.	There is only 25% load on each UPS.	Not the cause
2C	Environment factors	High Temp & humidity can cause component failure	UPS room temp is being maintained at 27 Deg C as per OEM recommendation.	Not the cause
2D	UPS 2 Circuit/ component faults	Static switch driver card failure.	Electronic card component failure due to ageing/weakness of components. Hence UPS-2 output was failed.	Yes
2E	UPS 1 Circuit/ component faults	SMPS for system control card(inverter control card) failure	Electronic card component failure due to ageing/weakness of components. Due to failure of SMPS card ,control voltage surge originated in 5V & 12V auxiliary output were disturbed. Hence UPS-1 output was failed.	Yes

ANALYSIS 2nd Phase:

Probable options are further studied by why-why analysis until root cause(s) are identified.

Probable causes	Why	Discussion	WHY	REMEDY
UPS 2 Static switch driver card failure.	Electronic card component failure due to ageing/weakness	As per card failure analysis at OEM service centre one of integrated circuit (IC) and some transistors were found defective.	Electronic component failure due to aging and weakness.	OEM recommendation to be taken for UPS system electronic component

Probable causes	Why	Discussion	WHY	REMEDY
				replacement interval
UPS -1 SMPS for system control card(inverter control card) failure	Electronic card component failure due to ageing/weakness	Due to premature failure of SMPS card, control voltage surge originated in 5V & 12V auxiliary output were disturbed. Hence UPS-1 output was failed.(Last replacement of SMPS was done on June 2022)	As per card failure analysis at OEM service centre some of capacitors were found defective. These capacitors are used to provide 5V control voltage to inverter control card and 12V control voltage to static switch driver card.	OEM recommendation to be taken for UPS system electronic component replacement interval
System obsolesce				OEM recommendation to be taken for UPS system component upgradation.

CORRECTIVE ACTIONS CARRIED OUT:

Sl. No	Recommendations	Responsibility	Target date
1	SOE assigned in DCS for both UPS fault signals. Loop check done (SYSTEM SIMULATION CHECK PENDING).	STEAG	Completed (28-07-2024)
2	Further implementation of recommendation as per OEM will be incorporated.	OTPC& STEAG	31.03.2025
3	As per OEM these system is obsolete and required upgradation at earliest.	OTPC-EMD	Opportunity Shutdown
4	Critical spares for UPS to be procured at the earliest	OTPC-EMD	31.03.2025
5	SMPS for control card and SMPS for gate driver card are to be replaced as per OEM recommendation.	OTPC & STEAG	As per OEM Recommendation

6	Both Unit UPS SCVS control to be made functional.(voltage stabilizer stepper motor part missing to be replaced and made available)	OTPC & STEAG	31.03.2025
7	Presently UPS Panels doors are in open conditions due to high temperature observed in past. Ensure panels and UPS room sealing all the times.	OTPC & STEAG	31.03.2025
8	Operation monitoring frequency increased.	STEAG	Complied
9	UPS Trends in SCADA to be monitored regularly	STEAG	Complied
10	Mark Vie powered from 125V DCDB panel (original scheme) or Separate Power Source (BB+FCBC) for Mark-Vie Controls	OTPC-EMD & STEAG-EMD	31.03.2025
11	Field Operator to visit UPS to record data and check alarm status in twice in the shift until faulty Current/Voltage Transducers for SCADA trends are replaced	STEAG	Complied
12	OEM spare and OEM service suggested to clubbed together	OTPC-EMD & STEAG	31.03.2025

REASON FOR FAILURE

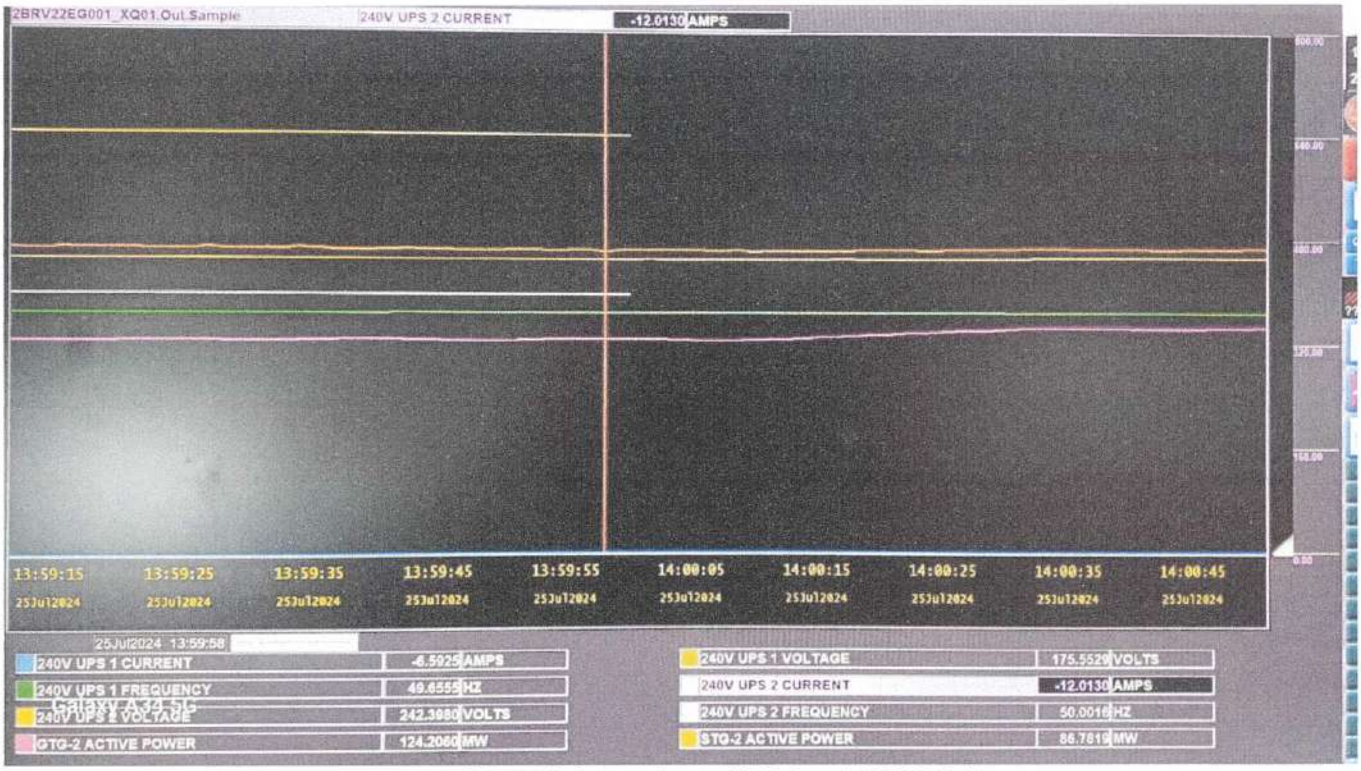
Design defect	X	Over design stress	X	Normal wear and tear		Workmanship issue	X	Low quality spares	X	Insufficient PMs	X

Others, please specify: Component Failure

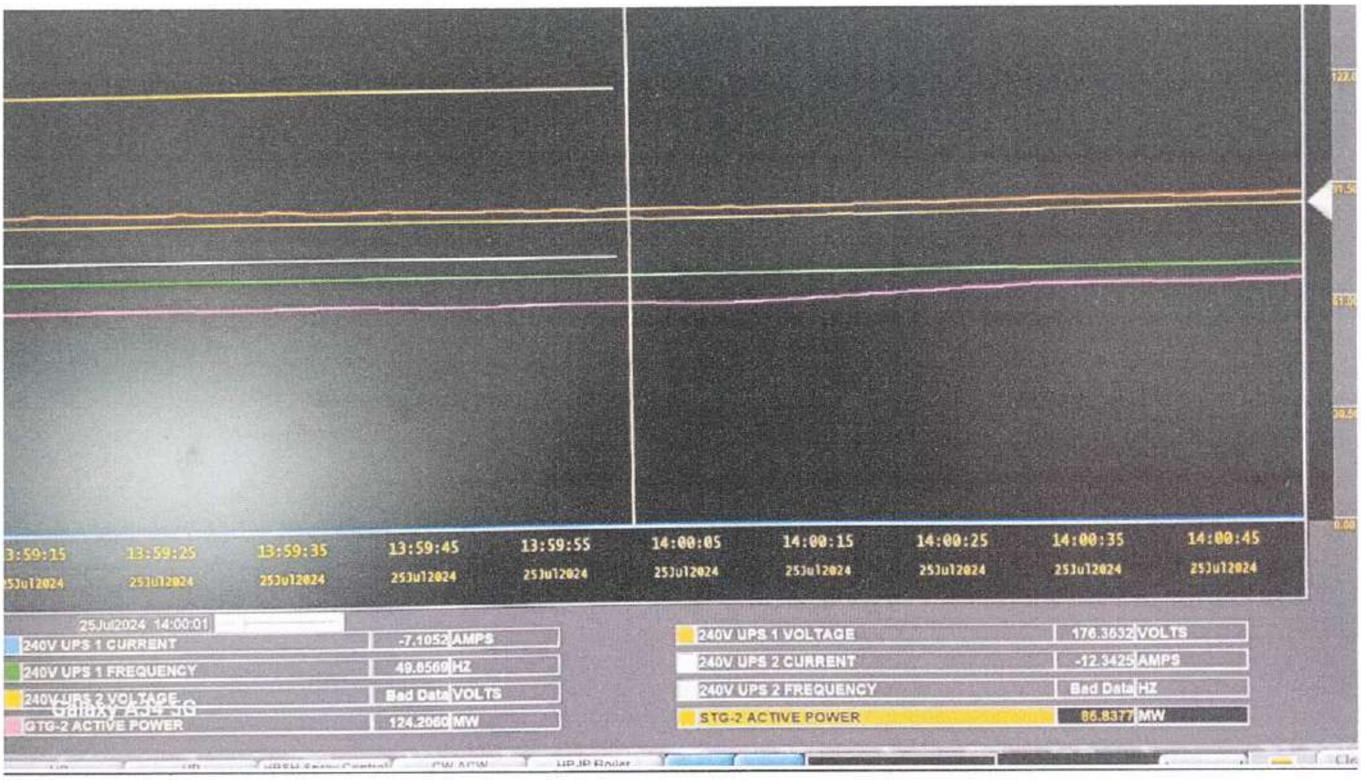
DEGREE OF CERTAINTY OF THE STUDY AND ACTION PLANS

SINo	QUESTIONS	
1	Could there be any other reasonable potential cause for the failure in addition to the captured causes	No
2	Confidence level on the analysis to identify the root cause(s):	High
3	Confidence level on the effectiveness of corrective actions	High
4	Confidence level on the effectiveness of preventive action plans proposed	High

Enclosures/Trends from DCS:

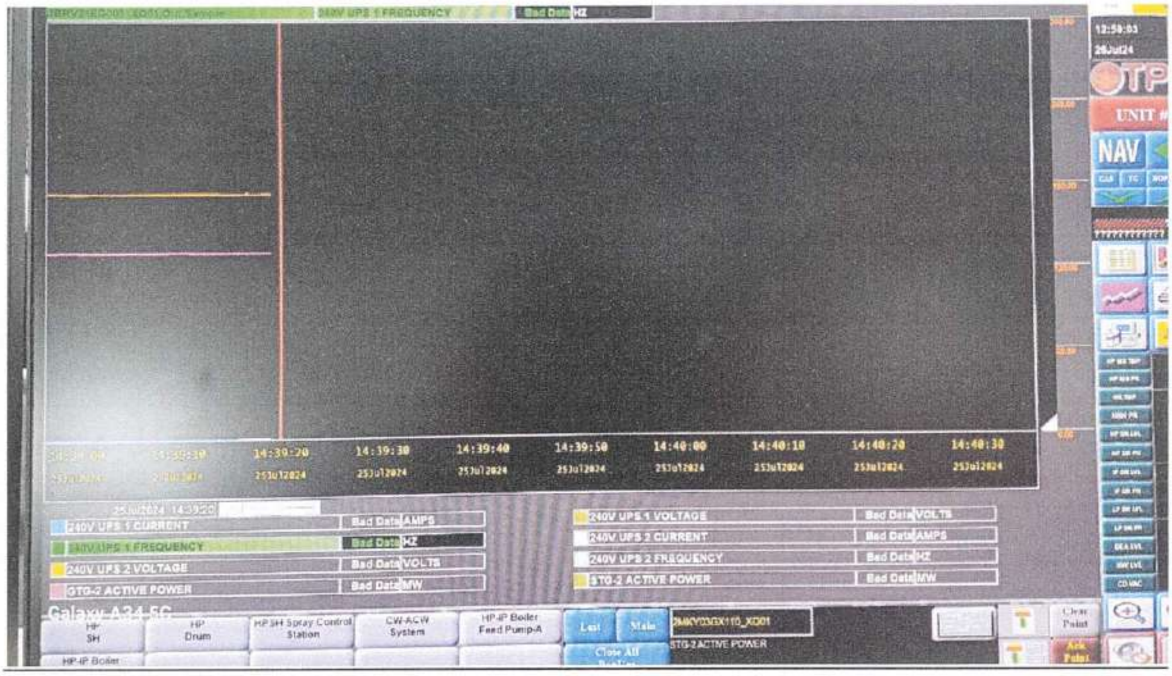


Trend-1: UPS data prior to UPS-1 and UPS-2 fail.

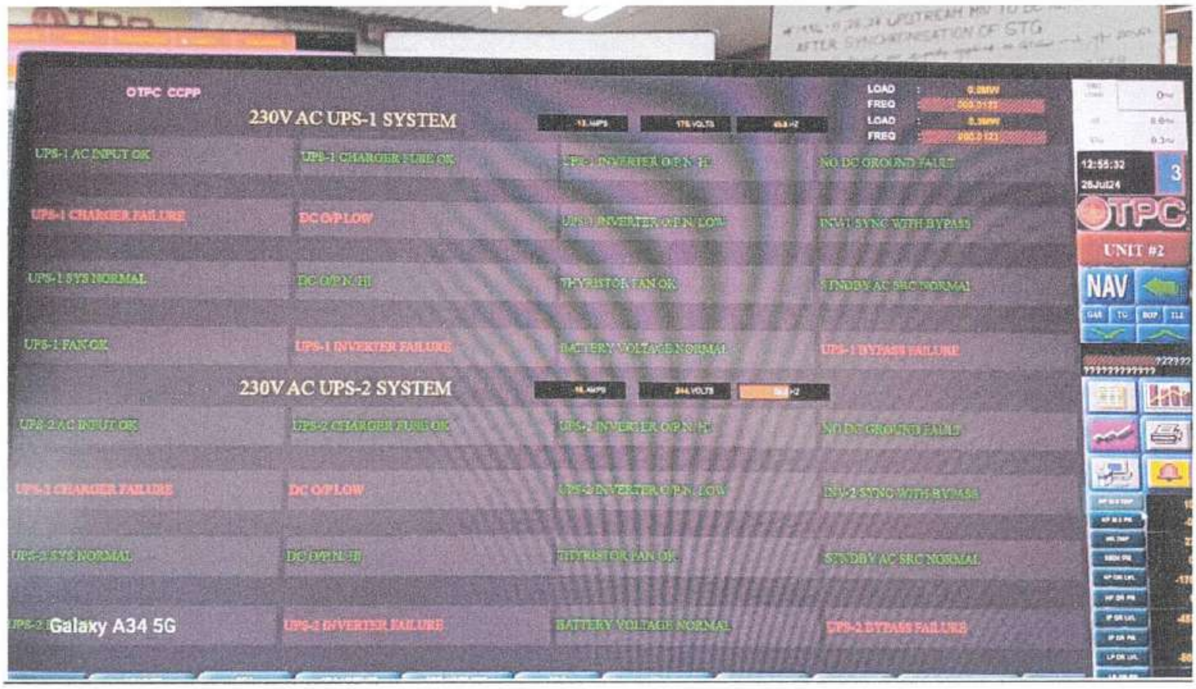


<u>**Trend-2: UPS-2 failed at 14:00 hrs, as no data available for UPS-2**</u>

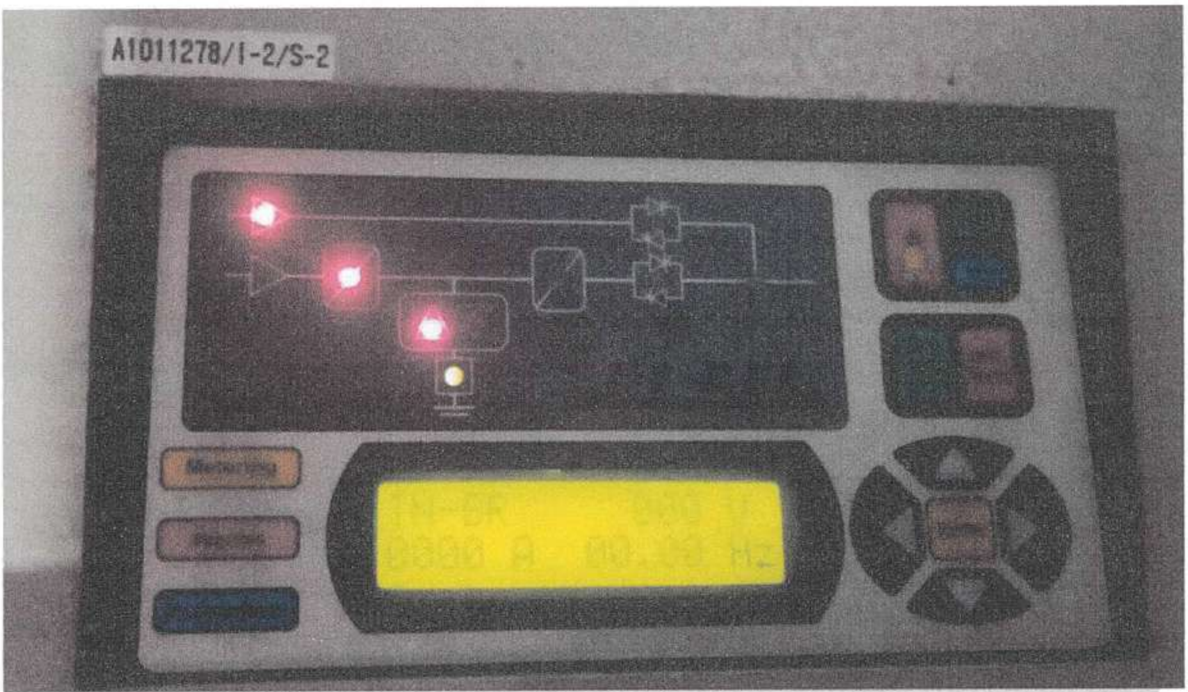
<u>**Trend-3: UPS-1 failed at 14:38 hrs, so date available afterwards**</u>



Trend-4: GTG-2 and STG-2 got tripped and no data available after wards.



Current status of Unit-2 UPS-1 and UPS-2



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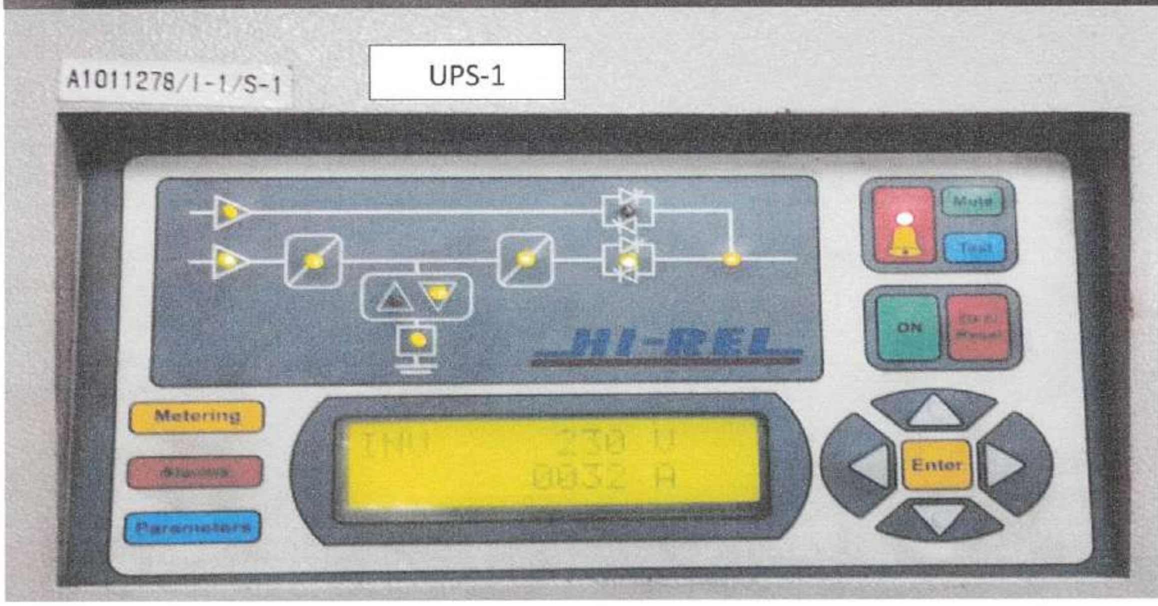

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HI-REL
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Parameters
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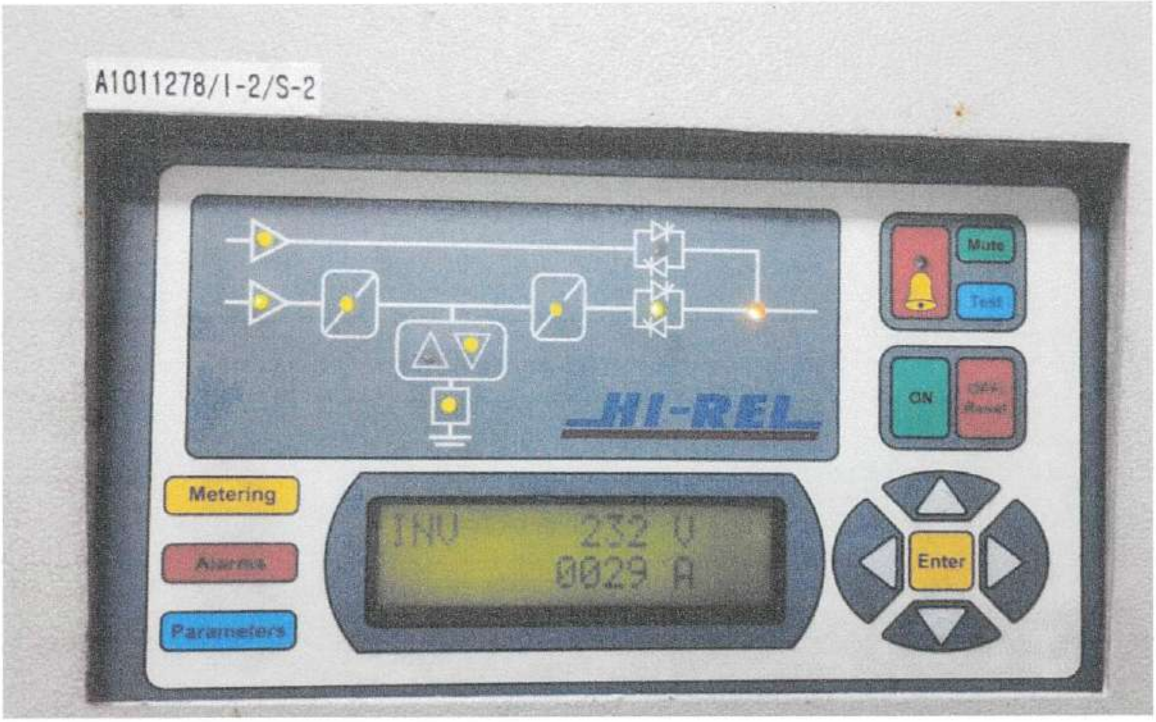
0032 A



A1011278/I-2/S-2
HI-REL
Mute
Test
ON
OFF/Reset
Metering
Alarms
Parameters
INV 232 V
0029 A
Enter

Technical cum Electrical System Safety Audit of Plant LT System (AC/DC System) By Bureau Veritas Industrial Services India Pvt. Ltd. On 14-09-2024		
Sr. No.	**NC/Observations**	**Recommendations**
1	**Main Gate Security Area**	
	No observation	
2	**Admin Building**	
	No observation	
3	**Training Hostel**	
	No observation	
4	**Canteen**	
	No observation	
5	**Main Control Room**	
	No observation	
6	**Training Centre**	
	No observation	
7	**CT PMCC U - 1 & 2**	
a	No smoke detectors installed	Smoke detectors to be installed
b	In CT PMCC-2 #2DC (GE make) door cutout holes are exposed due to missing indicating lamps in panel#10R	Door cutouts to be closed by either reinstalling the indicating lamps or by a blanking plate
8	**BFP Building PMCC U - 1 & 2**	
	No smoke detectors installed	Smoke detectors to be installed
9	**Raw Water Pump House Building**	
	SLD is not displayed	A legible copy of the SLD, visible and readable with naked eye, for the electrical panels installed in the room to be displayed.
10	**Switchyard Building**	
	No observation	
11	**Chemical Laboratory**	
	No observation	
12	**Watch Tower-18 Nos.**	
	No observation	
13	**Security Hostel Building**	
	No observation	
14	**GBC Building**	
	SLD is not displayed	A legible copy of the SLD, visible and readable with naked eye, for the electrical panels installed in the room to be displayed
15	**River Intake Building**	
	This building was inundated with flood water during the audit period. Hence, could not be visited.	
16	**Fire Building**	
	No observation	
17	**Chemical Building**	
	No observation	
18	**Fire Water PMCC**	
	No smoke detectors installed	Smoke detectors to be installed
19	**Medical Building**	
	No observation	
20	**Gate Security Building**	
	No observation	
21	**Hydrogen Plant Building**	
	Temporary plastic sheet cover on MCC#OSG to protect from dripping water from the roof	A permanent solution to prevent dripping of water from the leaky roof on the panels to be arranged on priority basis.
22	**Admin PMCC Building**	

	In PMCC #ODC one MCC module racked out without a LOTO tag	LOTO tagging & locking procedure to be strictly followed during any maintenance job
23	**CCTV Security Building**	
	No observation	
24	**Workshop Building**	
	No observation	
25	BOP Area Buildings like DM Plant, ETP, STP Buildings	
	No observation	
26	**Main Turbine Building - Block 1 and 2**	
a	In 6.6kV Station Switchboard #OCA, door of spare transformer feeder panel #RF3 found open without any LOTO tag / lock	LOTO tagging & locking procedure to be strictly followed during any maintenance job
b	In STG MCC #1KA one module door found open without LOTO tag / lock	LOTO tagging & locking procedure to be strictly followed during any maintenance job
c	In Air Conditioning MCC-1 #OSA, live cable alley door open in panel #3R	Ensure all live terminals / busbar are securely closed / covered after maintenance activities are carried out to prevent any electric shock hazard
d	In 125V DCDB-1A, only tag “Do not operate” found but no lock	A lock to be provided in the panel to ensure any inadvertent operation of the panel
e	In 220V DCDB #OFA door cutout holes are exposed due to missing switch handle in panel #3R	Door cutouts to be closed by either reinstalling the switch handle or by a blanking plate
f	In 6.6kV Unit Switchboard #1CB, LT chamber door of panel #13 (CW Pump #B) found open.	All doors, covers of electrical panels must be securely closed post maintenance work to prevent from electric shock, unauthorized operation, accidental hit, entry of dust & vermin etc.
27	**220V, 125VDC Battery Chargers**	
	In Battery Charger Room Unit #2, 125V FCBC-1, door found open, exposing live terminals & busbar	Ensure all live terminals / busbar are securely closed after maintenance activities are carried out to prevent any electric shock hazard
28	**Plant Internal and External Lighting System**	
	Growth of wild vegetation on and around SLPs and street light poles	Recommend for concreting /pebbling the base of the SLPs & street light poles to mitigate the issue. Also, regular clearance of wild vegetation growth near all electrical equipment is highly recommended.
29	**Others, If any**	
a	List of displayed authorized electrical persons are not updated	List of authorized Electrical persons, possessing valid electrical workmen / supervisor license to be displayed in the electrical rooms
b	Maintenance work on live panels carried out without any barricade	Maintenance / work zone to be barricaded with warning tape.
c	Lightning protection	A detailed study of the Lightning Protection Zone coverage of the entire plant is recommended to identify the uncovered areas / locations.
d	Points to be included in HIRA & SMPs	Contactless voltage detection to be conducted before any maintenance work is carried out in the street light poles
e	Points to be included in HIRA & SMPs	Cable / pipe locator to be used prior to issuing work permits for excavation work.

PLANT SAFETY COMMITTEE MEETING

Minutes Of Meeting dated 14.08.2023
Venue: Admin Conference Hall
Time: 3:00 PM to 05:00 PM

Sl. No.	Area / Location	Observation	Date of the point raised	Responsibility	Action to be taken	Target Date	Status
1	Plant	Departmental Safety committee meeting shall be conducted on every month prior to commencement of Monthly safety committee meeting	22.11.2022	EVERY DEPT	Every dept shall conduct Dept safety committee meeting.all high potential points are to be shared in Plant Safety committee meeting forum	1st Week of every Month	Open
2	MAL drain valve (Unit#1)	Approach is required for STG MAL drain valve	22.11.2022	MMD & CMD	1.Earlier purchased gratings used to close near misses raised in Workplace, Presently GI Gratings are not available PR raised for GI gratings, Expected completion 30 NOV 2023. 2.Temporary Sccafolding is proposed.which will be installed by CMD-OMS, Expected Date 20.08.2023	30.11.2023-MMD with replaced the Gratings . 20.08.2023- CMD_OMS Will provide temporary scaffolding.	Open
3		Portable/Adjustable lights shall be used or mounted on helmets for all necessary area.	22.11.2022	EMD	Material Received, (OTPC has purchased 20 nos lights and few were provided to OMS EMD Dept, OMS yet to procure and the same has to be provided to the concern person during work activity.		Open
4	Air Filter Area	Permanant lights is required inside the air filter house.(Both Unit)	22.11.2022	EMD	PR raised(PR NO 1100002911) for trolley mounted transformer for hand held lights. Inspection of Air filter house to be done during oppurtunity shutdown.		Open
5	Watch Tower, CCTV Area & Boundary Wall	De vegitation is required (to avaoid wild animals) entirer plant location	22.11.2022	CMD	Work In Progress		Open

6		**PA Systems to be checked which is already installed to be revived**	**08.04.2023**	**IT & IMD-OTPC**	**It can be discussed further with management for furthre procurement**		**HOLD**
7	Hydrogen area	Provision for proper grounding of Static sensitive device at H2 area	08.04.2023	CMD		20.08.2023	Open
8	C&F Building, Control room(Heavy Duty and comfortable chair), Fire station, C&I Office,Hydrogen plant, RWIS	Chairs required in C&F Building, Control room(Heavy Duty and comfortable chair), Fire station, C&I Office,Hydrogen plant, RWIS	08.04.2023	HR&A	List to be prepared by concern dept and to be shared with EHS&F dept and EHS&F dept will share with HR&A (Expected date-18.08.2023)		Open
9	Cable gallary (U#1&2)	Poor lighting inside the Cable gallary (U#1&2) and Potential Snake hazards.	08.04.2023	HR&A & CMD	HR&A-OMS:: will do Fumegation activity by 30.08.2023)	30.08.2023	Open
10	Battery Chanrging rom, Filter House.	Lights are not available at few Toilets area such as Battery Chanrging rom, Filter House.	08.04.2023	EMD		30.08.2023	Open
11	Filter House.	Cleanliness of the toilet need to be done propoerly (Horizontly it has to be done through out the plant)	08.04.2023	HR&A & CMD	Cleaning done but some toilets are broken and water supply not available.		Open
12	H2 plant	Modification required at KOH mixing tank area(Acid proof tailes)	08.04.2023	CMD	Jointly visit have to be done with CMD,EHS&F,OPN & H2 plant area concern,Expected date 20.08.2023		Open
13	Diesel Tank/FWPH	Containment area to be made around relocated diesel tank.	08.04.2023	CMD	Dyke wall has to be made, CMD-OTPC & OMS Expected date:30.09.2023	30.09.2023	Open
14	Main Store	Poor illumination at Main store open yards	08.04.2023	EMD		30.08.2023	Open
15	**Hydrogen area,GBC,IGCS,FGCS Hydrogen Manifest (U#1&2) area**	**Mobile phones to be kept out side in few location i.e. Hydrogen area,GBC,IGCS, Hydrogen Manifest (U#1&2) area**		**EHS&F-OTPC**	**This points are under discussion stage**		**HOLD**
16		Provision for proper grounding of Static sensitive device at H2 area			OMS-CMD will do this activity by 20.08.2023	20.08.2023	Open
17	Compression Gas area/High Pressure area	All Pnumatic lines need to be secured with Whip Check.(Wherever required)	14.08.2023	MMD	List has to be prepared and based on that it will be installed by the Concern dept.		Open
18		Wireless /Walkie Talkie details shall be prepared and all damaged walkie talkie shall be repaired accordingly.	14.08.2023	HR&A		20.08.2023	Open

19	RWIS	RWIS External cables are to be dressed in proper way.	14.08.2023	EMD			Open
20	All Plant area	All extension board without ELCB/RCCB must be discarded	14.08.2023	EMD/MMD/CMD/IMD/ OPN/IT/STORE			Open
21	U#1 & U#2 and BOP Areas.	ELCB in NLP's are ,missing in U#1 & U#2 and BOP Areas.	14.08.2023	EMD	List to be prepared by Mr.Asishs Kumar Paul from EMD-OMS and accordingly action will be taken		Open
22	Chemical Store	ZOK dums are to be shifted into the chemical store area.	14.08.2023	STORE Dept.		20.08.2023	Open
23	H2 filling station at Unit#1&2.	Rubber mats shall be installed in H2 filling station at Unit#1&2.	14.08.2023	OPN	This practice shall be monitored by EHS&F dept	20.08.2023	Open
24	All SLP	Gloves for opeartion helpers (Electric Shock proof hand gloves) to be provided, For external electrical activity mostly in SLP Operation.	14.08.2023	OPN	EHS&F dept has provided 1 Kv gloves to the Shift incharge(2 Nos)	16.08.2023	Open
25	All SLP's	Devegitation below SLP's shall be done periodically	14.08.2023	CMD			Open
26		Proper Safety mask(nose mask) is reuqired for Pest control -Vendor/Employees	14.08.2023	CMD		20.08.2023	Open
27	Main Store	Main door Store shutter(Store#1) need be repaired and periodical maintenance is reuiqred to avoid Ergonomic hazards	14.08.2023	CMD		30.08.2023	Open
28		Over Stacking height for goods carrying vehicles are to be maintained as per RTO Rules and the same shall be maintained at the time of entrance of the OTPC main gate	14.08.2023	C&M,Store & EHS&F			Open

FINAL REPORT

PLANT PERFORMANCE AUDIT-2

For 2 x 363.3 MW Combined Cycle Power Plant, India

BV PROJECT NO. 410764

PREPARED FOR

ONGC Tripura Power Company Limited (OTPC)

12 JULY 2023

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Acronym List

ACRONYM	DESCRIPTION
^oC	Degrees Centigrade
AC	Alternate Current
ACRT	Accelerated Creep Rupture Test
APS	Automatic Plant Start-up/Shutdown Control Scheme
ASME	American Society of Mechanical Engineers
AVR	Automatic Voltage Regulator
BHEL	Bharat Heavy Electrical Limited
BOP	Balance-of-Plant
BSI	Borescope Inspection
Btu	British Thermal Unit
Btu/kWh	British Thermal Unit per Kilowatt-Hour
CCPP	Combined Cycle Power Plant
CEMS	Continuous emission Monitoring System
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Commercial Operation Date
CRH	Cold Reheat
CT	Cooling Tower
CW	Circulating Water
DC	Direct Current
DCS	Distributed Control System
DGR	Daily Generation report
DLE	Dry Low Emission
DLN	Dry Low Nox
DM	Demineralized
EAF	Equivalent Availability Factor
EAF	Equivalent Availability Factor
EAF	Equivalent Availability Factor
ECR	Equipment Condition Report
ECT	Eddy Current Test

ACRONYM	DESCRIPTION
EFOR	Equivalent Forced Outage Rate
EHS	Environmental Health and Safety
ELCID	Electromagnetic Core Imperfection Detection
ESDV	Emergency Shutdown Valve
ETP	Effluent Treatment Plant
FFH	Factored Fired Hours
FOF	Forced Outage Factor
FOR	Forced Outage Rate
FSFL	Full Speed Full Load
FSNL	Full Speed No Load
GE	General Electric
GSU	Generator Step Up
GT	Gas Turbine
GTG	Gas Turbine Generator
HMBD	Heat and Mass Balance Diagram
HP	High Pressure
hp	Horsepower
HP	High-Pressure
HR	Heat Rate
HRSG	Heat Recovery Steam Generator
HSO	Hot Section Overhaul
HV	High Voltage
Hz	Hertz
I&C	Instrumentation and Control
I/O	Input/Output
IAF-II	India Alternative Fund- II
IL&FS	Infrastructure Leasing & Financial Services Limited
IP	Intermediate- Pressure
IR	Infrared
IRIS	Internal Rotary Inspection
Kcal	Kilocalories

ACRONYM	DESCRIPTION
kJ	Kilojoule
klb/h	Kilopounds per hour
kV	Kilovolt
kVA	Kilovolt-ampere
kVar	Kilovar
kW	Kilowatt
kWh	kilowatt-hour
LD	Liquidated Damage
LEAP	Life Expectancy Analysis Program
LED	Light Emitting Diode
LHV	Low Heating Value
LP	Low-Pressure
LTSA	Long Term Service Agreement
LV	Low Voltage
m/s	Meters per second
m^3/sec	Cubic meters per second
mA	Milliamperes
MO	Major Overhaul
MS	Main Steam
MT	Magnetic Particle Test
MTD	Month Till Date
MV	Medium Voltage
MW	Megawatts
MWh	Megawatt Hour
NCV	Net Calorific Value
NDT/ NDE	Non-Destructive Examination/ Non-Destructive Testing
NERC	North American Electric Reliability Corporation, USA
NOx	Nitrogen Oxides
O&M	Operations and Maintenance
O2	Oxygen
OAR	Operation Assessment Report

ACRONYM	DESCRIPTION
OEG	Operational Energy Group
OEM	Original Equipment Manufacturer
OMS	O&M Solutions Pvt. Ltd
ONGC	Oil and Natural Gas Corporation Limited
OTPC	ONGC Tripura Power Company Limited
P&ID	Process and Instrumentation Diagram
PCB	Pollution Control Board
PG Test	Performance Guarantee Test
PLC	Programmable Logic Controller
PM	Preventive Maintenance
PT	Dye Penetrant Test
PTC	Performance Test Codes
RCA	Root Cause Analysis
Rpm	Rotations per Minute
RT	Radiographic Test
RTD	Resistance Temperature Detector
RVI	Remote Visual Inspection
SMP	Standard Maintenance Procedure
SOP	Standard Operating Procedure
SOX	Sulphur Oxides
ST	Steam Turbine
STG	Steam Turbine Generator
TAT	Turn around time
TBC	Thermal Barrier Coating
TPH	Tons per hour
UTM	Ultrasonic Thickness Measurement
VGV	Variable Guide Vane
VI	Visual Inspection
VIGV	Variable Inlet Guide Vane
VMU	Vibration Monitoring Unit
YTD	Year Till Date

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1 Executive Summary

ONGC Tripura Power Company Limited (OTPC) is a joint venture of Oil and Natural Gas Corporation Limited (ONGC) and Govt. of Tripura. OTPC is operating a 726.6 MW (2X363.3 MW) Combined Cycle Power Plant (CCPP) at Palatana in the state of Tripura, India. The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015.

Black & Veatch has been contracted by OTPC to perform technical system audit, plant performance audit, and provide recommendations for improvement in plant performance, reliability, and safety of the plant. A list of **27** recommended performance improvement project is provided in ***Section 6.1.5.*** These recommendations are categorized based on "risk level", "priority", "CAPEX" and "On-line vs. Shutdown" planning. Few major upgrades specially for steam turbines such as steam seal upgrades, LP last stage modifications etc. are recommended to be analyzed in consultation with major retrofit package providers besides OEMs and planned during next capital overhauls at expected 100,000 Hrs.

1.1 Performance Analysis at Base Load

1.1.1 Heat Rate Analysis

Black & Veatch supported the conductance of site performance test with OTPC and OMS on 1st – 3rd of Feb-23 based on in-situ instrumentations. This assessment was part of 2nd audit cycle activity performed by Black & Veatch. The below table 0-1 compares the gross heat rate (Corrected) with PG test and [1]CERC norms.

Table 1-1 Gross Heat Rate Analysis

Unit	Perf. Test O/P (Uncorrected)	Perf. Test HR (Uncorrected)	PG Test		CERC	
			Output	HR	[1]HR	DIFF.
UOM	MW	kCal/kWh	MW	kCal/kWh	kCal/kWh	%
Block-1	335.70	1622.02	373.59	1504.9	1581	2.59
Block-2	339.19	1623.11	368.06	1505.5	1581	2.66

Both Block 1 and 2 were operated at base load. In Block-1, corrected heat rate for audit 2 was varying by 4.43% from OEM's PG test value. In Block-2 performance test corrected heat rate was varying by 5.68% from OEM's PG test results.

Overall, combined cycle heat rate (uncorrected) for Unit 1 and 2 are higher by 2.59% and 2.66% respectively from CERC's permissible limit of 1581 kCal/kWh for base load operation.

[1] CERC tariff regulation 2019 specifies under u/s chapter 12; Norms of Operation to be 1.05 times of design gross heat rate for natural gas-fired combined cycle plant. The CERC value as applicable for OTPC is thereto derived by applying a 5% margin over the design heat rate of 1505.7 kCal/kWh.

1.1.2 Auxiliary Power Analysis

BLOCK	GROSS GENERATION (MW)	% OF RATED CAPACITY	AUX. ENERGY CONSUMPTION (%)	CERC NORMS (%)
Block-1 & 2	657.06	90.4	[2]3.446%	[3]3.30

APC is calculated at the station level based on EM data and deducting total hourly export (MWH) with hourly gross generation for the test period. The APC of station is around 4.4% higher than the CERC permissible limit for CCGT.

1.1.3 Performance Comparison with Other 9F Based Combined Cycle Units

S. NO	DESCRIPTION	UOM	BLOCK-1	BLOCK-2	[4]GLOBAL BENCHMARKS		
					Min	Max	Median
1	Gross Heat Rate (NCV basis)	kCal/kWh	1572.35	1591.27	1487	1766	1588
2	Plant Auxiliary Power Consumption	%	3.446		2.6	5.7	3.82

Black & Veatch compared OTPC heat rate and auxiliary power consumption with the industry standards. The data used for this assessment is referred using Black & Veatch's two decades of monitoring & diagnostic service of combined cycle plants. The performance of OTPC is shown graphically in the chart below. The chart shows that OTPC heat rate at 1581.82 (combined for block 1 and 2) is lower than the global median of 1584.81, however there are potential for average improvements inherent further up to 2-3% on the lower side duly accounting for machine's permanent degradation and its operating characteristics. Given Major Inspection (MI) for block 1 and block 2 are concluded in 2021 and 2022 respectively, the expected heat rate based on OEM supplied curve is reset at lower side to 1527.9 kCal/kWh and 1521.5 kCal/kWh respectively. The permanent degradation after 1 MI cycle is ~0.6-0.7% of design heat rate for both the blocks i.e., 10-12 kCal/KWh. With the considerations above, we expect that there is a potential for reduction of up to 2-3% in combined cycle heat rate by implementing the 27 recommendations outlined in section 6.1.5. ***Assuming overall reduction of 3%, a target heat rate of 1534 kCal/kWh or alternatively reduction of 45-50 kCal/kWh with respect to performance test heat rate can be targeted by OTPC in short to midterm.***

[2] Based on Energy Mater Data for the 2nd of February (15:00 -18:00 Hrs).

[3] Gas-based generating stations using electric motor driven Gas Booster Compressors, the Auxiliary Energy Consumption in case of Combined Cycle mode shall be 3.30%

[4] Following is the criterion used to ensure that comparison is justified in the context of OTPC.

- 10+ Combined cycle plants (9FA / 7FA) with block outputs in the range of approximately 300 to 1000 MW was considered.
- Operating history after COD for these plants are varying from 4 years to 12 years.
- Plants are in North America, China, Canada, and India.
- All plants are operated generally at either base load or sometimes at part load following grid dispatch instructions.

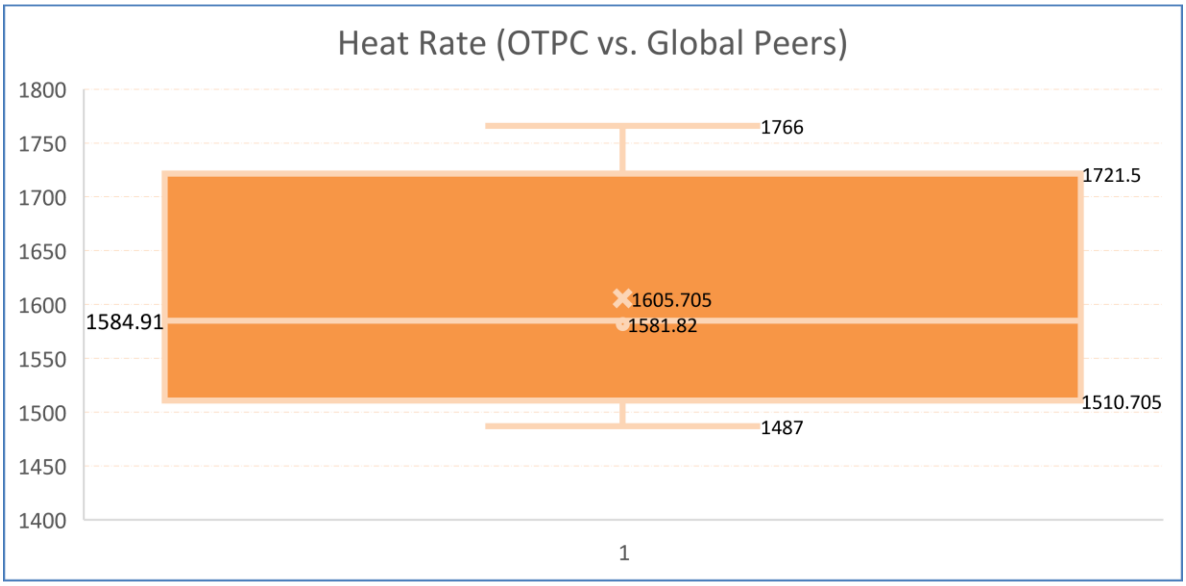
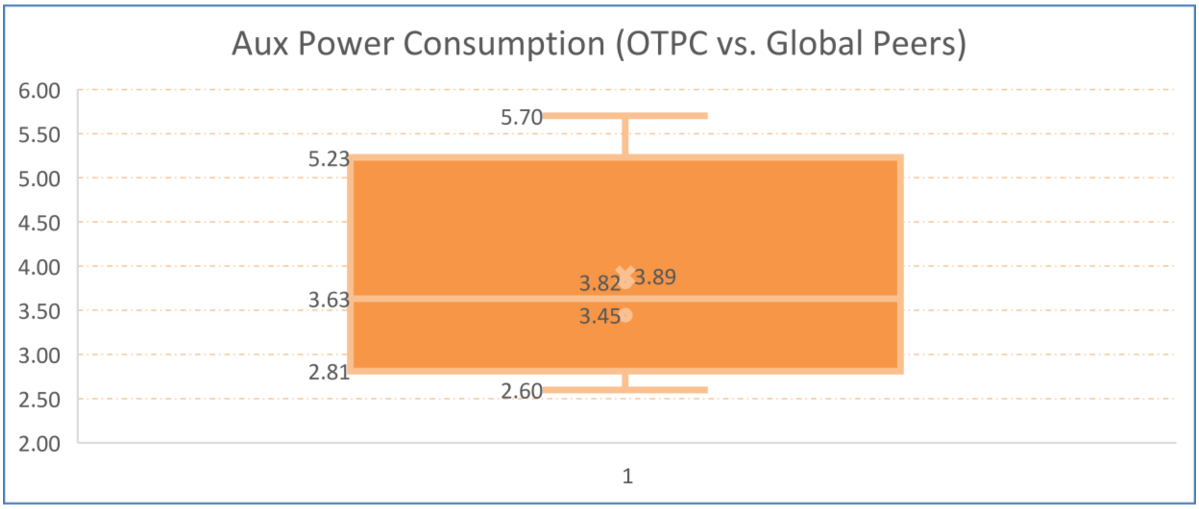


Figure 1 Box & Whisker Chart - OTPC vs. Global Peers

Figure 2 shows box and whisker plot of Aux power consumption. The OTPC auxiliary power consumption at 3.45% was lower than median of 3.82 and marginally higher than CERC norms of 3.30% respectively.



1.2 Recommended Improvement Actions

A list of 27 improvement project is provided in section 6.1.5 of the report and is reproduced below. These projects have each a potential of reducing heat rate and auxiliary power consumption varying with respect to severity of issues and measured adopted to rectify them including capital investment and technical support extended by OEMs and other equipment supplier. Please note that benefits of the projects are not additive and always complementary, hence heat rate improvement projects are required to be carefully evaluated to avoid double accounting or overstated expectations. We have classified these projects in two categories.

- Operational Adjustments
- System Modifications

Table 1-2 Heat Rate & APC Improvement Projects (1-5 Years)

Project ID	Project Description	Expected Heat Rate Reduction	Exp. APC Reduction	Type	CAPEX / Unit	Payback
1	HP/IP Section Internal Efficiency Improvement by Seal Upgrade	12-15 kCal/kWh	1.0-1.5 MW	System Modification (COH)	$1-1.5 million	<3 Years
2	Estimation of HP-IP Leakage by N2 Method (Services)	-	-	Operational Adjustment	$25-$35K	
3	LP Turbine efficiency Improvement by improving blade design and Increased annulus area (last stage blade replacement	10-30 kCal/kWh	Upto 1.0-2.0 MW	System Modification (COH)	$1.5-$2 million	3-5 Years
4	Addition of HP Exhaust pressure and temperature (Supply+ Service)	-	-	Operational Adjustment	$ 30-40K	
5a	Arrest Suspected Air Ingress in Condenser from Low Pressure Piping, LP turbine seals and diaphragm	5-10 kCal/kWh	-	Operational Adjustment	$ 30-40K	<1 Year
5b	Vacuum Pump “Under venting” Issue (Online Monitoring, Cleaning of Seal Water Cooler, Cavitation Avoidance)	5-10 kCal/kWh	-	System Modification (Minor)	$15-20K	<1 Year
5c	Condenser Cleaning (Online tube cleaning / Retubing with improved metallurgy	5-10 kCal/kWh	-	System Modification	$0.5-0.6 million	<2 Year
5d	Cooling Tower Projects (Fill pack replacements, CW flow equalization, Higher air flow using improved fan design, New Screen Design for CT basin)	10-15 kCal/kWh	Upto 0.5-1 MW, Condenser vacuum	System Modification	$0.8-1.2 million	<3 Year
6	Mitigate Inlet air filter choking and extend filter replacement cycle using Coalascer pads or Upgrade fine filter to EPA grade after cost benefit assessment with OEM	-	-	Operational Adjustment	$20-30K	<1 Year

Project ID	Project Description	Expected Heat Rate Reduction	Exp. APC Reduction	Type	CAPEX / Unit	Payback
7	Segregation of service air and instrument air usages (study)	-	Upto 100-150 KW	System Modification	$20-30K	<1 Year
8	Centralized controller for better loading / unloading frequency and average pressure band reduction	-	Upto 100 KW	System Modification	$80-100K	<1 Year
9	Arresting Leakages / Suspected Valve Passings CW Butterfly valve Plater Heat Exchanger BFP Recirculation IP Bypass Steam line	2-5 kCal/kWh	Upto 200 KW	Operational Adjustment	$50-80K	<1 Year
10	Real time monitoring of plant performance and continuous optimization	10-15kCal/kWh	Upto 0.5-1 MW	Operational Adjustment	$100-120K	<1 Year

A tabular and graphical representation for proposed recommendations and expected benefit is shown below.

Table 1-3 Heat Rate Improvement Strategy

Description	Units	Value[5]
Design Heat Rate	kCal/kWh	1505
Expected Heat Rate	kCal/kWh	1525
Target Heat Rate (Part Load, Gas Issues)	kCal/kWh	1534
Perf. Test Heat Rate	kCal/kWh	1582
Gap in Heat Rate (Target - Perf. Test)	kCal/kWh	48
Condenser Projects (5a,5b,5c)	kCal/kWh	-15
Cooling Tower Projects (5d)	kCal/kWh	-10
Steam Turbine Projects (1,2,3,5))	kCal/kWh	-20
Operational Adjustments (7,7,8,9)	kCal/kWh	-5
Predictive Analytics (10)	kCal/kWh	-10

[5] Values in negative indicates reduced gap between actual and target by project implementation. All improvement values are considered as median for representation purpose. Please refer 6.1.5 for range (minimum – maximum)

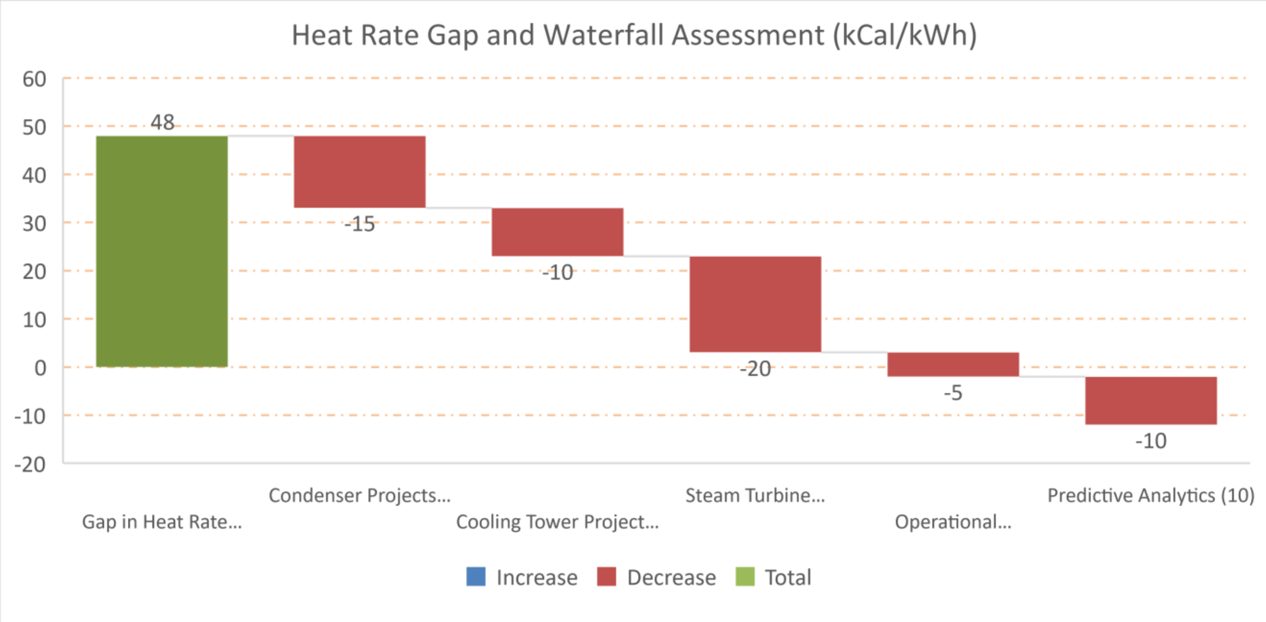


Figure 2 Heat Rate Gap and Waterfall Assessment

In conclusion, we have concluded two performance audits which were carefully organized between successive major inspections for Unit 2 and Unit 2 in 2021 and 2022 respectively. OTPC has implemented many upgrades and process improvements in the two units (ECP4 package upgrade for compressor, major retrofits in GT internals (nozzles, blades, shrouds, bearings replacement), IGV replacements, energy efficiency projects like CT fills replacements, new fan design, energy efficient lighting, insulation replacement etc. The focus for improvement is now required to be shifted towards bottoming cycle systems (HRSG, Steam turbine, Condenser and Auxiliaries) where we see considerable improvement potential through both system modification / upgrade strategy and operational adjustments. We are thankful to OTPC for giving opportunity to Black & Veatch to get associated in its decarbonization endeavor. Black & Veatch recommends systematic implementation of these projects in short-mid-term period for long-term efficient, reliable and safe plant operation achieving its environmental sustainability and decarbonization goals.

2 Facility Description

ONGC Tripura Power Company Limited (OTPC) is a joint venture of Oil and Natural Gas Corporation Limited (ONGC), and Government of Tripura. OTPC is operating a 726.6 MW (2X363.3 MW) Combined Cycle Power Plant (CCPP) at Palatana located about 60 (sixty) km from Agartala in the state of Tripura. The plant has 2 units each of 363. 3 MW on 1X1X1 configuration. Each unit consists of 1 GTG, 1 HRSG, and 1 STG along with associated plant auxiliaries supplied by BHEL.

The balance of plant system consists of Gas Booster Compressor house, river water intake system, fuel supply system, plant & fire water system, air supply system, hydrogen plant, nitrogen plant, 400 KV & 132 KV switchyard, etc.

The first block (363.3 MW) of the power plant was declared under Commercial Operation from 4th January 2014 and the second block (363.3 MW) of the two blocks was declared under commercial operation from 24th March 2015. The commissioning details of the station are shown below.

Table 2-1: Block-1 & 2 COD details

BLOCK NO	CAPACITY (MW)	TECHNOLOGY	DATE OF COMMISSIONING	DATE OF COMMERCIAL OPERATION
1	363.3	1X1 GE 9FA Combined Cycle	January 2013	4^{th} Jan 2014
2	363.3	1X1 GE 9FA Combined Cycle	November 2014	24^{th} Mar 2015

The plant receives gas from ONGC's gas fields located within 20-60 (twenty to sixty) km from the site. OTPC has entered into long term "Gas Sale and Purchase Agreement" (GSPA) with ONGC for purchase of fuel.

OTPC has entered into Operation and Maintenance Agreements with O&M Solutions Pvt. Ltd.(OMS) for providing operation and maintenance services including supply of consumables for the entire Plant. OTPC also has a maintenance services contract for services and supply of parts for Covered units of GT with General Electric International Inc and GE Energy Parts Inc respectively.

2.1 Equipment Design Information

Table 2-2: Equipment Design Information

DESCRIPTION	SPECIFICATION
Gas Turbine GT 2X363.3 MW	
Manufacturer	GE
Model ISO rated power Exhaust Temperature Speed Emission Control	9351FA Natural Gas Combustion turbine and Brush Generator 235400 KW 602.2 Deg. C 3000 RPM Dry Low NOx (DLN) 2.0
GT Turbine Generator (2 No)	

DESCRIPTION	SPECIFICATION
Manufacturer	BHEL, Haridwar
Terminal Voltage Stator Current Coolant Speed	15750 V 10022 A Hydrogen 3000 RPM
Heat Recovery Steam Generator (2 No)	
Manufacturer	BHEL
Features	Horizontal, natural circulation, water tube, top supported, fully drainable, modular design, Triple pressure with reheat type waste heat boiler
Maximum Capacity	289 TPH
Steam Turbine (2 No)	
Manufacturer	BHEL, Hyderabad
Type	Two Cylinder reheat Condensing turbine
Rated Speed	3000 RPM
Gas Booster Compressor [3 No]	
Manufacturer	BHEL
Model	BCL 406
Type	Centrifugal compressor
Drive Type	Electric Motor
Motor Power	3840 KW
Gas Heater	
Manufacturer	Not Availlable
Type Gas Flow	TEMA"AEL" 51520 kg/hr
GT Control System	
Type Model Make Control panel supply Monitor/Printer Supply	Electronic Speedtronic ™Mark VI/ Upgarded to Mark VIe M/S General Electric, USA 125 DC 240 AC
Plant Switchyard	400 kV and 132 kV switchyard with ICTs

3 Scope of Work and Audit Methodology

3.1 Scope of Performance Audit

The scope of Plant Performance Audit would be as follows

- Analyze the present key performance parameters of the plant and Identify reasons for variation/deviations of parameters, controllable losses, etc. and suggest ways to improve key performance indicators.
- Compare the plant performance parameters with design parameters.
- Compare the current plant performance parameters with performance targets.

3.2 Audit methodology

Black & Veatch team gathered available data to perform its assessment for this Report through the online data room. Black & Veatch conducted site visits to the OTPC site from 1st Feb – 4th Feb, 2023. The site visits involved meetings with representatives of OTPC and OMS. The purpose of the site was to assess the physical condition of the assets, to witness plant performance test and to gather additional information from operations personnel.

3.3 Performance Test Data Collection Guidelines

Black & Veatch has followed guidelines based on relevant ASME and PTC codes like PTC- 22, PTC -6, PTC -46, etc. for the performance evaluation. Some of the general guidelines are as below,

- Each unit shall be operated preferably in automatic mode and in a manner consistent with good utility practices.
- The total test duration comprises of the stabilization period, performance test period, and post-test period.
- The gas turbine shall be operating in baseload condition with IGV full open preferably.
- The test period will be preferably 120 minutes however, the test period shall not be less than 60 minutes if 120 minutes is not possible. ***Please refer table 3.1 for additional details***.

Table 3-1: Expected Minimum and Maximum Period for Performance Test

PERIOD	TIME	EXPECTED	MINIMUM
Stabilization period	Minutes	60	30
Test period	Minutes	120	60
Post-test period	Minutes	30	30
Total period	Minutes	210	120

- Before the start of the stabilization period, it shall be ensured that data is getting recorded at least for the parameters mentioned in the performance test data requirement section.

- The test shall not be carried out in conditions wherein there are expected major change in ambient parameters like ambient pressure, dry bulb temperature, and relative humidity.
- The test shall be repeated if there is starting/stopping of rain in between the test period.
- Following are critical stability conditions required per PTC 22. PTC 22 indicates sample standard deviation.

Table 3-2: Acceptable variations as per PTC 22

S.NO	VARIABLE	VARIATION ALLOWED PER PTC 22
1	Gross Power Output	0.65%
2	Air Temperature	1.3 DEGF (0.7 DEGC)
3	Fuel Flow	0.65%
4	Barometric Pressure	0.16%
5	Rated Speed	0.33%

- The test shall be restarted if there is a major disturbance or fluctuations during the performance test period.
- All drum blowdowns are to be kept closed.
- All drain /vent valves to be kept closed. Report if there are any water or steam leaks in the system.
- The electrical output from the combustion turbine shall be measured at the generator terminals with precision power meters.
- Fuel gas flow to the combustion turbine shall be measured using one or more calibrated orifice flow sections (designed in accordance with ASME MFC-3M), or other agreed-upon alternative meters (s) which meet the accuracy requirements of the test.
- Ambient conditions shall be measured with instrumentation that meets the accuracy requirements of the test.
- Upon completion of the test or during the test itself, the test data shall be reviewed to determine if any data should be rejected prior to the calculation of test results.
- All drain /vent valves to be kept closed. Report if there are any water or steam leaks in the system. All drum blowdowns were kept closed.
- The electrical output from the combustion turbine shall be measured at the generator terminals with precision power meters.

4 Principle Assumptions

In completing this assessment, Black & Veatch has used and relied upon certain information provided by OTPC and OMS. Black & Veatch believes the information provided is true and correct and reasonable for the purposes of this report. In preparing this report and the opinions presented herein, Black & Veatch has made certain assumptions with respect to conditions that may exist or events that may occur in the future. However, some events may occur, or circumstances change that cannot be foreseen or controlled by Black & Veatch and that may render these assumptions incorrect. To the extent that the actual future conditions differ from those assumed herein or provided to Black & Veatch by others, the actual results will differ from those that have been forecast in this report.

Throughout this report, Black & Veatch has stated assumptions and reported information provided by others, all of which were relied upon in the development of the conclusions of this report. Following is a summary of principal considerations and assumptions made in developing the opinions expressed herein:

- Natural gas and associated transportation will continue to be available in the quantities and qualities required by the plant throughout the remaining terms of agreements in place.
- The assets will be operated and maintained in accordance with good industry practices, with required renewals and replacements made in a timely manner.
- Equipment will not be operated in a manner to causes it to exceed the equipment manufacturer's ratings or recommendations.
- All contracts, agreements, rules, and regulations will be fully enforceable in accordance with their respective terms, and all parties will comply with the provisions of their respective agreements.
- All licenses, permits and approvals, and permit modifications (if necessary) will be obtained and/or renewed on a timely basis; and any such renewals will not contain conditions that adversely impact the operating and maintenance costs.

5 Plant Performance Test Result Analysis

Before the site visit, Black & Veatch has provided the formats and general guidelines for DCS data collection during stable operating conditions at baseload.

The baseload performance test data for Block-1 was recorded from 15:00 Hours to 17:00 Hours at 1 minute interval on 2nd of February. Similarly, Block-2 was kept at baseload operation from 15:00 Hours to 17:00 Hours on 3rd of February and performance test data was recorded for results evaluation.

5.1 Overall Plant Performance

5.1.1 Design Parameters

The plant's design parameters at base reference conditions provided by BHEL are shown in the below Table.

Table 5-1: Plant Parameters at Reference Design Condition

PARAMETERS	UNIT	VALUE
Block-1 & 2 Gross Output	MW	363.3
Block-1 &2 weighted average gross Heat Rate (NCV basis)	Kcal/kWh	1505.7
Auxiliary Power Consumption for the entire plant	%	3.41
NOx for each Block	PPM	50
Reference Condition		
Ambient Pressure	Bar (a)	1.0
Dry bulb Temperature	DEGC	27
Relative Humidity	%	77
LHV	KJ/KG	49328
CW inlet temperature	DEGC	32

5.1.2 Heat Rate Analysis

The table 5-2 describes the high-level results of the plant performance test conducted on 2nd and 3rd February.

Table 5-2 Gross Heat Rate Analysis

Unit	Perf. Test Output (Corrected)	Perf. Test HR (Corrected)	PG Test			CERC
			Output	HR	DIFF.	6HR
UOM	MW	kCal/kWh	MW	kCal/kWh	%	kCal/kWh
Block-1	344.62	1572.35	373.59	1504.9	4.43	1581
Block-2	344.7	1591.27	368.06	1505.5	5.68	1581

Table 5-3: Uncorrected & Corrected Heat Rate

DESCRIPTION	BASIS	UOM	DESIGN	BLOCK-1	BLOCK-2
Gross Load	Uncorrected	MW	363.3	335.70	339.19
	Corrected			344.05	344.70
Gross Heat Rate (NCV Basis)	Uncorrected	Kcal/kWh	1505.7	1622.02	1623.11
	Corrected			1572.35	1591.27

Table 5-4: Heat Rate Comparison between Expected (Degradation Curve) and Performance Test

UNIT	FIRED HOURS	EXPECTED HEAT RATE (KCAL/KWH)	TEST HEAT RATE (COR) (KCAL/KWH)	%DIFF. FROM EXPECT.	REMARKS
Block-1	70040.3	1527.9	1572.35	2.90	GT-1 Major inspection was done in 2021 at 56950 FFH
Block-2	60526.7	1521.5	1591.27	4.58	GT-2 Major Inspection is done in June 2022 at 55489 FFH.

Performance Analysis

The % difference from expected is higher in Block-2 due to following reasons.

- Lower bottoming cycle parameters in general specially pressure, temperature, flow rate at different sections of HRSG and ST cylinder
- Higher GT Inlet Filter DP i.e. 35 mm of H2O
- High back pressure

6 CERC tariff regulation 2019; Gas plant having COD on or after 1.04.2009 - 1.05 X Design heat rate of unit/ block at 100% MCR and at site ambient conditions, zero percent make up, design cooling water temperature/back pressure

The expected heat rate derived from degradation curve supplied by OEM, are based on multiple assumptions i.e. operations within design conditions, Waterwash frequency (on-line and off-line), inspection intervals, steam turbine back pressure etc. The expected heat rate is placed in the table to support the benefits of MI in block 2 with degradation getting reset to new lower value trajectory after MI.

Table 1 Expected vs. Actual (% HR Degradation)

	Dec'21 (Block 1 - After MI)			Feb'23 (Block 2 -After MI)		
	Fired Hours	Expected Degradation	Actual Degradation	Fired Hours	Expected Degradation	Actual Degradation
Block 1	60619.5	1.03%	1.32%	70040.3	1.48%	2.90%
Block 2	51903.8	2.34%	4.55%	60526.7	1.05%	4.30%

Expected Degradation – Based on BHEL curve, Actual Degradation - Based on Performance Test Corrected Value

Black & Veatch has summarized the major equipment efficiencies calculated from the performance test results and compared the results with design.

Table 5-5: Performance Test Comparison with Design

Efficiency	UOM	Design	Performance Test Results	
			Block-1	Block-2
Overall Efficiency of CCPP	%	57.12	54.33	54.23
Compressor Efficiency	%	92.41	87.02	86.98
Gas Turbine Efficiency	%	35.14	34.98	35.49
HRSG Efficiency	%	83.3	89.18	88.20
STG Efficiency (Shaft O/P / Heat I/P)	%	33.91	29.69	30.08
HP Turbine Efficiency	%	89.1	**85.12**	**85.86**
IP Turbine Efficiency	%	95.8	**94.16**	**94.51**
LP Turbine Efficiency (UEEP)	%	89.1	**66.25**	**64.89**

- CCPP efficiency for blocks 1 and 2 are evaluated using PTC 46 standard and values are found to be around 54.33% and 54.23% respectively against the design value of 57.12%.
- Compressor polytropic efficiency is reported as 87.02% and 86.98% compared to design of 92.41%.
- HP turbine section internal efficiency is found to be 85.12% and 85.86% respectively.
- LP turbine efficiency (based on useful energy end point) is found to be 66.25% and 64.89% respectively.

5.2 Gas Turbine

The below table describes the performance output results of block 1 and 2 gas turbines compared against the design values.

Table 5-6: Block 1 &2 GT Performance against Design Values

Parameters	Unit	Index	Design	Performance Test	
				GT-1	GT-2
GT Load (Uncorrected)	MW	A	232.39	224.77	221.73
[7]GT Load (Corrected)	MW	Acor.	232.39	225.78	229.211
Fuel Flow	SM3/Hr	B	66738	65432.64	66157.85
LHV	Kcal/M3	C	8313.87	8321.773	8321.724
Ambient temperature	Deg C		27	27.67	27.44
GT Efficiency	%	860/[(BXC)/ AX1000]	35.14	36.09	35.94
GT Corrected Gross Heat Rate (LHV basis)	Kcal/kWh	D	2447.66	2382.76	2392.98
Specific Fuel Consumption	Kg/kWh	[BXRHO/AX1000]	0.21	0.211	0.209

[7] GT Load is corrected for ambient pressure, ambient temperature, RH, fired hours, frequency, LHV and power factor.

- GT efficiency is found to be 36.09% and 35.94% respectively and is within expected range. The calculation of efficiency is performed on GT corrected power output by direct method.
- Specific fuel consumption for blocks 1 and 2 at 0.211 and 0.235 kg/kWh respectively are noted to be higher than the design value of 0.21 kg/kWh.

5.3 Axial Compressor Performance

Parameters	Units	Index	Design	Block 1	Block 2
Compressor Inlet Pressure	kg/cm2	A	1.02	0.967	0.977
Compressor Discharge Pressure	kg/cm2	B	16.83	14.19	14.13
Compressor Inlet Air Temperature	Deg. C	C	27	27.67	27.44
Compressor Discharge Air Temperature	Deg. C	D	410	412.09	413.37
Air Flow	Kg/sec	E	602.59	596.42	586.71
IGV Angle	Deg	F		87.10	87.21
Combustion Turbine Gross Load (Site)	MW	G	232.39	224.77	221.73
Compressor Adiabatic Efficiency	%	F(PR,[8]Gc)	92.99	81.94	81.86
Polytropic Coefficient	-	K=[LN (PR)/LN(PR/TR)]	1.415	1.46	1.46
Polytropic Efficiency	%	F(K,Gc)	**95.13**	**87.02**	**86.98**
Compressor Pressure Ratio	-	PR=B/A	16.5	14.67	14.46
Compressor Temperature Ratio	-	TR=D/C	2.276	2.28	2.28

- GT compressor efficiency as per test data is found to be 87.02 % and 86.98% for block 1 and 2 respectively. During test, block 1 and 2 was operated at 224.77 MW and 221.73 MW respectively.
- The pressure ratio during test condition is calculated to be 14.67 and 14.46 respectively against design of 16.5. The air flow through compressor was calculated based on the difference in the flow of GT exhaust and natural gas mass flow rate.
- Overall, the performance of compressor is satisfactory.

During the site visit, Black & Veatch was informed about filter replacement cycle being twice in 1 year, generally 1 each in summer and winter cycle. This cycle of replacement is despite inlet air pulsation system being operational for the two units.

5.3.1 Recommendations:

5.3.1.1 Inlet Air Filter Replacement Cycle

Due to increase of fine dust in the ambient air, fine filters are getting exhausted within 4-6 months. This filter replacement requires shutdown of the unit. We recommend exploring the possibility of

[8] Gc – Gas Coefficient (Inlet and Outlet of Compressor)

installing Coalascer pad rolls before the prefilters. These Coalascer pads have good dust holding capacity. These pads can be changed online whenever these get choked.

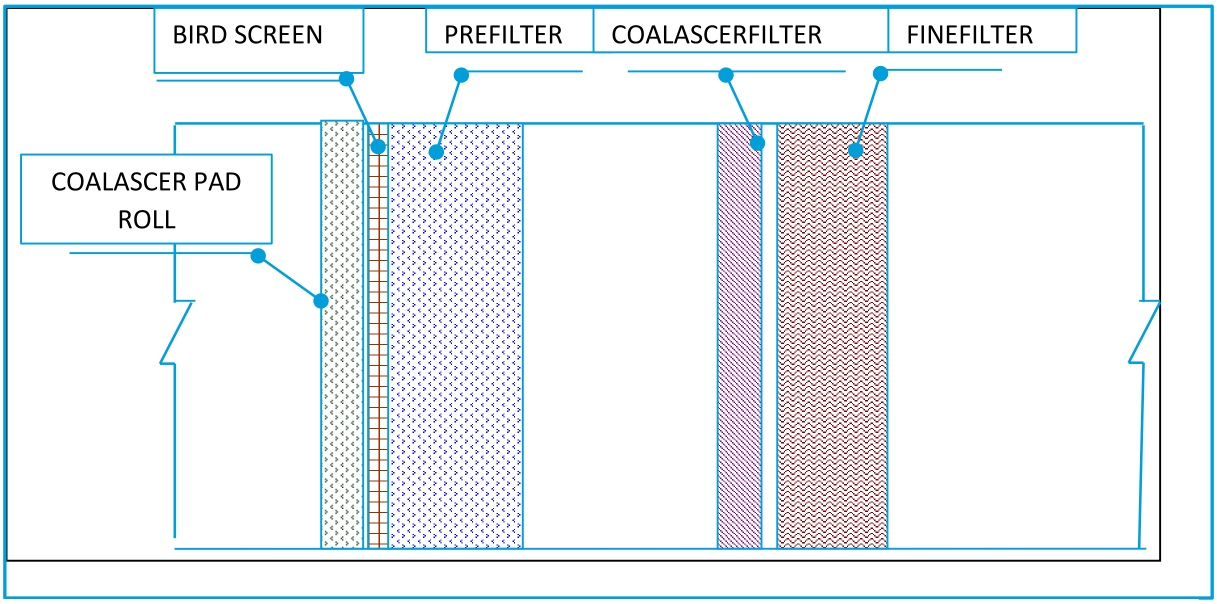


Figure 3 Coalascer Pad

The installation of coalescer pad rolls before bird screen will increase pressure drop (generally a pressure drops of 50 Pa impacts GT efficiency by 0.1%) but normally these pads are changeable on-line with ease and also extend filter replacement cycles. This modification is to be consulted with OEM and filter manufacturer before implementation for site specific environmental condition. The other possibility is upgrading / replacing fine filters to EPA grade (E10 or E11) without coalescer pad, but here also – there is a benefit-loss assessment with higher inlet air -dP (loss) and lower fouling in compressor (gain) as described above.

5.4 HRSG Performance

5.4.1 Design Parameters

The below table describes the design parameters of HRSG 1 & 2 as per the technical diary shared by OTPC.

Table 5-7: HRSG Design parameters

PARAMETERS	VALUES
HP Feed water Pressure, temperature, flow	158 kg/cm2, 152.1 DEGC, 289.6 TPH
HP Drum Pressure, temperature	145 kg/cm2, 339 DEGC
HP Main steam Pressure, temperature, flow	134 kg/cm22, 540 DEGC, 289.6 TPH
IP Feed water Pressure, temperature, flow	100 kg/cm2, 152.1 DEGC, 65 TPH
IP Drum Pressure, temperature	36.6 kg/cm2, 246 DEGC
IP SH outlet steam Pressure, temperature, flow	34.6 kg/cm22, 330 DEGC, 35.6 TPH
LP Feed water Pressure, temperature, flow	6.6 kg/cm2, 149.6 DEGC, 36.7 TPH
LP Drum Pressure, temperature	5.1 kg/cm2, 159 DEGC

PARAMETERS	VALUES
LP SH outlet steam Pressure, temperature, flow	4.4 kg/cm22, 230 DEGC, 36.7 TPH
CRH Inlet Pressure, temperature	34.8 kg/cm2, 345 DEGC
HRH outlet Pressure, temperature	33.2 kg/cm2, 540 DEGC
HRSG inlet pressure, Temperature, flow (flue gas)	266.71 mmWC, 700 DEGC, 2217.6 TPH

The below table describes the HRSG 1and 2 full load operating parameters compared against the design full load parameters and PG test DCS screenshot values (instantaneous).

Table 5-8: HRSG 1 and 2 full load parameters and comparison with design values

PARAMETERS	UOM	DESIGN	HRSG-1		HRSG-2	
			PG Test	Perf.Test	PG Test	Perf.Test
HP Main Steam Pressure,	Kg/cm2	134	129.09	126.0	126.80	122.84
HP Main Steam temperature	Deg C	540	536.05	530.6	541.00	534.6
HP Main Steam flow	TPH	289.6		292.3		286.9
IP Main Steam Pressure,	Kg/cm2	34.6	33.93	33.56	31.97	32.55
IP Main Steam Temperature	Deg C	330	312.76	312.2	326.27	327.06
IP Main Steam Flow	TPH	35.6		34.74		35.9
CRH Inlet Pressure,	Kg/cm2	34.8	33.61	35.98	30.97	34.22
CRH Inlet Temperature	Deg C	345	344.71	350.27	NA	353.22
HRH Outlet Pressure	Kg/cm2	33.2	32.71	35.02	31.90	33.30
HRH Outlet Temperature	Deg C	540	538.90	538.1	541.00	538.16
Feedwater outlet temperature	Deg C	152	147.45	149.73	149.44	149.12

5.4.2 HRSG Efficiency

The below table indicates the HRSG-1 & 2 main parameters and efficiency values from performance test output results at the GT baseload condition.

Table 5-9: HRSG Efficiency Results

PARAMETERS	UNIT	BLOCK-1	BLOCK-2
HP steam production / hr	TPH	290.9	286.9
HP steam Enthalpy	kcal/kg	818.3	821.7
IP steam production / hr	TPH	33.8	35.9
IP steam Enthalpy	kcal/kg	719.8	729.4
LP steam production / hr	TPH	36.9	36.5
LP steam Enthalpy	kcal/kg	699.7	699.0
HRSG inlet temp	Deg C	622.0	614.8

PARAMETERS	UNIT	BLOCK-1	BLOCK-2
HRSG outlet temp	Deg C	105.2	103.4
Air flow rate	TPH	2328.1	2366.6
HP Feedwater Enthalpy	kcal/kg	149.7	149.1
IP Feedwater Enthalpy	kcal/kg	147.7	146.6
LP Feedwater Enthalpy	kcal/kg	143.6	144.3
[9]HRSG (Eff)	%	89.18	88.20

- Black & Veatch has calculated the HRSG Efficiency by Input/Output method and noted that HRSG 1& 2 efficiencies are noted to be around 89.18% and 88.20% against the design value[10] of 83.35%.

5.4.3 LP Circuit Performance

The below table describes the performance of the LP circuit based on performance test results.

Table 5-10: LP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	TEST	
				HRSG-1	HRSG-2
LP Feed Water Pressure	Kg/cm2	10.4		13.4	13.6
LP Feed Water Temperature	Deg C	149.5	[A]	143.6	144.3
Enthalpy of LP Feed Water	Kcal/kg	150.7		144.6	145.3
Energy from LP FW	Kcal/sec	1536.43	[C]	1422.8	1455.0
LP Drum Pressure	Kg/cm2	5.1		4.8	4.8
LP Saturation Temperature	Deg C	158.92	[B]	157.4	157.5
LP Main Steam Flow	TPH	36.7	[E]	35.4	36.1
LP Main Steam Pressure	Kg/cm2	4.8		4.7	4.6
LP Main Steam Temperature	Deg C	229		235.5	234.5
LP Steam Enthalpy	Kcal/kg	696.9	[F]	699.5	699.0
Energy From LP Steam	Kcal/sec	7105.08	[D=E*F]	6881.8	7000.1
Energy Gain from LP Circuit	Kcal/sec	5568.65	[D-C]	5459.0	5545.1
Approach	Deg C	9.42	**[B-A]**	**13.7**	**13.2**

- The energy gain from the LP circuit is around 5459 and 5545 Kcal/sec for HRSG 1 & 2 respectively against the design values of 5568 Kcal/sec.

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[9] HRSG Efficiency is based on ratio of heat pick up in HP, IP, and LP circuit (output) and heat input from fuel gas across the control volume. [HP Steam flow X HP Steam Enthalpy Gain + IP Steam Flow X IP Steam Enthalpy Gain + RH Steam Flow X RH Steam Enthalpy Gain + LP Steam Flow X LP Steam Enthalpy Gain] / [Flue Gas Flow Rate X (HRSG Inlet Temp – HRSG Outlet Temperature) X Cp of Gas] *100

[10] Design details are calculated based on the design data available in technical diary and heat balance diagram.

- LP circuit approach is found to be around 13.7 and 13.2 Deg C respectively for HRSG 1 and 2 against the design value of 9.42 deg C.

5.4.4 IP Circuit Performance

The below table describes the performance of the IP circuit based on performance test results.

Table 5-11: IP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
IP Feed Water Flow	TPH	65.16		55.62	70.09
IP Feed Water Pressure	Kg/cm2	43.6		54.44	52.73
IP Feed Water Temperature	Deg C	150.2		147.73	146.64
Enthalpy of IP Feed Water	Kcal/kg	121.7		149.42	148.28
Energy from IP FW	Kcal/sec	2202.91	G	2308.52	2886.81
IP Drum Pressure	Kg/cm2	36.6		37.02	35.77
IP Saturation Temperature	Deg C	244.01	[B]	247.40	245.46
IP Main Steam Flow	TPH	35.8	[D]	33.82	35.90
IP Main Steam Pressure	Kg/cm2	36.6		33.56	32.55
IP Main Steam Temperature	Deg C	246		312.20	327.06
IP Steam Enthalpy	Kcal/kg	730.2	[E]	719.80	729.39
Energy From IP Steam	Kcal/sec	7262.01	F=D*E	6762.11	7272.68
Energy Gain from IP Circuit	Kcal/sec	5059.1	H=F-G	4453.59	4385.87
IP Economizer Outlet Temp.	Deg C	231	[B]	228.69	231.11
[11]Approach	Deg C	13.01	**[B-A]**	**18.71**	**14.35**

- Energy gain from the IP circuit is around 4453.59 and 4385.87 Kcal/sec for HRSG 1 & 2 respectively against the design values of 5059 Kcal/sec.
- IP circuit approach is found to be around 18.71 and 14.35 Deg C respectively for HRSG 1 and 2 against the design value of 13.01 deg C.
- Higher approach signifies reduced hear transfer in the economizer section either due to internal/ external fouling or surface area constraints. The assumption is that upstream parameters of HRSG like feedwater pressure, temperature is close to expected range. Please note that before inferring heat transfer issues, it is important that a trend of degradation is established over time with correct measuring points.

[11] Approach = IP economizer feed water outlet temperature – Saturation temperature corresponding to IP drum pressure

- Heat pick-up in the HRSG -1 IP circuit is observed to be below the design (~9-10%). The difference is attributable to lower IP steam flow rate and enthalpy and higher IP feed water inlet enthalpy with the addition of 6.48 TPH spray in bypass.
- Heat pick-up in the HRSG-2 IP circuit is lower due to higher IP feed water flow caused by IP bypass spray flow of 19.46 TPH. This has also impacted reheat circuit energy gain.

5.4.5 HP Circuit Performance

The below table describes the performance of the HP circuit based on performance test results.

Table 5-12 HP Circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
HP Feed Water Flow	TPH	289.6	[H]	290.12	284.64
HP Feed Water Pressure	Kg/cm2	158		147.69	144.98
HP Feed Water Temperature	Deg C	152.1		149.05	147.91
Enthalpy of HP Feed Water	Kcal/kg	155.5	[I]	152.15	150.95
Energy from HP FW	Kcal/sec	12510.11	[G=H*I]	12261.64	11935.58
HP Drum Pressure	Kg/cm2	145		137.08	134.31
HP Saturation Temperature	Deg C	338.46	[B]	335.59	329.4
HP Main Steam Flow	TPH	289.6	[E]	300.15	291.95
HP Main Steam Pressure	Kg/cm2	135		125.97	122.84
HP Main Steam Temperature	Deg C	540		530.57	534.62
HP Steam Enthalpy	Kcal/kg	821.8	[D]	818.32	821.67
Energy From HP Steam	Kcal/sec	66114.53	[F=D*E]	68227.21	66635.59
Energy Gain from HP Circuit	Kcal/sec	53604.42	[F-G]	55965.57	54700.02
HP Economizer Outlet Temp.	Deg C	334.19	[A]	331.20	**318.2**
[12]Approach	Deg C	4.27	[B-A]	4.40	**11.2**

- Energy gain from HP circuit is around 55965.57 and 54700 Kcal/sec for HRSG 1 & 2 respectively against the design values of 53604 Kcal/sec.
- HP circuit approach is found to be around 4.40 and 11.20 Deg C respectively for HRSG 1 and 2 against the design value of 4.27 deg C. In general, steam parameters (pressure and temperature) in HP sections are observed to slightly lower if compared to design or Unit 1. Unit specific variation in operating characteristic within range is normal, however this variation should be continuously checked.

[12] Approach = HP economizer feed water outlet temperature – Saturation temperature corresponding to HP drum pressure

- Approach signifies heat transfer gain in the superheater section of HRSG from the fuel gases. HRSG for HP Circuit 2 is high as we see lower HP economizer outlet temperature i.e. 318.9 Deg. C as compared to design of 334.19 Deg. C. Please note in general HP -2 pressure and temperature parameters are lower during the test. As noted above, a single point deviation is only a snapshot and a trend over time is to be analyzed with correct measurement to check any fouling in the tube section.

5.4.6 Reheater Circuit Performance

The below table describes the performance of the RH circuit based on performance test results.

Table 5-13: Re-heater circuit Performance

PARAMETERS	UNIT	DESIGN	INDEX	PERFORMANCE TEST	
				HRSG-1	HRSG-2
CRH Flow	TPH	269.45	[D]	270.67	266.72
CRH Pressure	Kg/cm2	35.85		35.98	34.22
CRH Temperature	Deg C	347.5		350.27	353.22
Enthalpy of CRH	Kcal/kg	740.3	[E]	741.03	743.67
Energy from CRH	Kcal/sec	55413.83	[F=D*E]	55714.37	55098.50
IP Feed water Flow	TPH	35.8		40.30	**55.36**
IP Feed Water Pressure	Kg/cm2	36.6		33.56	32.55
IP Feed Water Temperature	Deg C	246		312.20	327.06
IP Bypass Spray	TPH	0		6.48	19.46
Enthalpy of IP Feed Water	Kcal/kg	730.2		719.80	729.39
Energy from IP FW	Kcal/sec	7262.01	[G]	8057.75	11216.12
HRH Flow	TPH	305.045	[A]	307.70	306.43
HRH Pressure	Kg/cm2	33.3		35.98	34.22
HRH Temperature	Deg C	540		538.14	538.16
Enthalpy of HRH	Kcal/kg	846	[B]	844.73	845.15
Energy from HRH	Kcal/sec	71739.49	[C=A*B]	72200.10	71938.46
Total Energy into Re-Heater	Kcal/sec	62675.85	[H=F+G]	63772.12	66314.62
Energy Gain from Re-Heater	Kcal/sec	9063.64	[C-H]	8427.98	**5623.84**

- Energy gain from the reheater circuit is around 8427.98 and 5623.84 Kcal/sec for HRSG 1 & 2 respectively against the design values of 9063.6413Kcal/sec.

[13] Design heat pick up is calculated based on the design data available in the technical diary and heat balance diagram the design values

- Heat picks up in the HRSG-2 reheater circuit is lower due to higher IP feed water flow caused by IP bypass spray flow of 19.46 TPH. This has also impacted reheat circuit energy gain adversely if compared to design heat gain.

5.4.7 Recommendations

5.4.7.1 Suspected IP Bypass System Steam Passing & Steam Valve Upgrade

IP bypass controllers are also not able to effectively contain the steam and even hair line cracks in control valve may lead to significant flow of steam to condenser impacting condenser vacuum adversely. Our test data shows that IP bypass spray valve for Unit 1 and 2 was 6.48 TPH and 19.4 TPH respectively which suggest that there may be suspected steam flow in the downstream pipe, even though bypass valve position is shown as fully closed. It is necessary that suspected steam leakage in IP steam pipe is quickly arrested in available opportunity.

Unlike traditional control valves, there are designs which uses multi-stage, multi-turn technology divides the pressure reduction into many smaller stages. The number of turns, or stages, is selected to ensure a specific fluid discharge velocity is achieved at the exit of the control element. This reduces the potential for cavitation and erosion, that would otherwise compromise the valve's ability to effectively control leakage.

5.4.7.2 CBD Tank Vents Open to Atmosphere

As per the design, the Continuous Blow-Down Tank (CBD) vent is routed to Deaerator however, based on site-visit discussions, it is understood that for both units, CBD vent lines are kept open to atmosphere. CBD vent should be routed to the Deaerator for fluid recovery and improved energy utilization.

5.5 Steam Turbine

The below table indicates the performance output results of ST-1 and 2 at the GT baseload condition.

Table 5-14: Steam Turbine Performance

Parameters	Unit	Design	Performance Test	
			ST-1	ST-2
Unit Load	MW	130.91	112.81	113.64
MS Pressure	Kg/cm2	133.88	125.97	122.84
MS Temperature	Deg C	537.8	530.57	534.62
HP Exhaust Pressure	Kg/cm2	37.03	34.12	32.33
HP Exhaust Temperature	Deg C	347.3	348.76	347.95
HRH Pressure (IP Turbine Inlet)	Kg/cm2	34.4	33.56	32.55
HRH Temperature (IP Turbine Inlet)	Deg C	539.6	538.14	538.16
IP Turbine outlet pressure	Kg/cm2	5.04	4.71	4.21
IP Turbine outlet temperature	Deg C	264.5	282.17	274.45
LP Turbine inlet pressure	Kg/cm2	4.96	4.63	4.21
LP Turbine inlet temperature	Deg C	261.2	235.58	233.60
LP Turbine outlet pressure	Kg/cm2	0.088	0.200	0.173
LP Turbine outlet temperature	Deg C	NA	58.41	56.39

Parameters	Unit	Design	Performance Test	
			ST-1	ST-2
HP FW Flow	TPH	289.6	290.12	284.64
HP SH Attemperation Flow	TPH	0.00	10.03	7.31
IP FW Flow	TPH	65.15	55.62	70.09
IP SH Attemperation Flow	TPH	0.00	6.48	19.46
RH Attemperation Flow	TPH	0.00	3.76	3.16
STG Thermal Efficiency (Design 36.66)	%	36.66	32.32	29.93
HP Turbine Cylinder Efficiency(design-89.1%)	%	89.79%	**85.12**	**85.86**
IP Turbine Cylinder Efficiency(design-95.8%)	%	95.78%	**94.16**	**94.51**
LP Turbine Cylinder Efficiency(design-89.1%)	%	89.04%	**66.25**	**64.89**

5.5.1 Recommendations:

5.5.1.1 HP/IP Section Internal Efficiency Improvement by Seal Upgrade

Leakage losses represent the greatest portion of turbine stage losses. The losses are magnified as the turbine packing and turbine diaphragm spill strips wear out progressively. A large amount of these losses is recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization.

New turbine blade cover and nozzle spill strip designs are available which greatly reduce turbine blade tip leakage losses. New interstage and end packing will reduce packing leakage losses, resulting in more steam available to power the turbine blades. Retractable packing and brush seal packing designs are available from various manufacturers, which aim to reduce leakage losses even further from original designs. This upgrade can be performed at the HP/IP turbine major inspection and should be performed after engineering analysis and in consultation with OEMs.

The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP and IP turbine efficiencies. Typical efficiency improvements up to 0.7-1.2 % in heat rate is reported in the past. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.

The retrofit requires checking the actual clearances of the seals with respect to manufacturer's design clearances[14]. This task will help assess the extent of wear in the seals or help to find out the deviation of clearances from manufacturer's design clearances.

Replacement of existing seals with superior quality seals[15]. A generally guideline for replacement of seals is provided in the table below.

[14] Manufacturer's design clearances were not available.
[15] Option is feasible only when the slots provided by manufacturer fit with new type of seal

Table 5-15 General Guideline for Seal Replacement

Seal	Type
HIP Inter stage	Double stepped
HP turbine seals	Stepped
IP Turbine seal	Stepped
LP turbine seal	Plain seal

Actual clearances if found to be deviating from design clearances, it is recommended to explore the replacement and upgrade of the seals during the capital overhaul at 100,000 hours of steam turbine operation. Following are recommended seal types and arrangements based on industry best practices.

Vernier labyrinth seal: Seals provide better leakage resistance. The gland is independent of differential expansion. Both the shaft and seal ring are finned, the pitch of the fins being slightly different on the two seal components. This has the advantage that some of the fins will always be directly opposite, providing a greater restriction.

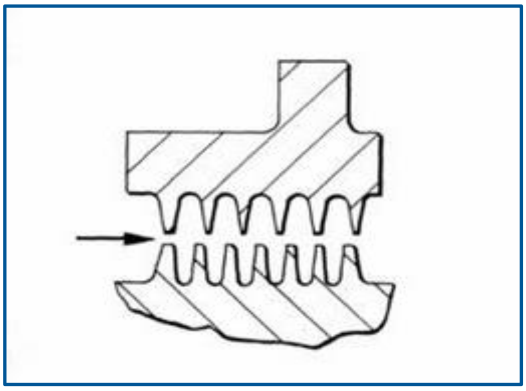


Figure 4 Vernier Labyrinth Seal

[16]**Spring backed labyrinth seal:** The radial clearance of the labyrinth gland is kept to minimum to minimize leakage across the gland (leakage is proportional to leakage area). The effects of rub are minimized in close clearance glands by making glands spring loaded.

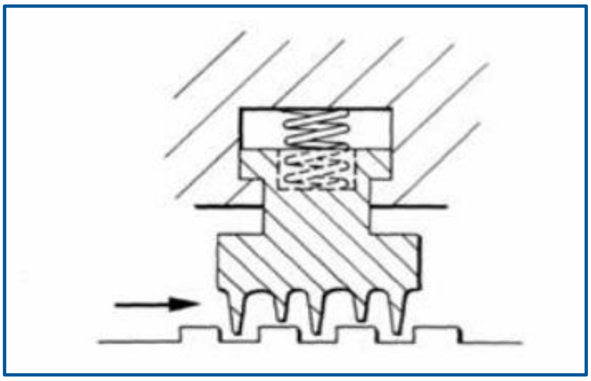


Figure 5 Spring Loaded Vernier Labyrinth Seal

[16]Power Plant Engineering, Black & Veatch

Labyrinth Glands with Fins in Radial & Axial Direction: The design increases the number of restrictions in a given gland length. The thickness of gland tip is kept minimum to avoid rubbing or if accidental rubbing happens, the heat generated is minimum.

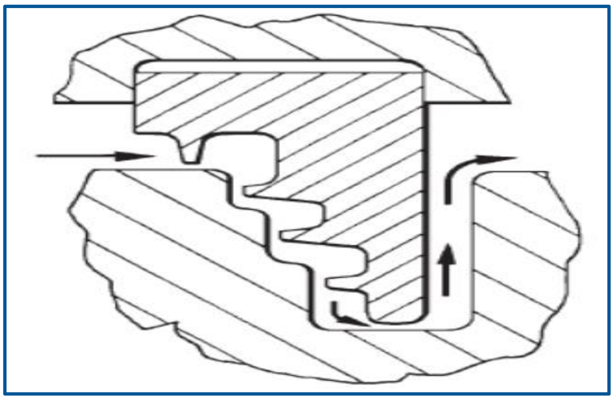


Figure 6 Labyrinth Glands with Axial and Radial Fins

5.5.1.2 Determination of HP to IP Leakage Flow (Temperature Inference Method)

The N2 packing leakage to IP turbine bowl is calculated using the temperature inference method. This method is an indirect method to determine the magnitude of leakage flow, since this leakage flow is inside the turbine, and it is impractical to directly measure it. Determination of the leakage flow shall also determine the true IP turbine efficiency. The leakage flow may be somewhat greater than or less than the actual design flows, depending upon the packing clearance and stage pressure.

A diagrammatic representation of available parameters for HP-IP turbine is shown below.

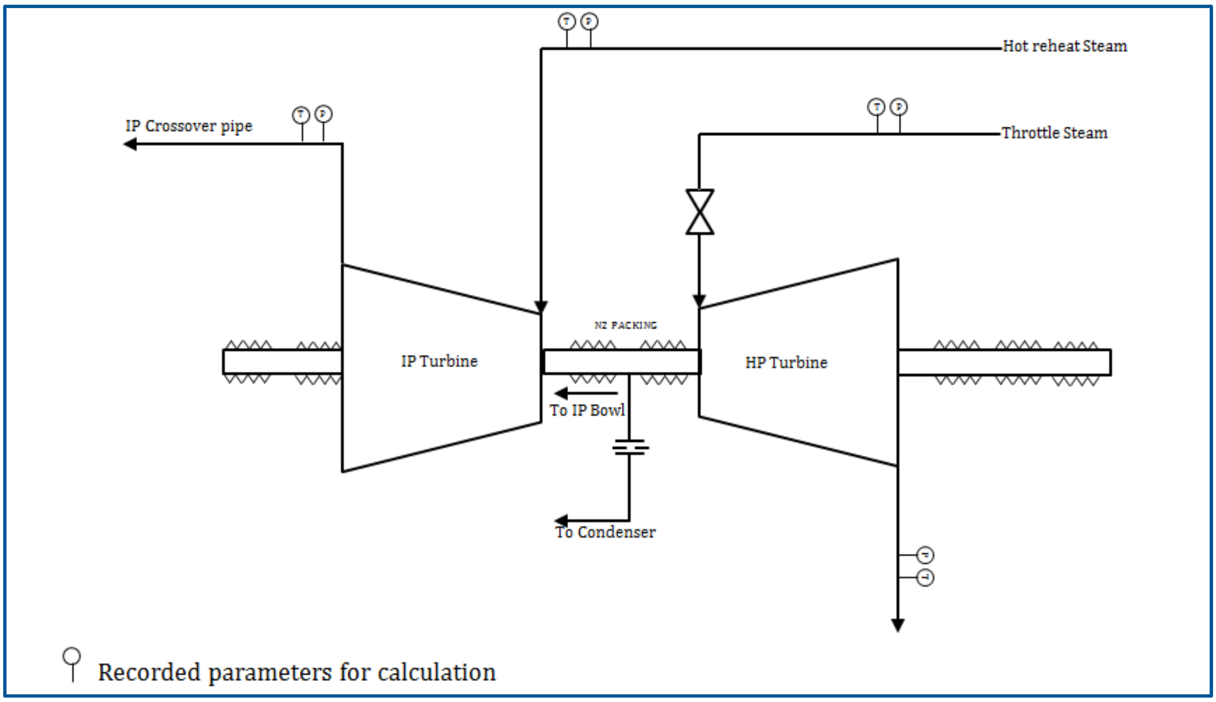


Figure 7 Determining HP-IP Leakage (Temperature Inference Method)

The basis of the temperature inference method is that IP section efficiency remains constant over the operating range. The method is based upon cooling effect that the internal HP to IP packing leakage on the apparent IP section efficiency.

The leakage from HP to IP section is generally cooler than the steam entering in the IP bowl, thereby yielding a reduced enthalpy condition at the IP exhaust and corresponding change in the "apparent" enthalpy efficiency drop.

The HP steam leaking to the IP cools the steam in the IP yielding an erroneously high value of measured IP efficiency, if not properly compensated. The amount of error in IP efficiency will vary according to the difference in enthalpy between the leakage steam and hot reheat steam. In this method, If initial temperature is raised and reheat temperature is decreased, this error will decrease and conversely it will increase if initial temperature is lowered and /or reheat temperature is increased.

In this method, at least three tests are run with variation in initial and reheat temperature. For each of the three tests, the measured IP efficiency for various assumed values of HP to IP leakage may be calculated. A curve of IP efficiency versus assumed leakage flow, as a percent of reheat flow is plotted. The lines for each test run will intersect at a point that indicates the actual HP to IP leakage and the actual IP turbine efficiency.

The temperature inference method is provided in **ASME PTC 6.2** code (***Please refer section C5 : Guiding Principle for Temperature Inference, IP Efficiency Plot and Ratio of Slopes Methods"***). In this method, at least three test runs are recommended with variation in main steam and reheat temperature.

For each of the three tests, the measured IP efficiency for various assumed values of HP to IP leakage may be calculated. A curve of IP efficiency versus assumed leakage flow as a percent of reheat flow is plotted. The lines for each test run will intersect at a point that indicates the actual HP to IP leakage and the actual IP turbine efficiency. An indicative methodology is provided, however please note that this is to be designed for individual units reviewing operational constraints and applicable temperature drop achievable without impacting the equipment adversely.

This test is to be carried out to estimate the N2 packing leakage between the HP and IP sections of the turbine. This is calculated by using the enthalpy drop test. Test procedure is as follows: -

- Maintain 100% load of the unit and main steam and hot reheat temperatures at base value. Once the parameters are stable test run will be carried out for 1 hour.
- Maintain MS temperature at base level and reduce the HRH temperature.
- Once the parameters are stable test run will be carried out for 1 hour.
- Bring the HRH temperature back to base value and then reduce MS temperature. Once the parameters are stable test run will be carried out for 1 hour.
- Retrieve the data for the steam parameters, estimate IP efficiency and perform the graphical analysis as described above for estimating HP-IP internal leakage.

5.5.1.3 Improving LP Turbine Efficiency by Improved Blade Design and Increased Annulus Area

The steam seal upgrade tends to decrease heat rate and increase LP turbine efficiency. The new gland seals also reduce the in-air leakage around the shaft. The improved gland seal reduces the amount of air that enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air in-leakage through improved seals can decrease (improve) back pressure by 4-12 KPa absolute with a corresponding heat rate improvement of nearly 1.0%.

Large OEMs globally also provide customized retrofit packages consisting of replacement of low-pressure turbine blades using improved blade design and increased exhaust annulus area to improve performance. The performance gain in the LP section based on industry experience is commendable with output increasing up to 1.00% and heat rate reduction up to 0.75% with only steam seal upgrades. The replacement is normally doable in capital overhaul, however the need for this retrofit to be carefully worked out evaluating turbine internal condition and aging of the machine.

The last stage buckets are responsible for approximately 10% of the turbine's total output. Redesign of the last stage buckets, including increasing length, reduces exhaust loss by increasing the amount of energy removed from the steam. This increases capacity and decreases heat rate. The project includes replacing the last stage LP turbine buckets or blades with new longer blades. Replacing the last stage diaphragm is also recommended to maximize efficiency gain. Longer last stage buckets reduce exhaust losses by maximizing the amount of energy extracted from the steam. This is done by increasing the area of the last stage to reduce exhaust velocity. Performance gains from replacing the last stage buckets is dependent on where the unit operates on the Exhaust Loss Curve. Combined with last stage bucket replacement, up to 3% improvement in output and 2.5% reduction in heat rate can be realized.

5.5.1.4 Performance Monitoring of HP Turbine Section & In-Situ Instrumentation for HP Exhaust Pressure and Temperature

One of the most critical measurements for analyzing HP turbine internal efficiency is HP turbine exhaust temperature. The ASME PTC test code 46 specifies this measurement to be close to HP turbine exhaust. Figure 5 below specifies the preferable location of measurement. Minimum 2 measurement of HPT exhaust temperature is recommended with instrument of 1 Deg. F or 0.56 Deg. C accuracy class for best results. HP exhaust pressure measurement is also recommended with an instrument of accuracy class 0.1%. The criterion for accuracy is stringent given the nature of calculations and its criticality to predict overall turbine internals condition.

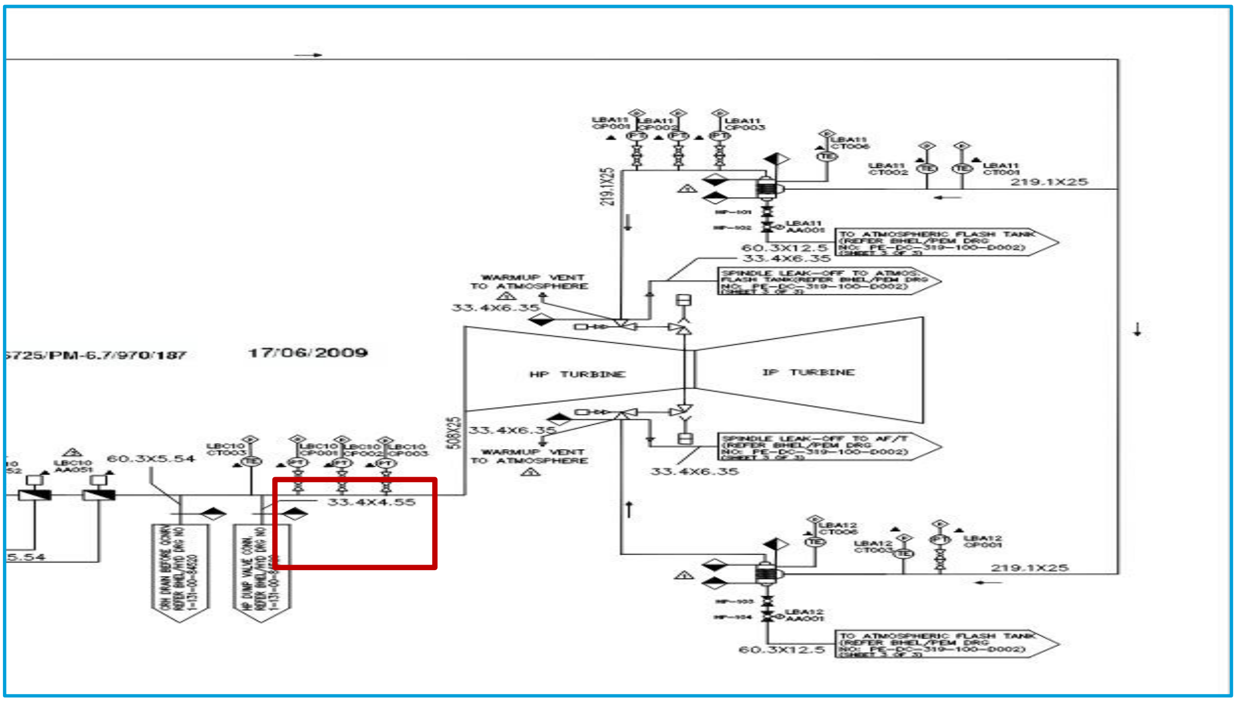


Figure 8 HP Exhaust Temperature Measurement

5.6 Condenser

The below table indicates the performance output results of Condenser-1 and 2 at the GT baseload condition against the design values.

Table 5-16:Condenser 1 & 2 Performance against Design performance

PARAMETERS	UNIT	DESIGN	INDEX	BLOCK -1	BLOCK-2
LP Exhaust Steam Flow	TPH	354.3		361.54	359.30
CW Inlet temperature	Deg C	32	[F]	34.33	31.18
CW outlet temperature	Deg C	41	[G]	44.30	40.57
Delta P (Difference) - LHS	mwc	**6**		**12.644**	
Delta P (Difference) - LHS	mwc	**6**		**12.972**	**12.380**
CW Flow	M3/hr	21000		23041	23044
Delta T (Difference)	Deg C	9	[H=G-F]	9.97	9.39
Vacuum	Kg/cm2(a)	0.095		0.200	0.1731
Saturation temperature	Deg C	44.43	[E]	59.64	56.56
Hot well temperature	Deg C	44.43		58.41	56.39
Sub-cooling	Deg. C	0		1.23	0.17
Dissolved O2 (Condensate)	ppb			17.86	3.13
TTD	Deg C	3.43	[E-G]	15.34	16.00

PARAMETERS	UNIT	DESIGN	INDEX	BLOCK -1	BLOCK-2
LMTD	Deg C	7.08	**H**	**19.9**	**20.3**
[17]Estimated Heat Duty	MW	**286.098**	**"U"*A*[H]**	**267.281**	**275.933**
Actual Heat Transfer Coefficient	kCal/hr-m2-C		[A]	1210.35	1154.12
Max. Possible Heat Transfer (100% Clean Tubes)	kCal/hr-m2-C		[B]	3718.91	3667.26
Cleanliness	-	0.8	**[A/B]**	**0.33**	**0.31**

- Condenser vacuum is reported as 0.200 kg/cm2 (a) and 0.173 kg/cm2 (a) at inlet CW temperature around 34.33 and 31.11 deg C in Unit 1 and 2 respectively.
- Condenser cleanliness is found to be around 0.33 and 0.31 respectively for condensers 1 and 2 against a design value of 0.80.

5.6.1 Back Pressure Deviation Check

Black & Veatch further analyzed the reasons for the higher back pressure in both units. The expected backpressure is calculated based on the design inlet parameters at clean condenser conditions.

Table 5-17: Unit 1 Condenser Spot back Pressure Check (Actual Vs Expected Analysis)

Back Pressure Check	UNIT	INDEX	Unit 1	Unit 2
Load	MW		112.81	113.64
Actual back pressure	bar	[F]	0.196	0.170
CW inlet temperature	Deg. C		34.33	31.18
CW outlet temperature	Deg. C		44.30	40.57
Hot Well Temperature	Deg. C		61.61	57.98
Barometric pressure	bar		1.006	1.005
Actual Back Pressure	kPa		**19.61**	**16.96**
Saturated Steam Temperature	Deg. C		59.64	56.54
Actual CW rise	Deg. C		9.969	9.39
Actual TTD	Deg. C		15.34	15.97
Expected back pressure	kPa	**[A]**	**10.24**	**9.00**
Optimum CW rise (From HBD @33 CW Inlet)	Deg. C		9.00	9.00
Optimum TTD (From HBD)	Deg. C		3.50	3.50
Back pressure due to CW inlet temp	kPa	[B]	15.71	14.25
Back pressure due to CW flow	kPa	[C]	16.17	14.42

[17] Condenser design heat duty – 246 mkCal/hr.
Estimated Heat Duty = Overall heat transfer coefficient*Surface Area of Condenser Tubes* LMTD

Back Pressure Check	UNIT	INDEX	Unit 1	Unit 2
Variation due to CW inlet temp. **= Back Pressure due to CW inlet temp – Target Back Pressure**	kPa	**[D=A-B]**	**5.47**	**5.25**
Variation due to CW flow **= Back Pressure due to CW flow – Back Pressure due to CW inlet temp**	kPa	**[E=C-B]**	**0.46**	**0.18**
Variation due to air/dirty tubes TTD **= Actual Back Pressure – Back Pressure due to CW flow**	kPa	**[F-C]**	**3.44**	**2.53**

Given the CW Inlet temperature of 34.33 Deg. C and 31.18 Deg. C for Condenser 1 and 2, If we consider design range of 9 deg. C (i.e. difference of CW inlet and outlet temperature) and [18]design TTD of 3.50 deg. C, we expect the back pressure to be 10.24 kPa and 9.00 kPa respectively. The back pressure measured at the test period was 19.61 kPa and 16.96 kPa respectively.

The deviation in back pressure due to CW inlet temperature is for Unit 1 is due to high CW inlet temperature (34.33Deg. C compared to design of 32 Deg. C) and high heat load. Please note that LP exhaust flow is higher by 7.24 TPH than design of 354.3 TPH with expected higher enthalpy steam entering condenser.

The gap in expected and actual vacuum is 9.37 kPa and 7.96 kPa respectively. The assessment shows that majority of back pressure deviation in Unit 1 (~37%) is attributable to impact of air ingress or dirty tubes. In Unit 2 (~32%) of back pressure deviation is attributable to air ingress / dirty tube.

Further evaluation of DP (delta pressure) across condenser suggests that delta P across both water boxes is much higher than design limits of 6 mwc. DO levels are also found to be higher in condensate water specially for Unit 1 which is 17.86 ppb.

Table 5-18 Condenser Parameters

PARAMETERS	UNIT	DESIGN	BLOCK-1	BLOCK-2
LP Exhaust Steam Flow	TPH	354.3	361.54	359.30
CW Inlet temperature	Deg C	32	34.33	31.18
CW outlet temperature	Deg C	41	44.30	40.57
Delta P (Difference) - LHS	mwc	**6**	**12.644**	**NA**
Delta P (Difference) - LHS	mwc	**6**	**12.972**	**12.380**
Dissolved O2 (In Condensate)	ppb	**-**	**17.86**	**3.13**
Condenser Cleanliness	-	**0.80**	**0.33**	**0.31**

5.6.2 Review of Condenser Cleanliness

The inspection was carried out on 21st June and 23rd June 2022 for Unit 2 during MI.

[18] Minor variation in TTD with CW inlet temperature is estimated based on HBDs. The HBD referred are PE-DC-319-100-D101, PE-DC-319-100-D106, PE-DC-319-100-D111 (100% CC load, 0% make up and 27 Deg. C, 9 Deg. C and 15 Deg. C ambient conditions respectively.

Observations After Opening of Condenser Water box :

- Tubes were choked from the slime and broken PVC fills.
- Tube sheet was not cleaned. Scales, depositions, slime and iron nodules were observed.
- Algae / organic growth was not concerning.
- No tube leakage observed while performing flood test.
- Issues found in water treatment (phosphate -zinc based compounds) for anti-scaling, bio-dispersion, corrosion inhibition, PH reduction and microbial control.

5.6.3 Condenser Instrumentation Adequacy

Plant operators and engineers require adequate instrumentation to continuously monitor plant operations, equipment health, and diagnostic of operation anomalies. As requested by OTPC, Black & Veatch has reviewed the instrumentation adequacy for calculating condenser performance.

5.6.3.1 Steam side Instrumentation:

Source: P&ID / 32-CONDENSATION SCHEME-21310084532-S00-R00

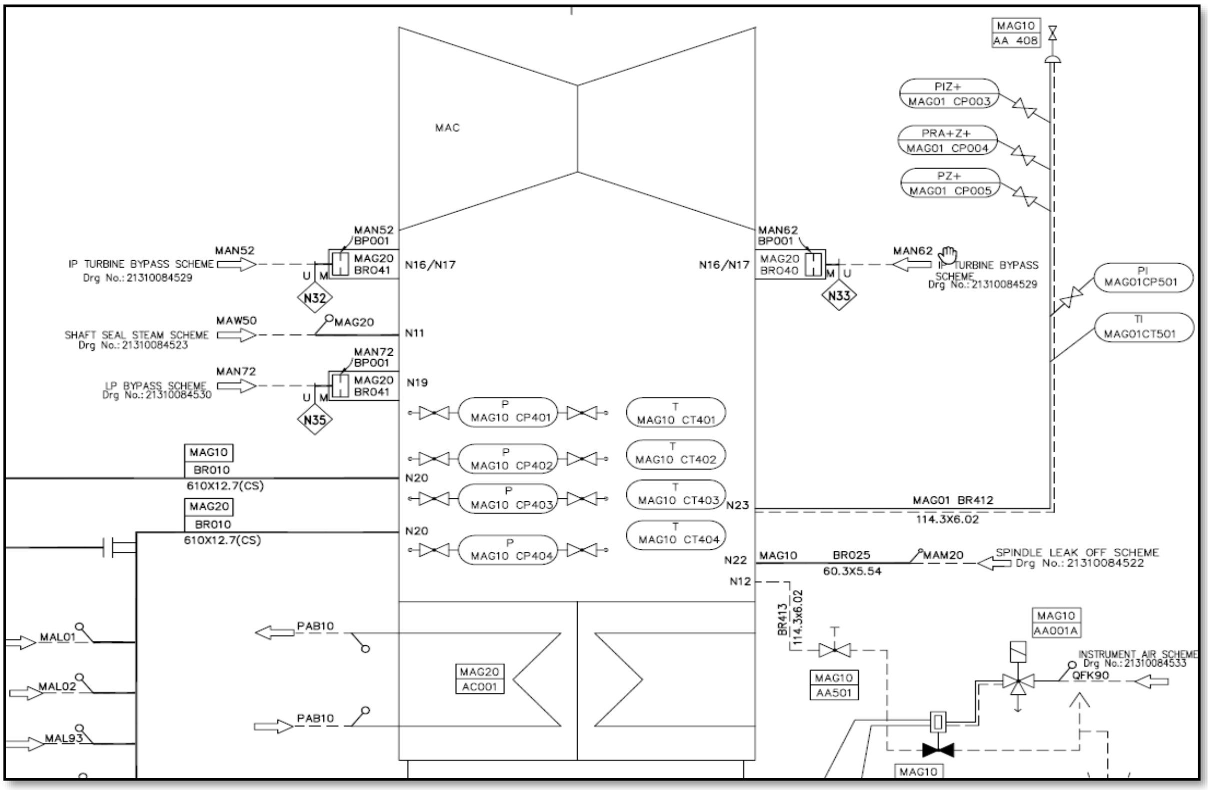


Figure 5-9: LP Turbine Steam Condensation System P&ID

As per the above P&ID and instrumentation schedule provided in the O&M manual (ONGC Steam Turbine/VOLUME-2 PART-2/Page no: 244), Black & Veatch understands that the following instrumentations are available for the condenser steam side measurements,

Table 5-19: Available Instruments for Condenser Steam Side Measurement

S.NO	MEASUREMENT	TAG NO
1	Condenser Pressure	MAG01 CP003

S.NO	MEASUREMENT	TAG NO
2	Condenser Pressure	MAG01 CP004
3	Condenser Pressure	MAG01 CP005
4	Condenser Pressure	MAG01 CP501
5	Condenser Pressure	MAG01 CP401
6	Condenser Pressure	MAG01 CP402
7	Condenser Pressure	MAG01 CP403
8	Condenser Pressure	MAG01 CP404
9	Condenser Temperature	MAG01 CT501
10	Condenser Temperature	MAG01 CT401
11	Condenser Temperature	MAG01 CT402
12	Condenser Temperature	MAG01 CT403
13	Condenser Temperature	MAG01 CT404
14	Vacuum Breaker Open	MAG10 CG051B
15	Vacuum Breaker Open	MAG10 CG051C

Black & Veatch opines that the instrumentation available for steam side measurements is adequate for calculating condenser performance. *The three condenser pressure instruments namely MAG01 CP003, CP004, and CP005 taken are used for the plant performance calculations.*

The below table describes the 2 hours average value of these three condenser pressure measurements taken during the performance test at full load conditions. ***Based on historian data made available to Black & Veatch, the sampling frequency of vacuum tags in DCS historian for Unit 1 are observed to be once every 60 minute which is very high. It is recommended to correct the tag sampling frequency in DCS to every minute interval.***

Table 5-20: Condenser Pressure Readings During Performance Test

BLOCK	TAG	AVERAGE VALUE IN
Block-1	11MAG01CP003XQ07.Out.Sample	0.2001
	11MAG01CP004XQ07.Out.Sample	0.1987
	11MAG01CP005XQ07.Out.Sample	0.2008
Block -2	21MAG01CP003XQ07.Out.Sample	0.1722
	21MAG01CP004XQ07.Out.Sample	0.1721
	21MAG01CP005XQ07.Out.Sample	0.1729

Black & Veatch recommend OTPC to ensure the calibration of all the instruments as recommended by OEM.

5.6.3.2 Waterside Instrumentation:

Source: P&ID/ PE-DG-319-165-N101 Rev 03 P&ID for CW-ACW SYSTEM

Black & Veatch has reviewed the instrumentation available in the CW waterside of the condenser for enabling condenser performance calculation as per the standards.

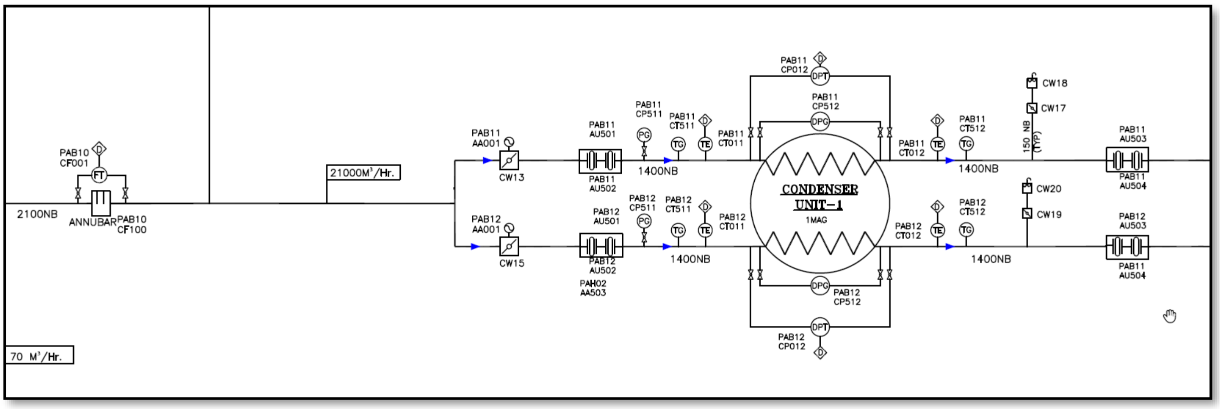


Figure 5-10: CW & ACW P&ID

As per the above P&ID, Black & Veatch understands that the following instrumentations are available at the condenser for waterside measurements.

Table 5-21: Available Instruments for Condenser Water Side Measurement

S.NO	MEASUREMENT	TAG NO
1	CW Flow (Annubar)	PAB10 CF001
2	CW Inlet Pressure Pass- 1	PAB11 CP511
3	CW Inlet Pressure Pass- 2	PAB12 CP511
4	CW Inlet Temperature Pass -1	PAB11 CT511
5	CW Inlet Temperature Pass -2	PAB12 CT511
6	CW Inlet Temperature Pass -1	PAB11 CT011
7	CW Inlet Temperature Pass -2	PAB12 CT011
8	DP Measurement Pass-1	PAB11 CP012
9	DP Measurement Pass-2	PAB12 CP012
10	DT Measurement Pass -1	PAB11 CP512
11	DT Measurement Pass -2	PAB12 CP512
12	CW Outlet Temperature Pass -1	PAB11 CT012
13	CW Outlet Temperature Pass -2	PAB12 CT012
14	CW Outlet Temperature Pass -1	PAB11 CT512
15	CW Outlet Temperature Pass -2	PAB12 CT512

It was observed that the CW (Annubar) (PAB10 CF001) flow measurement values of Unit-1 & 2 are around 23041.93 TPH and 33414.21 TPH. Black & Veatch validated the flow in Unit 2 using CW pump head and discharge characteristic and found the flow measurement to be erroneous. The calibration of this instrument is recommended in nearest opportunity.

CW Flow is the total flow measurement at the CW header which includes the CW flow to condenser circuit and ACW circuit. As per the P&ID (PE-DG-319-165-N101 Rev 03 P&ID for CW-ACW SYSTEM), there are separate flow meters to measure ACW flow to each PHE which also includes CW blowdown flow (flow meter is available to measure the blowdown) and HRSG blowdown tank flow.

Cross verification of the CW flow at the Cooling tower riser utilizing portable offline meter(like Ultrasonic flow meter) on a periodic basis is recommended once in every 6 months.

5.6.3.3 Air Extraction side Instrumentation:

Source: P&ID/ Vacuum Pump Manual/Chapter 5/ Drawings/Page no:2

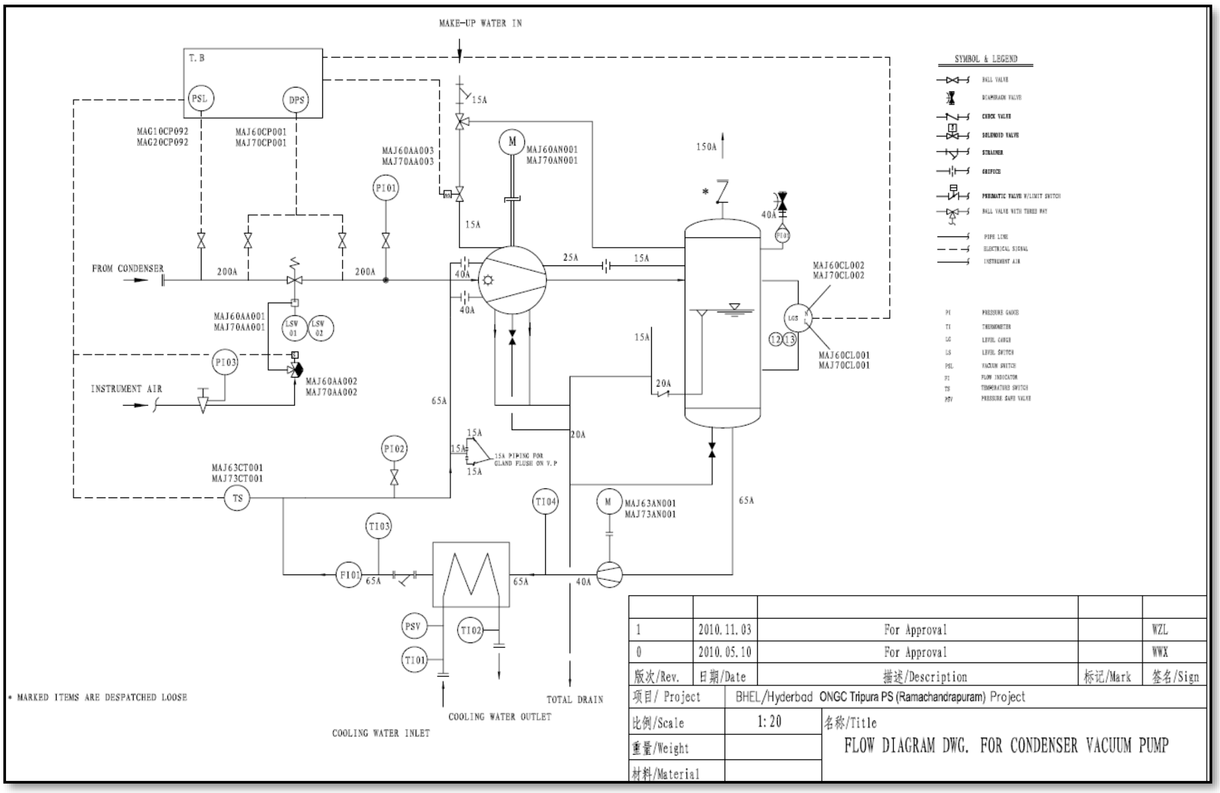


Figure 5-11: Air Extraction system P&ID

As per the above P&ID, Black & Veatch understands that Vacuum pumps are equipped with the following instruments,

- Inlet Air Pressure indicator at Inlet of main Vacuum Pump (PI01)
- Seal Water Pressure indicator at Inlet of main Vacuum Pump (PI02)
- Flow measurement Rota meter to measure Air outlet from Vacuum pump Separator (FI01)
- Seal Water Cooler Inlet Temperature Thermometer (T104)
- Seal Water Cooler Outlet Temperature Thermometer (T103)
- Cooling water inlet to seal cooler Temperature Thermometer (T102)
- Cooling Water Outlet from seal cooler Temperature Thermometer (T103)
- Separator Level Gauge and Level Switch

5.6.4 Recommendations:

5.6.4.1 On-Line Performance Monitoring of Vacuum Pump & Seal Water System

Black & Veatch opines that the instrumentation available at the air extraction system is adequate for calculating vacuum pump performance. However, as most of the readings are not readily available in DCS, Black & Veatch recommends following instruments for continuous monitoring of Vacuum pump and seal cooler performance in DCS.

Table 5-22 Vacuum Pump Performance and Recommended On-Line Measurements

PARAMETERS	STATUS	ON-LINE INDICATION	MONITORING
Seal Water Flow (Inlet to Seal Water Cooler)	Not Available	Not Available	Continuous
Seal Water Inlet and Outlet Temperature (Seal Water Cooler)	Gauge Available	Not Available	Continuous
Seal Water Inlet and Outlet Differential Pressure	Not Available	Not Available	Continuous
ACW Inlet and Outlet Temp. (Seal Water Cooler)	Gauge Available	Not Available	Continuous
Seal Water Temperature (Inlet to Vacuum Pump)	Gauge Available	Not Available	Continuous
Rota Meter Flow	Available	Not Available	Continuous

5.6.4.2 Investigate Suspected Air Ingress in Condenser Shell

Helium leak test is technology of choice due to availability, applicability (Can be done when unit is in operation) and detectability (Sensitivity of 10-6 mbar, fast (less than 20 seconds) , and ability to detect very fine leakages) of leakage points which are in condenser system but isn't useful for leakages which are under water up to condensate extraction pump (Downstream of hot well, flange joints, bellows, valves, suction strainer, and associated pipelines).

Infrared thermography has come to age as far as locating air ingress points are considered. Due to advancement of technology and drop in prices, good quality thermography cameras are available in reasonable rates in market today. But infrared thermography is best used when combined with other techniques like helium or acoustic technique to pinpoint areas of air ingress.

Ultrasonic acoustic leak detection system with high sensitivity is available which can be used for regular inspections to ensure near airtight condenser. In case of vacuum leak, air moves from a high-pressure side (outside condenser) to a low-pressure side (Inside condenser) and during its passage turbulent flow gets generated creating ultrasound frequencies (>20 KHz). This has strong ultrasonic components which are heard through noise attenuating headphones, the greater the leak, the greater would-be sound intensity. Ultrasonic acoustic leak detection when combined with Infrared thermography & Helium leak detection technique is proven to yield reliable and repeatable results with less false negatives. A typical helium leak set up is shown below.

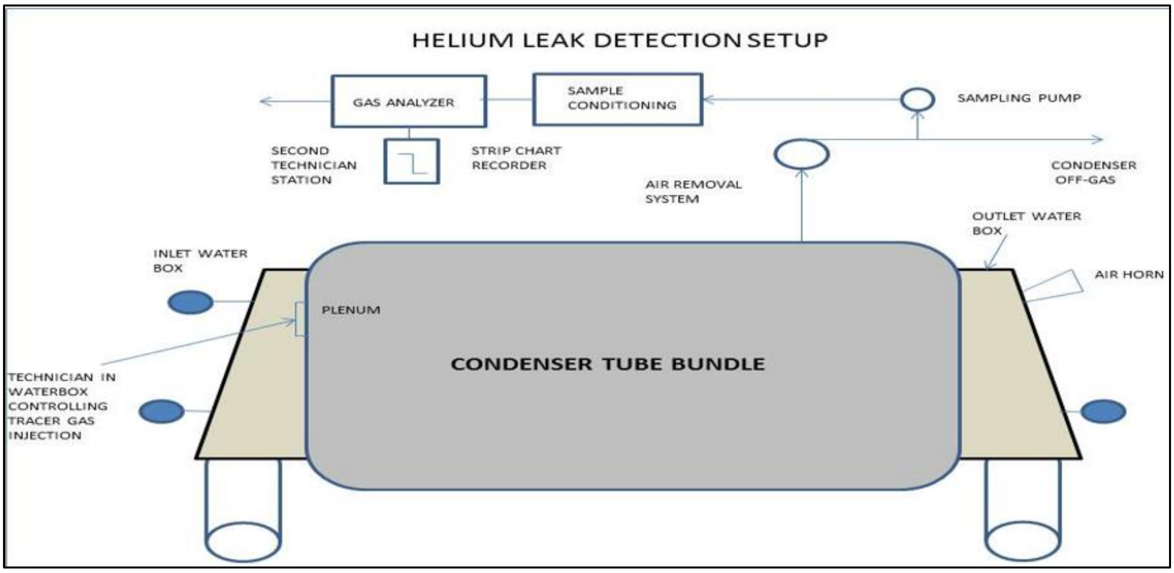
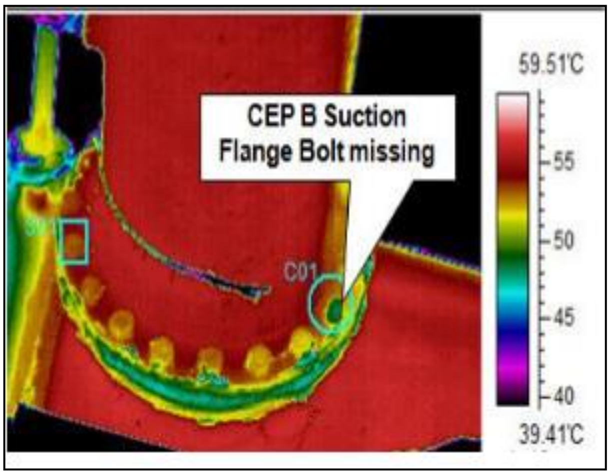


Figure 12 Helium Leak Set Up

Common primary source of leakages is generally listed as follows.

- Atmospheric relief valve or vacuum breakers
- Rupture disks
- Condenser Drains
- Turbine Seals
- Low Pressure Turbine Diaphragm / End Seals
- Turbine Instrumentation Lines
- Condenser Expansion Joint
- Tube sheet to Shell Joint
- Air removal suction component
- Condenser Instrumentations
- Low Pressure feed water heaters, associated piping, valves and instruments
- CEP strainers, vents, drains and seals
- Pipe flanges, Orifice flanges
- Valves
- Manholes

An assessment like infrared thermography often yields best results for wet sections after hot well. The two figures below suggest leakages observed which otherwise are difficult to detect by Helium leak test alone.



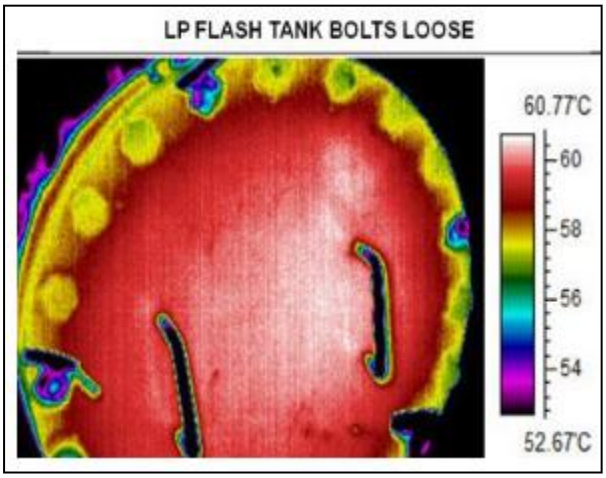


Figure 14 Infrared Thermography CEP Suction Flange **Figure 13 LP Flash Tank**

5.6.4.3 Online Tube Cleaning (OLTC) system

Black & Veatch recommends conducting a feasibility study for the installation of an Online Tube cleaning system for increasing heat-transfer effectiveness.

Online Tube Cleaning System facilitates continuous cleaning of the Condenser Tubes up with the Plant in operation. Cleaning is accomplished by passing slightly oversized Sponge Rubber Balls though the condenser tubes. Install a retrievable ball tube cleaning system to periodically remove bio fouling material from the inner surface of condenser tubes, keeping condenser tubes free of scale will maintain design heat transfer between the condensing steam and circulating water.

Major Components and Auxiliary Equipment of OLTC system are as follows.

- Ball Separator
- Ball Recirculating Skid
- Measuring and Control System
- Ball Monitoring System
- Ball Charger and Feeder

Ball charging is normally from the inlet to condenser and ball separator installed in the Condenser CW outlet pipe is ball catching equipment which separates the cleaning balls from cooling water for recirculation. The Ball Separator is fitted with single/double screens at a selected angle for the smooth collection of balls. The backwashing of the screens is initiated by DP measurement automatically. A ball recirculation system ensures these balls to be again routed to CW inlet pipe to condenser. The installation of ball cleaning system may be localized managed by a PLC or remotely using DCS. An HMI with audio/ visual alarms can also be provided.

5.6.4.4 Regular Replacement of Sacrificial Anodes

Black & Veatch recommends regular inspection of sacrificial anodes during every outage/condenser inspection if applicable. Sufficient stock of sacrificial anodes should be maintained for 100 percent replacement of damaged or worn-out anodes during every outage if Applicable For OTPC

5.7 Vacuum Pump

Table 5-23 Vacuum Pump Design Data

DESCRIPTION	PARTICULARS
Pump Design Point	1” of Hg (a)
Seal Water flow	13.6 m3
ACW Inlet (Design)	13 Deg. C
ACW Outlet	14.5 Deg. C
Seal Water Inlet (Cooler)	23.9 Deg. C
Seal Water Outlet (Cooler)	16.5 Deg. C
Condenser Design Pressure	2.84” of Hg(a)
Pump Capacity (HEI)	20 SCFM
Discharge Pressure	Atmospheric
Make Up Water	CEP Discharge
Design ITD	19 Deg. F

5.7.1 Condenser Performance and Vacuum System

Following section describes condenser performance in view of removal condensable and non-condensable gases in conjunction with vacuum pump operation. The analysis is based on data collected during the performance test.

Table 5-24 Condenser Performance and Vacuum System

Description	UOM	Expect.	Index	Unit 1		Unit 2	
				1A	1B	2A	2B
*Seal Liquid Temperature (Inlet to Cooler)	Deg. C	42.9	[A]	60.0	55.0	55.0	54.0
*Seal Liquid Temperature (Outlet to Cooler)	Deg. C	35.5	[B]	40.0	38.0	41.0	34.0
DT across Seal Cooler	Deg. C	**7.4**	**[A-B]**	**20.0**	**17.0**	**14.0**	**20.0**
Approach of Cooler	Deg. C	**3.5**	**[B-C]**	**4.0**	**5.0**	**7.0**	**4.0**
ACW Inlet Temperature	Deg. C	32	[C]	36.0	33.0	34.0	30.0
ACW Outlet Temperature	Deg. C	33.5	[D]	38.0	35.0	35.0	31.0

Description	UOM	Expect.	Index	Unit 1		Unit 2	
				1A	1B	2A	2B
Actual ITD (Tsat at Vac. Pump Suction Pres. - Seal Water Temp)	Deg. C	**10.6**	**Tsat(E)-B**	**15.0**	**17.0**	**10.3**	**17.3**
Vacuum Pump Air-Steam Inlet Temperature	Deg. C	-	-	53.0	54.0	51.0	51.0
Condenser Water Inlet Temperature	Deg. C	-	-	34.3	34.3	31.2	31.2
Condenser Water Outlet Temperature	Deg. C	-	-	44.3	44.3	40.6	40.6
Condenser Vacuum (Transmitter)	bar (a)	-	-	0.196	0.196	0.170	0.170
Vacuum Pump Inlet Pressure (Estimated)	bar (a)	[A]	[E]	0.158	0.158	0.131	0.131
Saturation Pressure Corresponding to Seal liquid Inlet Temperature	bar (a)	[B]	[F]	0.074	0.066	0.078	0.053
Cavitation Margin (Seal Liquid Inlet Temp.)	**bar (a)**	**[A-B]**	**[E-F]**	**0.084**	**0.091**	**0.054**	**0.078**

Note: Data marked in asterisk is measured locally by available gauge.

5.7.2 Review of Vacuum Pump & Seal Water Cooler Performance

Liquid Ring Vacuum Pump (LRVP) supports condenser operation by continually extracting the non-condensable gases (air) that enter the condenser to maximize the condensing capability and minimizes turbine exhaust back pressure. Surface condenser produces the vacuum while LRVP ensures sustenance of the condenser vacuum.

The LRVP should always operate in conjunction with the condenser. Under-venting of the condenser is caused when the LRVP cannot remove the non-condensable load entering the condenser. The condenser pressure will rise, and turbine operation is affected. This is caused when the high temperature of the seal water in the LRVP will not allow the pump to operate at the same pressure as the condenser. Based on local measurements performed during performance test, it is evident that the difference between seal water outlet temperature and ACW inlet temperature (also known as Seal water cooler approach) for pump 1A, 1B, 2A and 2B are 4-7 deg. C higher than expected.

Given the estimates for seal water cooler approach being based on temperature gauge readings which were not calibrated, we expect the seal water cooler approach to be much higher or possibly lower also in few cases than what is found during the test.

The seal cooler is used on LRVP systems where the service liquid is reused after it exits the LRVP. The service liquid is cooled to a lower temperature, so that desired vacuum and capacity of the LRVP can occur. The cooler is often overlooked when the LRVP system is maintained.

The proper heat transfer function of this heat exchanger is essential for trouble-free vacuum system operation. If the correct heat transfer between the two fluids is not taking place, the LRVP will operate in a different pressure range than the condenser. As stated previously, the condenser and the LRVP must operate in conjunction with one another using similar water temperatures.

Besides seal water cooler performance, there are two more suspect to vacuum pump underperformance.

- Increase in non-condensable heat load (Air -Ingress)
- Increase in condensable component of heat load (Higher steam loading likely caused due to inefficiency in LP turbine and last stage blades)
- Suspected Cavitation of Impeller & Cones
- Direction of Rotation (Check the pump Direction of Rotation (Normally clockwise if viewed from the drive end). Gas compression should be from the suction to the discharge port.

5.7.3 Recommendations

5.7.3.1 Develop and Implement Standard Maintenance Practice (SMP) for Cleaning of Seal Water Cooler

The seal water cooler may have to be cleaned to maintain its heat transfer capability. Ensure that the proper flow and temperature of cooling water is being supplied to the heat exchanger. If the temperature rise is low on the cooling water side and the seal water is not cold enough, fouling could be the problem. It is critical that the seal water cooler be cleaned at regular intervals and should be as closely scrutinized as the main condenser for proper operation. Proper system flushing after before any start up is also important to avoid fouling in tubes. Ensure that there is no place for air to accumulate inside the exchanger reducing its heat transfer surface. ***A SMP for Seal Water Cooler Cleaning is recommended to be adhered by maintenance personnel.***

Seal water flow and differential pressure measurements (On-line) are to be ensured for continuous monitoring of vacuum pump performance. Please refer table 4-14 for recommended on-line measurements of Vacuum pump. A cleaning cycle with frequency once every 6 month is preferable if feasible or as per recommendation of OEM whichever is earlier. A cooling with moderate chemical treatment is also feasible and is to be checked with OEM.

5.7.3.2 Cavitation Avoidance

High seal water inlet temp. may lead to pump cavitation. High seal water temperature in due course of two-stage compression may potentially exceed the corresponding saturation temp. (boiling point) causing cavitation. This problem can be mitigated if seal water flow and temperatures are made available for operators’ guidance and seal water cooler performance is regularly audited. Table 4-21 provides recommendations for online measurements of vacuum pump performance.

Cavitation related damage of Vacuum pump internals was reported by M/s Millennium Enterprise in its report and MOM dated 26th April 2022. The recommendations as per the report are also to procure SS rotor and installing flow meters for seal water.

Another method is using acceleration, true peak detection, frequency banded vibration sensor which is sensitive only to those frequencies normally excited during cavitation. This loop powered sensor provides a 4-mA to 20-mA output signal proportional to the sensed vibration level. A 4-mA to 20-mA output sensor may extend its signal to DCS and alarm limits can be set for alerting the operator. Even if it is not possible to shut the pump down once cavitation is detected, the knowledge that it is occurring can be used by plant personnel for troubleshooting and addressing the issue in a planned manner.

5.8 Cooling Tower

The cooling towers' performance was tested when both units were operating at baseload. The below tables describe the design details of the cooling tower performance parameters.

Table 5-25: Cooling Tower Design Details

DESCRIPTION	UNITS	PARTICULARS
CT basin capacity	m3	7000
No of Cooling Towers		2 (one for each unit)
No of cells in each CT		8 (7W+1S)
Capacity of each cell	m3/hr	3428.57
CT inlet temperature	Deg C	31
CT Outlet temperature	Deg C	42
Design Wet Bulb Temperature	Deg C	27.25
Evaporation Efficiency	%	85
No of fans in each CT		8
No of blades in each Fan/type		8 blades / Aerofoil
Fan motor capacity	kW	110

The below table describes the performance test output of cooling tower values against the design values.

Table 5-26: Cooling Tower- 1&2 Performance Test output against Design Values

DESCRIPTION	UNIT	DESIGN	INDEX	CT -1	CT-2
No of Cells in Service	Nos	8(7W+1S)		8W	8W
Dry Bulb Temp	Deg.C	NA	[M1]	26.68	26.42
Relative Humidity	%	NA	[M2]	37.62%	53.66%
Wet Bulb Temperature	Deg C	27.25	[M3]	17.76	19.90
CT inlet temperature	Deg C	32.00	[A]	34.33	31.18
CT Outlet temperature	Deg C	41.00	[B]	44.30	40.57
CT Range	Deg C	9.00	**C=[B-A]**	**9.97**	**9.39**
CT Approach	Deg C	4.75	**D=[A-M1]**	**16.57**	**11.28**
CT Effectiveness	%	65.5%	[C/C+D]%	37.6%	45.4%

Based on Performance calculation

- Effectiveness of cooling tower is calculated as 37.6 % and 45.4 % respectively for CT-1 &2 against the design effectiveness of 65.5%
- Cooling tower Approach is calculated as 16.57 Deg C and 11.28 Deg C respectively for CT-1 &2 against the design Approach of 4.75 DEGC.
- Cooling Tower Range is calculated as 9.97 DEGC and 9.39 Deg C respectively for CT-1 &2 against the design Range of 8 Deg C.

5.8.1 Recommendations:

5.8.1.1 Fill pack replacement in CT 1 and CT 2

Black & Veatch was informed that a program for fill pack replacement is already underway. In Unit 1, 2 fill packs in 2 cells and in Unit 2, fill packs in 5 cells are replaced till Feb-23. The plan is to be progressively replace all the fill packs in the two cooling towers. It is also recommended to upgrade the design from existing MC67 PVS fills design with other cross-corrugated Fills such as C.10.19 folded end fills.

Another upgrade is use multi-layer combinations of fill packs (rather than single later) such as 2 layers of 600 mm of 19 mm flute size with 1 layer of 300 mm of 12 mm flute size at the top can be checked for feasibility. This will help in doing the cleaning of fills and also can improve the thermal performance.

5.8.1.2 Measurement of CT flow in Risers and Equalization of flow across CT Cells

In multi-cell CT design, the inlet flow to each cells differs greatly due to long pipe length. Part of this issue is addressed by reducing the diameter of pipe as water traverses from the front most cell to the rear cell. The flow in riser pipes is often required to be adjusted to ensure that flow / cell is even across the cooling towers. ***A measurement of CT riser flow once in 6 month or after any major shutdown is recommended to ensure improved L/G (liquid to gas ratio) for each cell.***

5.8.1.3 Develop SMP for CT Fills Cleaning

Review the preventive maintenance schedule of cooling towers fills cleaning. Given the concentration of suspended solids found during visual inspection, fills cleaning may be undertaken 1 cell/month by drawing out the fill packs, weighing the fill packs in dry condition before cleaning, cleaning it by pressurized jet of water, observing the weight drop and then repacking it correctly without affecting/damaging the edges and flute profiles or honeycomb structure. ***A SMP for CT fills cleaning is recommended to be adhered by maintenance personnel.***

5.8.1.4 Provision for higher air flow by improved design of fans airfoil (Improved L/G ratio)

Replacement of GRP blades with high grade Epoxy coated blades in the fan of improved aerodynamic design. The primary objective is to ensure higher air flow through the fills for lowering the CT water outlet temperature. A well design retrofits can provide benefits up to 20% increased air flow / cell then conventional design for same power consumption.

5.8.1.5 Improvement in Air-Water Distribution of CT Cells

CTs often undergo deterioration over the period of operation and need sufficient and effective maintenance periodically. We recommend the following activities to be performed in pre-defined scheduled maintenance intervals.

- Inspection of water distribution system, fills, drift eliminators during each monthly PM.
- Installation of water nozzles in dry patches after internal inspection.
- Check for any damage to the PVC water distribution pipes, their end covers, leakage from the joints, damaged nozzles, missing distribution rings of the nozzles, blockage of nozzles below RCC ducts, etc. to ensure proper spraying of water evenly throughout the fill surface.
- In situ cleaning of fills and drift eliminator with clarified water once in a quarter to remove loose dirt or sludge.

- Check of fan blade tip clearance and maintain it as per the OEM recommendation, typically it is less than 50mm.
- Blade angle can be adjusted to the max allowable value to increase air flow as recommended by OEM, typically it is maintained around 12 to 14 degrees. However, this needs to be validated through OEM.
- While inspecting the fills and water distribution, use wooden ply or sheets for walking to avoid damage of fill edges.

5.8.1.6 CT Basin Screen Design

If the CT outlet channel has two slots to put the two separate screens, then we recommend keeping the upstream screen size opening to around 1.5” – 2” to restrict the large size debris and 1/2” (12 mm- 15 mm) opening for the downstream screen to restrict the smaller size fills or debris.

After doing this modification more frequent cleaning of the downstream screen may be required otherwise the CT basin will overflow in case of heavy blockage. This design typically has benefit of less pass through of broken fills, debris, and other external materials into condenser water box and tube sheet. Please refer figure 7 for a typical CT forebay screen designed for a utility in North India.

Figure 15 CT Basin Screen Design

5.9 Miscellaneous Pumps

Measurements of all major HT motors of HRSG, turbine & BOP area were taken using the Power Analyzer, which measures Voltage, Current, kW, and P.F., etc. The parameters were measured to measure the hydraulic efficiency of pumps. The measurements taken are tabulated and presented below Table.

Table 5-27: Block-1 & 2 Pump Parameters

HT PUMPS	DESIGN MOTOR RATING (KW)	VOLTAGE (KV)	CURRENT (AMPS)	POWER FACTOR	[19]HYDRAULIC POWER (KW)[A]	ELECTRICAL POWER (KW)[B]	EFFICIENCY [A/B*100] (%)
HP/IP BFP-1A	4000	6.77	232	0.862	1490.4	2344.9	63.60
HP/IP BFP-2A	4000	6.79	228	0.850	1443.4	2279.1	63.30
CEP 1B	600	6.77	46.9	0.834	275.9	458.6	60.20
CEP 2B	600	6.79	48.1	0.851	265.8	480.8	55.40
[20]DMCW 1B	300	6.75	26.0	0.851	157.6	257.5	61.20
DMCW 2B	300	6.79	26.2	0.850	184.3	261.9	70.40
CW Pump- 1A	1150	6.80	106.0	0.756	682.1	974.2	70.02
CW Pump- 1B	1150	6.80	109.9	0.760	681.2	957.8	71.12
CW Pump- 2A	1150	6.80	106.1	0.756	758.1	944.2	80.29
CW Pump- 2B	1150	6.80	109.9	0.760	734.2	983.2	74.66

[19] (Pump TDH X Flow X Density X g)/3600/1000

[20] DMCW Pump 1B was running at 1495 TPH and DMCW Pump 2B flow as 1840 TPH. Design flow rate is 1730 m3/hour and design pump efficiency is 84%.

The major pumps performance parameters do not indicate any major deviation except few cases where pumps operating point and design duty points are deviating large. There is a potential energy saving for pumps specially CEPs (continuous duty) if they are operated under VFD control.

OPTC has already implemented VFDs in low pressure BFP in Unit 2 and is under service.

5.10 Condensate Extraction Pump

Following tables provides performance assessment of CEP.

Table 5-28 CEP Performance

PARAMETERS	UNITS	DESIGN	INDEX	CEP 1B	CEP 2B
Discharge Pressure	Bar			24.66	24.37
Suction Pressure	Bar			0.196	0.170
Suction Temperature	Deg C	49.2		58.41	56.39
Discharge Temperature (Estimated)	Deg C			61.71	58.08
Discharge flow	m3/hr.	660.0		413.41	401.85
Speed	RPM	1484.0			
Voltage	KV	6.6	[A]	6.77	6.78
Current	A	65.0	[B]	46.9	48.1
Power Factor			[C]	0.83	0.85
Power	KW	600.0	[F=SQRT (3)*A*B*C]	458.6	480.1
Hydraulic Power	KW	466.0	[E]	275.9	265.8
Specific Weight	kg/m3	988.4		984.0	985.0
Pump TDH	mwc	210.0		**249.3**	**246.7**
Hydraulic Efficiency (TDH)	%	80.0	**[E/F]**	**60.20**	**55.40**

- The difference in pump design and operating efficiency is attributable due to operating point deviating from design considerably.
- Pump actual TDH is higher than design, suggesting higher power consumption as higher head increases the power consumption proportionately.
- Assessment of deaerator level control valve system shows potential for lowering the head by opening of the level control valve to full and operating pump at reduced speed using VFD.

5.10.1 Recommendations:

5.10.1.1 Retrofit of MV VFD for Power Saving in CEP

Under operating conditions, the deaerator level control valve remains throttled to maintain the deaerator inlet pressure of 4 kg/cm2. The power consumed by CEP at full load is about 460-480 kW (based on performance test data). The CEP discharge pressure is about 24Kg/cm2 which reduces to around 20 kg/cm2 at the inlet of deaerator level control valve (~ pressure drop of 20 kg/cm2 at valve throttling of 72%). Deaerator level control valve is throttling the condensate pressure from 20

kg/cm2 to around 4 kg/cm2 at the inlet of deaerator. Please refer snapshot of CEP operation during the performance test of Unit 1. Similar observation is reported for Unit 2 also.

Given the present operation of CEPs away from design efficiency point, it is recommended to retrofit the pump motor with a VFD to reduce the speed and thereby its discharge pressure adequately to avoid deaerator level controller valve throttling, while still meeting the pressure requirement of its duty points. A careful design review and performance analysis will result in the potential power saving is in the tune of minimum 100-120 KW at full load after adjusting for the increased HVAC auxiliary load of VFD. A detailed review of this retrofit is outside the scope, however industry experience suggests a pay back period typically of less than 3 years for such retrofit.

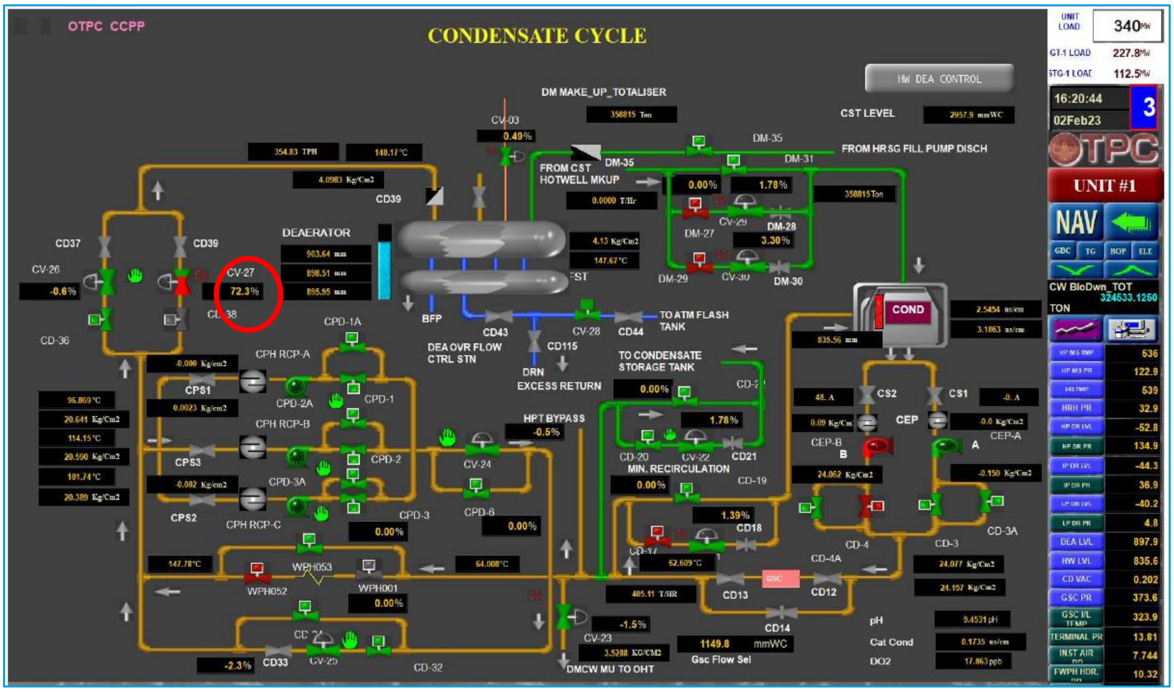


Figure 16 CEP Operation in Unit 1

- Deaerator at a pressure of 4.0 bar.
- HP/LP Bypass spray.
- LP Turbine Exhaust cooling sprays.
- Gland steam de-super heater
- Condenser drain flash box
- Condensate dozing (if applicable)

5.10.1.2 Retrofit of CEP Gland Packing to Mechanical Seals

Mechanical seal OEMs such as Eagle Burgmann, Borg Warner, etc. can be consulted for converting the gland packing to mechanical seal. This will help in increasing the life of shaft seal and reducing the dissolved oxygen content in the condensate. The performance data suggest significantly high DO level in Unit 1 (17.86 PPB).

5.11 Circulating Water Pump

Following tables provides performance assessment of CW Pumps.

Table 5-29 CW Pump Performance Evaluation

Parameters	Units	Design	INDEX	CW-1B	CW-1C	CW-2A	CW-2B
Discharge Pressure	Bar	NA		3.0303	3.0744	3.1235	3.0450
Suction Pressure (Estimated)	Bar	NA		0.9614	0.9614	0.9614	0.9614
Discharge Temperature	Deg C	NA		34.33	34.33	31.18	31.18
Suction flow	m3/hr.	12000	[G]	11648.0	11395.0	**12400.0**	**12450.0**
Voltage	KV	6.60	[A]	6.76	6.76	6.80	6.799
Current	A	108.6	[B]	110.0	107.6	106.0	109.9
Hydraulic Power	KW	865.0	[E=G*H]	682.1	681.2	758.1	734.2
Power Factor		0.8	[C]	0.7564	0.760	0.7564	0.76
Input Power	KW	1018.0	F=[SQRT(3)*A*B*C]	974.2	957.8	944.2	983.3
Pump Total Dynamic Head (Bowl)	mwc	22.0	[H]	21.59	22.04	22.54	21.74
Hydraulic Efficiency (Bowl)	%	85.0	**[E/F*100]**	**70.02**	**71.12**	**80.29**	**74.66**

5.11.1 Recommendations:

5.11.1.1 Measures for High CW Flow and for Arresting Suspected Passing in Butterfly Valve

In a parallel pump operation, passing of CW discharge valve of standby pump will lead to short circuiting of CW flow to the forebay. It is practically difficult to identify the short circuiting, but this issue leads to lower CW flow across the condenser, hence it is recommended to inspect all the valves internally and replace the elastomeric seals, seal retaining segments, metallic seals of valve disc, etc. Gearbox of the actuator should be adjusted to close the valves properly and should be crosschecked internally for its full closer.

5.11.1.2 Plate Heat Exchanger Isolation

Plate heat exchangers are often designed to operate as (1W + 1S) configuration, however many times, PHE are charged from ACW side for quick line up in case a changeover is warranted. This compromises standby PHE cleaning and effectiveness while adding to ACW power consumption. Standby PHE is recommended to be closed from both DMCW and ACW side as far as feasible to save unnecessary use of pumping power while keeping a close watch on in-service PHE differential pressure.

5.12 HP/IP Boiler FEED Pump

Table 5-30 HP/IP Boiler Feed Pump Performance Evaluation

Parameters	Units	Design	Index	HP BFP 1A	HP BFP 2A
Discharge Pressure	Bar	179.9		146.15	144.19
Suction Pressure	Bar	14.4		15.50	15.47
Suction Temperature	Deg C	149.5		146.66	146.40
Discharge Temperature	Deg C	149.5		149.73	149.12
Suction flow	m3/hr.	420	[G]	446.31	438.60
Voltage	KV	6.6	[A]	6.77	6.79
Current	A	405	[B]	232	228
Power Factor		0.89	[C]	0.862	0.85
Shaft Power	KW	3112.0	F=[SQRT(3)*A*B*C]	2344.9	2279.1
Hydraulic Power	KW	2490.0	[I=G*H]	1490.4	1443.4
Pump TDH	mwc	2000	[H]	1331.8	1312.2
Hydraulic Efficiency (TDH)	%	80.0	**[F/I*100]**	**63.60**	**63.30**

- The HPBFP efficiencies are observed to be within expected range. The deviation in efficiency can be explained based on pump design and operating duty point differences

5.13 DMCW Pump

Parameters	UOM	Design	Index	DMCW-1B	DMCW-2B
Discharge Pressure	Bar			7.08	6.91
Suction Pressure	Bar			3.25	3.27
Suction Temperature	Deg C	49.2		0.00	0.00
Discharge Temperature (Estd)	Deg C			40.35	41.15
Discharge flow	m3/hr.	1760.0	[G]	**1495.0**	**1840.1**
Speed	RPM	1486.0		NA	NA
Voltage	KV	6.6	[A]	6.75	6.79
Current	A	33.0	[B]	26.0	26.2
Power Factor			[C]	0.85	0.85
Power	KW	294.0	F=[SQRT(3)*A *B*C]	257.5	261.9
Hydraulic Power	KW	246.8	[I=G*H]	157.6	184.3
Pump TDH	mwc	44.0	[H]	39.0	37.1
Hydraulic Efficiency (TDH)	%	83.9	**[F/I*100]**	**61.20**	**70.40**

- The DMCW Pump efficiencies are observed to be within expected range. The deviation in efficiency can be explained based on pump design and operating duty point differences.

- DMCW Pump 1B was running at 1495 TPH and DMCW Pump 2B flow was 1840 TPH. Design flow rate is 1730 m3/hour and design pump efficiency are 84%. Given the pump 2B, being operated at higher than design flow (1840 TPH), a passing is suspected either via PHE (if standby PHE is isolated) or DMCW common recirculation line.

5.13.1 Recommendations:

5.13.1.1 Measures for Arresting Higher Flow Rate in DMCW 2B

A flow measurement using ultrasonic flow meter is required to adjust the pump operating points near the design duty point. Any suspected passing either in common recirculation valve or stand by PHE can be ascertained and arrested. Pump 1B and 2B are found to operate at different flow rate (difference by 345 TPH) which shall be corrected.

5.14 Compressed Air System

OTPC plant has two instrument air screw compressors with the capacity of 15 m3/min for the compressed air requirement. The operating pressure of the compressor is 8.5bar. The rated KW of drive motor is 132 KW. The input KW of compressor at rated condition is 119 KW and at unloaded condition, it is 27 KW. We have collected half hourly power consumption data for the compressor for 2.5 hours. Please refer below table for the details. The pressure at air drier outlet is 8.0 bar.

Description	Voltage (Volt)	Current (Load)	Current (Unload)	PF	Electrical Power (KW)
IAC -1A	435	185	56	NA	NA
IAC-1B	434	-	52	NA	NA
IAC-2A	438	184	55	NA	NA
IAC -2B	442	-	53	NA	NA

The power measurement for IAC was not available for Black & Veatch to conclude, however analyzing historical data suggest that power consumption of compressor at unload and load conditions are typically in the range of 22-25 KW and 100-110 KW respectively. The loading/ unloading cycle of IAC suggested few optimizations as evident in the table below.

Description	15:00	15:30	16:00	16:30	17:00	Instrument Air Pressure (bar)
IAC-1A	Unload	Unload	Load	Load	Unload	7.78
IAC-1B	**Unload**	**Unload**	**Unload**	**Unload**	**Unload**	
IAC-2A	Unload	Unload	Unload	Load	Load	7.72
IAC-2B	**Unload**	**Unload**	**Unload**	**Unload**	**Unload**	

IAC -1B and 2B are found to be completely unloaded for the period of performance test, while IAC 1A and 2A operated cyclically to maintain instrument air header pressure. Load/unload compressors

have two pressure setpoints: an upper setpoint and a lower setpoint. The compressor regulates the pressure between these two setpoint. When the lower pressure is reached, the compressor starts 'pumping air'. This setpoint is called the 'loading setpoint'. To avoid an ever-last uncontrolled rise in pressure, the compressor has an upper setpoint, called the 'unload setpoint' - where the compressor stops pumping air. There is various microprocessor-based control for Improved Loading / Unloading of Compressor which also reduces overall power consumption of the compressed air system.

5.14.1.1 Service Air and Instrument Air Segregation

Segregating the plant service and operating air and instrument air system can result in energy savings. In past assessments, Black & Veatch has seen plants that combine their service, operating, and instrument air system into a single system. In OTPC also, compressors are operated to meet both service air and instrument air requirements. Utilizing instrument air for service and controls together will result in higher energy demands specially for air-drying application.

5.14.1.2 Centralized Controller for Equalizing the Run-Hours of Two Parallel Compressors & Energy Saving

Normally, the load/unload pressure of each unit are set to react to changes in air demand. If the system pressure drops, an additional compressor will switch to loaded running. However, the sequence will always be the same, and this leads to a higher pressure than required. Central controllers can be set to prevent unequal wear of compressors, equalizing the running hours on multiple machines for more efficient service scheduling and reduced cost. Another advantage of centralized controller is that they reduce the average pressure band (load and unload set points). It also reduces the operating pressure of machines. By reducing the pressure by 1 bar (or 14.5 psi), energy usage gets lowered by 5-10%, while reducing the pressure by 1 bar (or 14.5 psi) decreases air leakages by average 10-15%.

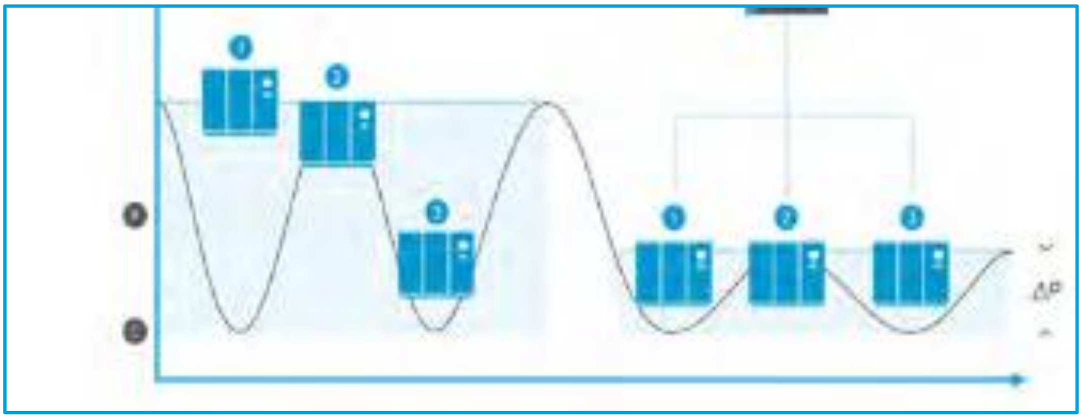


Figure 17 Average Pressure Band Trend for Parallel Compressor Operation

6 Recommendations

6.1 Based on Plant Performance Audit

The recommendations related to performance impact are categorized based on Risk, Priority, Capex requirement, and shutdown requirement. The assumed criteria and basis for these categorizations are provided below.

6.1.1 Risk Categorization:

The identified recommendations are further categorized into different risk levels based on the threats and hazards involved with the recommendations in the system. The different risk categorizations are as below

- Low
- Minor
- Moderate
- Major
- Critical

6.1.2 Priority Categorization:

The identified recommendations are further categorized into different priority levels based on the period the recommendation is expected to be planned for the reliable operation of the plant. The different priority categorizations and their criteria are as below

Table 6-1: Priority Categorization

PRIORITY	CRITERIA
Immediate	Important and urgent
Short term	Important and urgent but can be delayed
Long term	Important, not urgent
Good to have	Not important, not urgent

6.1.3 Capex Requirement Categorization:

The identified recommendations are categorized into different CAPEX requirements based on the high-level Capex estimate required to implement the recommendations. The different CAPEX requirements and their range considered are as below,

Table 6-2: Priority Categorization

CAPEX REQUIREMENT	RANGE (INR LAKHS)
High	> 100 lakh
Medium	25 to 100 lakh

CAPEX REQUIREMENT	RANGE (INR LAKHS)
Low	< 25 lakh
Not Applicable	

6.1.4 Shutdown Requirement Categorization:

The recommendations are further analyzed and shutdown requirements to implement the recommendations are identified. The shutdown requirement is based on the time period expected to implement the recommendations. The different shutdown requirements considered are as below,

Table 6-3: Priority Categorization

SHUTDOWN REQUIREMENT	RANGE (DAYS)
No	0
Minor Outage	15-30 days
Major Outage	30-45 days

6.1.5 Recommendation Summary

Black & Veatch has utilized information gathered at various stages during the execution of this Performance system Audit and assessments carried out in the above sections as a basis for identifying recommendations. Black & Veatch has identified around 10 recommendations for plant performance improvement and reliable plant operation. The below table describes the number of identified recommendations with respect to each categorization explained above.

Table 6-4: Recommendations Under Different Categories

PRIORITY	RISK CATEGORY	CAPEX REQUIREMENT	SHUTDOWN REQUIREMENT
Immediate - 4 no's	Low - 1 no	High -4 no's	No -4 no's
Short term - 21 no's	Minor - 1 no	Medium - 4 no	Minor Outage -14 no's
Long term - 1 no's	Moderate - 14 no's	Low - 15 no’s	Major Outage -2 no's
Good to have -1 no	Major -1 no	NA - 4 no's	No Outage -11 no’s
	Critical - 10 no's		

The recommendations to improve the plant performance are provided in the below table.

Table 6-5: Plant Performance Improvement Recommendations

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
1	Compressor	5.3.1.1	Inlet Air Filter Choking	Due to increase of fine dust in the ambient air, fine filters are getting exhausted within 4-6 months. This filter replacement requires shutdown of the unit. We recommend exploring the possibility of installing Coalascer pad rolls before the prefilters. These Coalascer pads have good dust holding capacity. These pads can be changed online whenever these get choked. Alternatively OTPC may also explore upgrading / replacing fine filters to EPA grade (E10 or E11) without coalescer pad after cost benefit assessment.	Moderate	Good to have	Low	Minor Outage	-	-
2	IP Turbine Bypass System	5.4.7.1	Suspected IP Bypass System Steam Passing & Steam Valve Upgrade	Test data shows that IP bypass spray valve for Unit 1 and 2 was 6.48 TPH and 19.4 TPH respectively which suggest that there may be suspected steam flow in the downstream pipe. It is necessary that suspected steam leakage in IP steam pipe is quickly arrested in available opportunity.	Minor	Short term	Low	Minor Outage	1-3	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				Unlike traditional control valves, there are designs which uses multi-stage, multi-turn technology divides the pressure reduction into many smaller stages. The number of turns, or stages, is selected to ensure a specific fluid discharge velocity is achieved at the exit of the control element. This reduces the potential for cavitation and erosion, that would otherwise compromise the valve's ability to effectively control leakage.						
3	HRSG	5.4.7.2	CBD Tank Vents Open to Atmosphere	As per the design, the Continuous Blow-Down Tank (CBD) vent is routed to Deaerator however, based on site-visit discussions, it is understood that for both units, CBD vent lines are kept open to atmosphere. CBD vent should be routed to the Deaerator for fluid recovery and improved energy utilization.	Moderate	Short term	Low	Minor Outage	-	-
4	Steam Turbine	5.5.1.1	HP/IP Section Internal Efficiency Improvement by Seal Upgrade	Leakage losses represent the greatest portion of turbine stage losses. The losses are magnified as the turbine packing and turbine diaphragm spill strips	Critical	Immediate	High	Major Outage		

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				wear out progressively. A large amount of these losses is recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization. The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP and IP turbine efficiencies. Typical efficiency improvements up to 0.7-1.2 % in heat rate is reported in the past. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.						
5	Steam Turbine (HP/IP Section)	5.5.1.2	Suspected high HP to IP Leakage Flow (Temperature Inference Method)	The N2 packing leakage to IP turbine bowl is calculated using the temperature inference method. This method is an indirect method to determine the magnitude of leakage flow,	Critical	Short Term	Medium	No	12-15	1.0-1.5

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				since this leakage flow is inside the turbine, and it is impractical to directly measure it. Determination of the leakage flow shall also determine the true IP turbine efficiency.						
6	Steam Turbine (LP)	5.5.1.3	Improving LP Turbine Efficiency by Improved Blade Design and Increased Annulus Area	The steam seal upgrade tends to decrease heat rate and increase LP turbine efficiency. The new gland seals also reduce the in-air leakage around the shaft. The improved gland seal reduces the amount of air that enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air in-leakage through improved seals can decrease (improve) back pressure by 4-12 KPa absolute with a corresponding heat rate improvement of nearly 1.0%.	Moderate	Long Term	High	Major Outage	10-30	1.0-2.0
7	Steam Turbine (HP Section)	5.5.1.4	Performance Monitoring of HP Turbine Section & In-Situ Instrumentation for HP Exhaust Pressure and Temperature	One of the most critical measurements for analyzing HP turbine internal efficiency is HP turbine exhaust temperature. The ASME PTC test code 46 specifies this measurement to be	Moderate	Short Term	Low	Minor Outage	-	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				close to HP turbine exhaust. A minimum 2 measurements of HPT exhaust temperature is recommended with the instrument of 1 Deg. F or 0.56 Deg. C accuracy class for best results. HP exhaust pressure measurement is also recommended with an instrument of accuracy class 0.1%.						
8	Vacuum Pump	5.6.4.1	On-Line Performance Monitoring of Vacuum Pump & Seal Water System	Black & Veatch opines that the instrumentation available at the air extraction system is adequate for calculating vacuum pump performance. However, as most of the readings are not readily available in DCS, Black & Veatch recommends the following instruments for continuous monitoring of Vacuum pump and seal cooler performance in DCS. •Seal Water Flow (Inlet to Seal Water Cooler) •Seal Water Inlet and Outlet Temperature (Seal Water Cooler) •Seal Water Inlet and Outlet Differential Pressure	Critical	Immediate	Low	Minor Outage	5-10	

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				•ACW Inlet and Outlet Temp. (Seal Water Cooler) •Seal Water Temperature (Inlet to Vacuum Pump) •Rota Meter Flow						
9	Condenser	5.6.4.2	Investigate Suspected Air Ingress in Condenser Shell	Helium leak test is technology of choice due to availability, applicability (Can be done when unit is in operation) and detectability (Sensitivity of 10-6 mbar, fast (less than 20 seconds) , and ability to detect very fine leakages) of leakage points which are in condenser system but isn’t useful for leakages which are under water up to condensate extraction pump (Downstream of hot well, flange joints, bellows, valves, suction strainer, and associated pipelines).	Critical	Immediate	Low	No	5-10	
10	Condenser	5.6.4.3	Online Tube Cleaning (OLTC) system	Black & Veatch recommends conducting a feasibility study for the installation of an Online Tube cleaning system for increasing heat-transfer effectiveness.	Major	Short Term	Medium	Minor	5-6	
11	Condenser	5.6.4.4	Regular Replacement of Sacrificial Anodes	Black & Veatch recommends regular inspection of sacrificial anodes during every	Low	Short term	Low	Minor	-	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				outage/condenser inspection if applicable. Sufficient stock of sacrificial anodes should be maintained for 100 percent replacement of damaged or worn-out anodes during every outage if Applicable For OTPC						
12	Vacuum Pump	5.7.3.1	Develop and Implement Standard Maintenance Practice (SMP) for Cleaning of Seal Water Cooler	The seal water cooler may have to be cleaned to maintain its heat transfer capability. Ensure that the proper flow and temperature of cooling water is being supplied to the heat exchanger.	Critical	Immediate	NA	No	Included in ID 8	-
13	Vacuum Pump	5.7.3.2	Cavitation Avoidance	High seal water inlet temp. may lead to pump cavitation. High seal water temperature in due course of two-stage compression may potentially exceed the corresponding saturation temp. (boiling point) causing cavitation. This problem can be mitigated if seal water flow and temperatures are made available for operators' guidance and seal water cooler performance is regularly audited.	Critical	Short Term	Low	Minor Outage	Included in ID 8	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				Another method is using acceleration, true peak detection, frequency banded vibration sensor which is sensitive only to those frequencies normally excited during cavitation. This loop-powered sensor provides a 4-mA to 20-mA output signal proportional to the sensed vibration level. A 4-mA to 20-mA output sensor may extend its signal to DCS and alarm limits can be set for alerting the operator.						
14	Cooling Tower	5.8.1.1	Fill pack replacement in CT 1 and CT 2	Black & Veatch was informed that a program for fill pack replacement is already underway. In Unit 1, 2 fill packs in 2 cells and in Unit 2, fill packs in 5 cells are replaced till Feb-23. The plan is to be progressively replace all the fill packs in the two cooling towers. It is also recommended to upgrade the design from existing MC67 PVS fills design with other cross-corrugated Fills such as C.10.19 folded end fills.	Critical	Short Term	High	No	15-20	0.5-1

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
15	Cooling Tower	5.8.1.2	Measurement of CT flow in Risers and Equalization of flow across CT Cells	In multi-cell CT design, the inlet flow to each cells differs greatly due to long pipe length. Part of this issue is addressed by reducing the diameter of pipe as water traverses from the front most cell to the rear cell. The flow in riser pipes is often required to be adjusted to ensure that flow / cell is even across the cooling towers. A measurement of CT riser flow once in 6 month or after any major shutdown is recommended to ensure improved L/G (liquid to gas ratio) for each cell.	Critical	Short Term	Low	No	Included in ID 14	-
16	Cooling Tower	5.8.1.3	Develop SMP for CT Fills Cleaning	Review the preventive maintenance schedule of cooling towers fills cleaning. Given the concentration of suspended solids found during visual inspection, fills cleaning may be undertaken 1 cell/month by drawing out the fill packs, weighing the fill packs in dry condition before cleaning, cleaning it by pressurized jet of	Critical	Short Term	NA	No	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				water, observing the weight drop and then repacking it correctly without affecting/damaging the edges and flute profiles or honeycomb structure. A SMP for CT fills cleaning is recommended to be adhered by maintenance personnel.						
17	Cooling Tower	5.8.1.4	Provision for higher air flow by improved design of fans airfoil (Improved L/G ratio)	Replacement of GRP blades with high grade Epoxy coated blades in the fan of improved aerodynamic design. The primary objective is to ensure higher air flow through the fills for lowering the CT water outlet temperature. A well design retrofits can provide benefits up to 20% increased air flow / cell then conventional design for same power consumption.	Moderate	Short Term	Low	No	Included in ID 14	-
18	Cooling Towers	5.8.1.5	Improvement in Air-Water Distribution of CT Cells	CTs often undergo deterioration over the period of operation and need sufficient and effective maintenance periodically. •Inspection of water distribution system, fills, drift eliminators during each monthly PM.	Critical	Short Term	Low	No	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				•Installation of water nozzles in dry patches after internal inspection. •Check for any damage to the PVC water distribution pipes, their end covers, leakage from the joints, damaged nozzles, missing distribution rings of the nozzles, blockage of nozzles below RCC ducts, etc. •In situ cleaning of fills and drift eliminator with clarified water once in a quarter to remove loose dirt or sludge. •Check of fan blade tip clearance •Blade angle adjustment						
19	Cooling Towers	5.8.1.6	CT Basin Screen Design	If the CT outlet channel has two slots to put the two separate screens, then we recommend keeping the upstream screen size opening to around 1.5" – 2" to restrict the large size debris and 1/2" (12 mm- 15 mm) opening for the downstream screen to restrict the smaller size fills or debris.	Moderate	Short Term	Low	Minor Outage	Included in ID 14	-

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
20	Condensate Extraction Pump	5.10.1.1	Retrofit of MV VFD for Power Saving in CEP	Given the present operation of CEPs away from design efficiency point, it is recommended to retrofit the pump motor with a VFD to reduce the speed and thereby its discharge pressure adequately to avoid deaerator level controller valve throttling, while still meeting the pressure requirement of its duty points. A careful design review and performance analysis will result in the potential power saving is in the tune of minimum 100-120 KW at full load after adjusting for the increased HVAC auxiliary load of VFD.	Moderate	Short Term	High	Minor Outage	-	120-150 KW
21	Condensate Extraction Pump	5.10.1.2	Retrofit of CEP Gland Packing to Mechanical Seals	Mechanical seal OEMs such as Eagle Burgmann, Borg Warner, etc. can be consulted for converting the gland packing to mechanical seal. This will help in increasing the life of shaft seal and reducing the dissolved oxygen content in the condensate. The performance data suggest significantly high DO level in Unit 1 (17.86 PPB).	Moderate	Short Term	Medium	Minor Outage	-	10-150 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
22	CW Pump	5.11.1.1	Measures for High CW Flow and for Arresting Suspected Passing in Butterfly Valve	In a parallel pump operation, passing of CW discharge valve of standby pump will lead to short circuiting of CW flow to the forebay. It is practically difficult to identify the short circuiting, but this issue leads to lower CW flow across the condenser, hence it is recommended to inspect all the valves internally and replace the elastomeric seals, seal retaining segments, metallic seals of valve disc, etc. Gearbox of the actuator should be adjusted to close the valves properly and should be crosschecked internally for its full closer.	Moderate	Short Term	Low	Minor Outage	-	100-150 KW
23	Plate Heat Exchanger	5.11.1.2	Plate Heat Exchanger Isolation	Plate heat exchangers are often designed to operate as (1W + 1S) configuration, however many times, PHE are charged from ACW side for quick line up in case a changeover is warranted. This compromises standby PHE cleaning and effectiveness while adding to ACW power consumption. Standby PHE is	Moderate	Short Term	NA	No	-	15-25 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				recommended to be closed from both DMCW and ACW side as far as feasible to save unnecessary use of pumping power while keeping a close watch on in-service PHE differential pressure.						
24	DMCW	5.13.1.1	Measures for Arresting Higher Flow Rate in DMCW 2B	A flow measurement using ultrasonic flow meter is required to adjust the pump operating points near the design duty point. Any suspected passing either in common recirculation valve or stand by PHE can be ascertained and arrested. Pump 1B and 2B are found to operate at different flow rate (difference by 345 TPH) which shall be corrected.	Moderate	Short Term	NA	No	-	Included in ID 23
25	Instrument / Service Air Compressor	5.14.1.1	Service Air and Instrument Air Segregation	Segregating the plant service and operating air and instrument air system can result in energy savings. In past assessments, Black & Veatch has seen plants that combine their service, operating, and instrument air system into a single system. In OTPC also, compressors are operated to meet both service	Moderate	Short Term	Low	Minor Outage	-	Upto 50-100 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				air and instrument air requirements. Utilizing instrument air for service and controls together will result in higher energy demands specially for the air-drying applications.						
26	Instrument/ Service Air Compressor	5.14.1.2	Centralized Controller for Equalizing the Run-Hours of Two Parallel Compressors & Energy Saving	Normally, the load/unload pressure of each unit are set to react to changes in air demand. If the system pressure drops, an additional compressor will switch to loaded running. However, the sequence will always be the same, and this leads to a higher pressure than required. Central controllers can be set to prevent unequal wear of compressors, equalizing the running hours on multiple machines for more efficient service scheduling and reduced cost. Another advantage of centralized controller is that they reduce the average pressure band (load and unload set points). It also reduces the operating pressure of machines. By reducing the pressure by 1 bar (or 14.5 psi), energy usage gets lowered by 5-10%, while	Moderate	Short Term	Low	Minor Outage	-	Upto 50-100 KW

ID	AREA	REF. SECTION	OBSERVATIONS	RECOMMENDATIONS	RISK	PRIORITY	CAPEX	SHUT DOWN	HEAT RATE (KCAL/KWH)	APC (MW)
				reducing the pressure by 1 bar (or 14.5 psi) decreases air leakages by average 10-15%.						
27	Real Time Performance Monitoring	-	Performance Monitoring Using Real Time Data and Predictive Analytics Approach	Machine learning-based predictive maintenance plan detects any failure event significantly quicker, compared to the traditional approaches. The strategy utilizes the following sequential steps: • Real-time data fetching, organizing, stacking, and classifying. • Process data may be temperature, current, flow, pressure, vibration, level or calculated variables. • Using engineering knowledge and the machine learning approach, develop a predictive model of the variable and save as the operating baseline • Detect process anomalies and diagnose / mitigate the issue before its occurrence	Moderate	Short Term	Low	No	10-15	0.5-1

7 Conclusion

Black & Veatch is thankful to OTPC for providing the opportunity to perform the Plant Performance Audit of its Combined Cycle Plant.

In this report, we have provided our observations and recommendations on –

- Major performance audit observations of individual equipment and system
- Comparative assessment with similar peer units.
- Performance improvement recommendations for sustainable operation.

Black & Veatch has reviewed the past reports and provided recommendations in ***section 6.1.5*** along with expected heat rate and aux power consumption benefits.

A summary of these recommended improvement project is tabulated as follows.

Table 7-1 List of Performance Improvement Projects Including Key Decision Metrics

PRIORITY	RISK CATEGORY	CAPEX REQUIREMENT	SHUTDOWN REQUIREMENT
Immediate - 4 no's	Low - 1 no	High -4 no's	No -4 no's
Short term - 21 no's	Minor - 1 no	Medium - 4 no	Minor Outage -14 no's
Long term - 1 no's	Moderate - 14 no's	Low - 15 no’s	Major Outage -2 no's
Good to have -1 no	Major -1 no	NA - 4 no's	No Outage -11 no’s
	Critical - 10 no's		

Black & Veatch recommends systematic implementation of these projects in short-mid-term period for long-term efficient, reliable, and safe plant operation achieving its environmental sustainability and decarbonization goals.

Chemistry Review

Second visit

ONGC Tripura Thermal Power Company (OTPC) is a joint venture of ONGC, Tripura Govt and others. It is using natural gas for power generation in northeast state Tripura. The Power Plant is in the Udaipur district of Tripura.

Gas turbine runs by natural gas and the hot exhaust gas is used by HRSG boiler. This HRSG boiler having 3 steam separation drum HP, IP and LP.

Visit period: 11th. September to 14th. September 2023.

During my second visit a good discussion held with HOD Operation and understood his concern area.

I talked to COO and briefed him. I also got his view about the plant and improvement initiative.

Acknowledgement:

I want to convey my thanks to the management and the executives who support me during my tenure of stay to complete my job effectively.

During my second visit I also got the warmth of hospitality as previously felt.

I want to thank Mr. Kuldeep Mishra Plant Chemist who conduct my visit and discussed a lot on technical front. I want to thank Head of O&M Prabhat Chandra and Technical Head Mr. Jayanta Chakraborty. I convey my thanks to Mr. Shoubhik Choudhury Head Operation for detailed discussion.

Special thanks to COO Mr. Sanjay Garhwal who gave me time for discussion and briefing.

Amitava Datta

Consultant-Chemistry

CW & CT:

OTPC has a concern of MW/Heat Rate loss due to condenser and there is feeling that it is related to CW Cooling water. Recently they have changed 100% cooling tower PVC fills after 10 years of unit running and after that again a deterioration is felt by them.

Though it is a common thing after overhauling improvements is observed and then an equilibrium position established. Presently CT efficiency is being measured by a 3rd party. As per discussion condenser tube delta T is also increases after just overhauling.

As it is already known that online tube cleaning is best solution to get rid of siltation problem in condenser tubes, but site does not have that so only alternative to OTPC is jet cleaning of tubes and that needs unit shutdown and part isolation facility not there. Shutdown for this cause is difficult to implement.

To reduce overall silt burden of CW water, side stream filtration facility is also not available at site.

The make-up water used for CW system is having conductivity around 120 and OTPC is maintaining around 4 COC so ultimate conductivity of CT water is less than or around 500 and LSI is maintained less than 0.5 by maintaining pH less than 8 by dosing sulphuric acid. So, from scaling point of view this water does not support that.

Regarding organics continuous dosing of Chlorine is practiced in Morning and Evening shift and maintaining 0.5 + ppm FRC and some intermediate high FRC shock dosing. Only night shift chlorine is not dosed from safety aspect.

Some recommendation suggested:

1. Side Stream Filtration: For long term planning needs capital investment for reduction of silt burden.
2. Online Tube Cleaning System (Sponge ball cleaning): Long term planning needs capital investment and through proper engineering.
3. Chlorine dioxide dosing (ClO_2) along with chlorine. Can be started within short period.
4. Chlorine dosing 24 hrs.
5. Cooling Tower basin cleaning through robotic technology without unit shut down may be explored.

CT Area Cleaning:

CT pond area is having old used CT fills that need to be cleared.

CT pond surrounding area having wild shrubs that need to be cut and removed. The area needs to be paved.

Chlorine dioxide (ClO_2) Dosing:

It is believed **ClO_2** is more powerful oxidizing biocide over chlorine and ClO_2 shock dosing is being practiced in different plants.

ClO_2 is generated online by two methods.

a. By reacting chlorine with Sodium Chlorite
b. By reacting HCl with Sodium Chlorite

For OTPC first one i.e., Cl_2 with $NaClO_2$ to be preferred.

$NaClO_2 + Cl_2 \rightarrow ClO_2$

ClO_2 dosing is common and provided by CW water treatment service providers.

Boiler Chemistry:

This is a heat recovery boiler where gas turbine exhaust gas of temperature 680 deg centigrade is being utilised. This boiler having 3 drums HP, IP and LP and the condenser tubes are made of Aluminium brass.

As the condenser is made of copper alloy higher ammonia/pH is not suitable and on the other side ferrous part where higher ammonia/pH is favourable; to meet both end the compromised pH of Steam condensate water to be kept in 8.8 to 9.2.

For feed water dosing use both hydrazine and ammonia. Grade of ammonia should be AR.

As today's boilers are running with DM water so drum water should not be laced with lot of phosphates to serve the boiler chemistry need. In normal operating condition try to maintain required drum pH by minimum dosing of Tri Sodium Phosphate (TSP) do not use Disodium Phosphate (DSP).

Turbidity:

Turbidity is a good indication of corrosion, and it is easy to test by turbidity meter. Monitor all steam water cycle turbidity daily.

DM Plant:

Maintain mixed bed outlet conductivity < 0.1 µS/cm. Maintain MB online conductivity meter healthy.

Hydrochloric Acid Storage Tank:

OTPC is having a HCl storage tank for regeneration of capacity 10 MT. Now a days HCl road tankers are normally coming minimum of 20 MT. To use HCl presently 200 lit drum HCl is being purchased and then transferred to 10 MT bulk storage tank by portable pumps. This activity is very unsafe.

More 2 x 10 MT tank installation may solve the problem.

Chemical Laboratory:

OTPC Chemistry is maintaining a good chemical laboratory. The laboratory having Conductivity meter 2, pH meter 2, Electronic balance 2, Spectrophotometer 1 etc. Spectrophotometer is used daily for lot of analysis, and it is 3 years old, so it is suggested to initiate procurement process now.

Boiler Chloride: Boiler Chloride test to be developed from the standard to check up to 0.2 ppm and boiler Cl^- to be kept below 0.5 ppm maximum preferably < 0.2 ppm.

Iron test to be developed from standard to determine <10 ppb iron in steam water cycle.

Turbidity (NTU) of steam water cycle to be checked daily and to be recorded.

Sulphate analysis in raw water etc to be developed from standard.

Spectrophotometer: Initiate procurement process for one spectrophotometer.

Ω

Photo Annexture:

Pic right: Good initiative taken such that no muddy water can to CT pond during rain.

Pic at Bottom: Indicates clarifier turbidity is maintained at low level.

Pic at left:

Old CT fills are around the CT pond area need to clear.

Pic at left: Wild shrubs are around the CT pond need to be cut and removed.

CT pond area should be very clean, better to be paved.

15827
Certificate Sl. No.

TRIPURA STATE POLLUTION CONTROL BOARD

PARIVESH BHAWAN, Pandit Nehru Complex, Gorkhabasti,
Kunjaban, Agartala - 799 006, West Tripura.

No.F.17(10)/TSPCB/S/Power/(L-Red)/2364/Vol-IV/ 14621-26 Date : 03/07 / 2024

CERTIFICATE FOR CONSENT TO OPERATE

Under Section 25/26 of Water (Prevention and Control of Pollution) Act, 1974 and
Under Section 21 of the Air (Prevention and Control of Pollution) Act, 1981

Reference : i) Your Application No. **277317** dated : **03-05-2024**
ii) Our NOC Register Sl. No.**14587** for : **Extension of validity**

Capital Investment : **Rs. 692.79 Cr.** Production Capacity:
Type : **Power Plant** Category **: Red**

With reference to the above Application, a provisional Consent to Operate Certificate (Extension of validity) is hereby issued in favour of **ONGC Tripura Power Company Limited, Managing Director, Udaipur-Kakraban Road, Palatana, PO: Palatana, Udaipur, Gomati, Tripura** to discharge its industrial and other effluents arising out of their premises into a stream/ well/ land as per section 25/26 of Water (Prevention and Control of Pollution) Act,1974 and to make emission from the plant /unit as per Section 21 of the Air (Prevention and Control of Pollution) Act,1981situated at **Udaipur-Kakraban Road, Palatana, PO: Palatana, Udaipur, Gomati, Tripura** subject to observance of other codal formalities of the Govt. of India/Govt. of Tripura/District Administration/ Agartala Municipal Corporation or concerned Nagar Panchayat or concerned Panchayat (whichever is applicable)/ Health Department/Industries & Commerce Department and subject to observance of the following terms & conditions:

2. Only Natural Gas should be used as the main feed stock.

2. No untreated liquid effluent would be allowed to be discharged in the water bodies. Treated liquid effluents to the maximum extent possible should be used/ recycled in the plant/irrigation of their green belt/agricultural field etc. All treated effluents must meet BSI standard and emission must conform to the emission standard as fixed by the Central Pollution Control Board.

3. Effluent carrying drains must be segregated from the storm water drains and effluent must be disposed of in effluent pond. In no case, effluent will be allowed to be discharged into nearby Nullah/Natural Water Course etc. without treatment and bringing it within IS I permissible limit or limits fixed by the Board.

4. Adequate steps should be taken for prevention and control of fire and explosion hazards likely to be caused due to storage and use of inflammable material like Natural Gas.

5. Families affected due to acquisition of land should be properly compensated in consultation with the State Government.

6. The NOx emissions should not exceed the specified standards of 300 Mg/NM^3

7. The gaseous emissions from various units should conform to the standards prescribed by the emission level and should not go beyond the stipulated standards. In the event of failure of any pollution control system adopted by the unit, the respective unit should be shut down and should not be restarted until the control measures are rectified to achieve the desired standards/ efficiency.

8. Adequate No. of monitoring stations should be provided in consultation with the State Pollution Control Board. Further, stack emissions should be monitored periodically. The data of stack emissions and ambient air quality should be sent to the State Pollution Control Board monthly.

9. To maintain the environmental and ecological balance in the area, provisions for planning selected species of trees within the compound and approaches alongwith provisions. for park, garden and fountain shall have to be made. Massive afforestation will have to be made by the Industry in the Factory and Township.The unit should submit the action plan on afforestation programme including the compensatory afforestation programme within a month of issuance of this Certificate.

10. An average of 50m wide green belt shall be developed around the plant periphery covering 28 ha of area.

Contd...p/2

Amarendra Jamatia

11. A separate Environment Management Cell with suitably qualified staff to carry out the various functions should be set up under the control of a Senior Executive, who will report directly to the Head of the organization.

12. The unit would constitute an internal Monitoring Committee within 3 months from the date of issuance of the Certificate.

13. The unit would monitor environmental impact on parameters as envisaged in the EIA report including two more parameters namely- i) Exploitation of water from Gomati River & its effect on local irrigation needs an quality of discharged water and impact of river life. ii) Sludge and condensate generation and disposal system in the process of operation.

14. No Air, Water and Soil pollution shall be created by the industry beyond the permissible limits prescribed by this Board. The Industry would incorporate adequate pollution control measures before they put the plant into operation.

15. As per provisions of Water (Prevention & Control of Pollution) Act, 1974 and Air (Prevention & Control of Pollution) Act. 1981 any officer empowered, by this Board in its behalf shall have without any interruption, the right to enter the industry at any time for inspection, to take samples for analysis and may call for any information etc. Violation of this right will lead to withdrawal of this permission.

16. The unit would ensure proper sludge disposal and condensate treatment facility in accordance with the provisions of the Environment (Protection) Rules, 1986 and the action plan in this regard should be intimated to the TSPCB within one month of issuance of this NOC.

17. Standard linings and flat embankment of effluent pond shall have to be provided in the pond to prevent and control of overflow, seepage and leakage of effluent to the nearby areas.

18. The unit shall have to deposit Water Cess as per the Water (Prevention and Control of Pollution) Cess Act, 1977.

19. Gaseous pollutants due to the burning of fuel to run engine, boiler, etc. should be controlled by adopting preventive measures.

20. Solid Wastes arising during the operation should be properly graded and disposed off scientifically without causing nuisances.

21. For low-lying areas, special care is to be taken by the Industry to prevent any overflow, seepage and leekage of effluent.

22. Fire warning systems (Alarm, Siren) is to be installed by the industry to guard against accidental pollution/mishap together with the fire fighting devices.

23. All pipe connections, joint, fitting etc. in the factory and plant are to be frequently checked and kept leak proof at all the time by the industry.

24. Proper housekeeping and adequate maintenance have to be ensured/ enforced as per provisions of relevant Acts.

25. Production process is to be monitored carefully and in the event of danger, immediate shut down is to be ensured by the industry.

26. Healthy working environment for the workers must be maintained and there should not be health hazards to the workers for inadequate arrangements for ventilation, dust removal etc. Arrangements should be regularly monitored.

27. The Board will be at liberty to withdraw the Consent Certificate at any time without notice if necessary steps for prevention of pollution and preservation of environment is not taken by the plant as per the mentioned conditions.

28. The issuence of this Certificate does not confer any right on any realistic or personal property or any exclusive privilage nor does it authorised the Certificate folder of inflecting any injury to private properties nor any invasion right.

29. This Certificate does not authorise or approve the construction of any physical structure or facilities or the undertaking of any works especially instructed herein.

30. The unit shall have to install adequate capacity of cooling towers at suitable location before starting operation. Special care should be taken to cool down the hot water before discharge as per B.S.I. Standard (Formerly, ISI). There should not be adverse effect on aquatic lives due to water temperature at the discharge point.

Contd...p/3

 Amarendra Pandit

31. The applicant is to construct Treatment Plant to treat their domestic waste which will arise from their colony and in no case, untreated sewage and effluent shall be discharged outside their compound.

32. The unit is to setup Rain Water Harvesting Plant for effective implementation of Water Resource Management Plan.

33. The applicant is to take special care so that nearby flora and fauna are unaffected due to their activities in area.

34. The Water temperature at the discharge point should not exeed 7 degree centigrade and above the ambient temperature of the receiving river.

35. Height of chimney shall not be less than 30 meters.

36. Adequate care is to be taken by the applicant to the sericulture of the nearby areas. The levels of noise and vibration in the compression room turbine area and the Noise Level shall be kept below 85 dB.

37. Special care is to be taken by the applicant to preserve the sericulture of the nearby areas.

38. Environmental Audit Statement shall have to be submitted to the Board once in every financial year.

39. Due care and maintenance of the DG sets should be taken in the following manner so that Pollution level can be minimised:

(i)The pre cleaner should be inspected for dirt/dust accumulation and it should be cleaned once in a week.

(ii)The vacuum indicator should be cheeked for red band and the outer element should be cleaned only by compressed air, with pressure not more than 60 psi, if required.

(iii)The water and sediment from water separator and fuel tank should be drained before starting.

(iv) Coolant condition should be maintained as per specifications.

(v)Lube oil pressure should be checked every morning before starting.

(vi)Engine log book of previous shift should be checked and then reset, if required.

(vii) The engine should be cleaned externally every day.

(viii)Leakage of engine oil, coolant and fuel should be checked before start up and engine oil should be topped, if required.

(ix)The engine should be primed before starting.

(x)The battery condition and electrical connection should be cheeked before starting as per O & M Manual.

(xi)The engine should be started and operated without load/idle for 2-3 minutes for any leakage or abnormal sound. Corrections should be made if necessary.

(xii)The engine should be started on electrical mode and proper functioning of safety control should be checked.

(xiii) The engine should be idled for three minutes before shut off.

(xiv) Recommended schedule maintenance checks should be carried out.

(xv) Only genuine parts should be used while replacing them during break down or preventive maintenance.

40. Personal Protective Equipment (PPE) like Gloves, Mask, Face Shield, Head Gear etc. shall have to be used by the workers of the unit during working period.

41. The said unit shall have to install OCEMS System.

42. The unit should take necessary measures to maintain the Noise Level mentioned as under

Noise level not to exceed

Day Time	Night Time
(6.00 am to 10.00 pm)	(10.00 pm to 6.00 am)
55db	45db

43. The unit shall have to comply all the terms and conditions of Environmental Clearance imposed by MoEFCC, Govt of India.

44. Solid waste generated in the unit shall be disposed of as per the provisions of the Solid Waste Management Rules, 2016

45. Plastic waste generated in the unit shall be disposed of scientifically as per the provisions of the plastic Waste Management Rules, 2016.

46. The unit shall comply with the provisions of the E-Waste (Management) Rules, 2022.

47. The unit shall strictly comply with the provisions under the Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989.

Amarnath Samanta

Contd...p/4

48. Banning order regarding identified plastic carry bags & other single use plastic item issued vide Notification No.F.8 (30)/DSTE/ENV/pt-v/5612-30 dated 03.08.2022 should be strictly adhered to.
49. Public liability insurance coverage shall have to be provided to the workers of the unit.
50. The unit will have to follow other norms & standards issued by TSPCB from time to time.
51. Compliance report may be submitted to the TSPCB once in a year.
52. Violation of any of the above conditions will lead to withdrawal of the certificate and/ or levying environmental compensation as per the Rules.

This certificate is valid upto 01.07.2029. Application for extension of validity of Consent Certificate shall have to be made One month before the date of expiry of validity of this Certificate.

Amarendra Jamatia
(Amarendra Jamatia) 2/7/2024
Asst Environmental Engineer
Tripura State Pollution Control Board

To
Managing Director
ONGC Tripura Power Company Limited
Udaipur-Kakraban Road, Palatana
PO: Palatana, Udaipur, Gomati, Tripura

Copy to :
1) District Magistrate, Tripura (G)
2) Director, Industries & Commerce,Tripura.
3) SDM, Udaipur, Tripura (G)
4) CEO, Udaipur Municipal Council, Tripura (G)
5) District Scientific Officer, DST&E, Tripura (G).

Amarendra Jamatia 2/7/2024
Asst Environmental Engineer
Tripura State Pollution Control Board

GOVERNMENT OF TRIPURA
OFFICE OF THE EXECUTIVE ENGINEER
WATER RESOURCE DIVISION NO. –III
UDAIPUR, GOMATI, TRIPURA

No. F. OTPC-01/EE/WR-III/UDP/364-65 Dated, Udaipur, the ~~3rd~~ 7th June, 2024

To
Head (Projects & Services)
OTPC, Palatana,
Udaipur, Gomati, Tripura

Subject: - Technical views regarding construction of an Intake Well near Palatana OTPC Plant
Ref. No. OTPC/UDP/Palatana/23-24/296, Dated 26/12/2023

It is to inform you about the developments regarding the state support agreement between the Government of Tripura (GOT) and ONGC Tripura Power Company Limited (OTPC), dated 15th January 2007. As per this agreement, GOT grants OTPC the permission to draw 125 MLD of raw water from the Gomati River for the operation of its power plant. This permission is valid for an initial term of 30 years.

Initial Proposal and Challenges:

OTPC initially proposed the construction of a well-type pump house upstream of the Maharani Barrage, along with an associated pipeline from the pump house to the OTPC facility in Palatana. However, after thorough review, several challenges were identified:

1. **Land Acquisition**: Significant difficulties and high costs associated with acquiring the necessary land.
2. **Feasibility**: Complexities in the construction of the well-type pump house and associated pipeline.

Meeting and Decision:

On 15th May 2024, the Head of Projects & Services at OTPC, Palatana, attended a meeting at the office of the undersigned to review the matter. During this meeting, alternative solutions were discussed to ensure compliance with the agreement while addressing the feasibility issues.

P.T.O.

Technical Views / Proposed Alternative Solution:

Our technical assessment concluded that constructing an intake well in the river-bed of the Gomati River, adjacent to the OTPC Complex, could be a viable solution. This alternative has several benefits:

1. **Proximity:** Closer to the OTPC facility, reducing pipeline length and associated costs.
2. **Feasibility:** Easier to implement with fewer land acquisition issues.

Important Considerations:

1. **Site Selection:** The intake well site must be chosen carefully to ensure sufficient water flow, even during lean periods.

2. **Impact on LI Schemes:** The design must ensure that existing Lift Irrigation (LI) schemes downstream are not adversely affected during lean periods.

Next Steps:

1. **Alternative Intake Points:** Identify other feasible intake points along the Gomati River to ensure minimal complications related to land acquisition and cost.

2. **Timely Completion:** Emphasize that the work needs to be completed at the earliest to ensure uninterrupted water supply for the OTPC power plant operations.

I appreciate your prompt attention to this matter and request that you proceed with the necessary actions to finalize and implement the selected solution / Technical Views from our end.

Yours faithfully

06/6/24

(Er. M. Mog)
Executive Engineer
Water Resource Division No.III
Udaipur, Gomati, Tripura

Copy to:-
The Assistant Engineer, GBSD, for information & necessary action.

Executive Engineer
Water Resource Division No.III
Udaipur, Gomati, Tripura

Regd. with A/D
Messenger

NO.F. **OTPC-01**/EE/WR-III/UDP/6920-22

GOVERNMENT OF TRIPURA
OFFICE OF THE EXECUTIVE ENGINEER
WATER RESOURCE DIVISION NO.III
UDAIPUR : GOMATI, TRIPURA

Dated, Udaipur, the 26 th February,2024

To
The Head (Projects & Services)
OTPC, Palatana, Udaipur
Gomati, Tripura.

Subject : Letter regarding insufficient water availability in river Gomati at OTPC river water intake pump house and permission to construct well type pump house at the upstream of Maharani barrage and laying of associated pipeline upto OTPC, Palatana/ **Quantity of water consumption.**

Reference: OTPC/UDP/Palatana/23-24/296 dated 26.12.2023.

Sir,

Apropos to the subhect cited above. A letter has been received by this office vide above reference. Accordingly, this office processed to the competent authority for permission as sought. But the quantity of water consumption has been asked by the authority for giving permission towards your end.

In the above circumstances, you are requested to send the quantity of water consumption per day for your plant.

This is for your kind information & necessary action please.

Yours faithfully
26/2/24
(Er. M. Mog)
Executive Engineer
Water Resource Division No.-III
Udaipur, Gomati, Tripura

Copy to:

1. The District Magistrate & Collector. Gomati District, Udaipur for kind information please.
2. The Superintending Engineer, W.R. Circle No.III, Udaipur for kind information please.

Executive Engineer
Water Resource Division No.-III
Udaipur, Gomati, Tripura

ONGC Tripura Power Company Limited

Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105, Phone: 0381-2363714, Fax: 0381-2363716

Ref: OTPC/UDP/Palatana/2023-24/452 Date:05.03.2024

To
The Executive Engineer,
Water resource Department,
Govt. of Tripura,
Gomati District, Udaipur.

Subject: - Letter regarding insufficient water availability in River Gomati at OTPC river water intake pump house and permission to construct well type pump house at the upstream of Maharani Barrage and laying of associated pipeline up to OTPC, Palatana / Quantity of water consumption.

Ref: - Your Letter NO.F. OTPC-01/EE/WR-III/UDP/6920-22 dated 26th February 2024.

Dear Sir,

A letter NO.F. OTPC-01/EE/WR-III/UDP/6920-22 dated 26th February 2024 has been received as on dated 28th February 2024 in which information regarding the water consumption per day for the OTPC plant has been requested.

As per state support agreement between "The State of Tripura and ONGC Tripura power company Limited (OTPC) dated 15th January, 2007, page no-10, clause no-3.7.1, GOT grants permission to the Company (OTPC) to draw 125 (One hundred and twenty-five) Million litres per day (MLD) of raw water from the intake point as specified by the company on River Gomati to power plant for an initial term of 30 (thirty) years. The copy of state support of agreement (Page no-10) is enclosed.

In view of above, necessary permission may be given to construct a well-type pump house at the upstream of Maharani Barrage and lay associated pipelines up to OTPC, Palatana for drawal of 125 million litres of water per day.

Hence, it is requested to consider OTPC's requirement and provide necessary approval. Your cooperation in this matter shall be highly appreciated.

Thanking You

OFFICE OF THE EXECUTIVE ENGINEER

ONGC TRIPURA POWER COMPANY LTD.
PALATANA
RECEIVED
DATE 05/03/24 NO. 452
TIME 3:12 pm
Remarks: Contents have not been read
SIGN.

05/04/24

Yours Sincerely,

05.3.24

(Tapas Bhowmik)
Head (Projects & Services)
OTPC, Palatana

Encl: Copy of state support of agreement (Page no-10).

CC.

1. DM & Collector, Gomati District, For kind information please.
2. COO, OTPC, For kind information please.

Regd. Office: Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura-799 105, Phone: 0381-2363714, Fax: 0381-2363716
Head Office: Admin Block, OTPC Power Plant, Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105
Phone: 0381-2363711 (D), Fax: 0381-236-3715, CIN: U40101TR2004PLC007544, Website: www.otpcindia.in
(An ISO 9001, ISO 14001 and OHSAS 18001 Certified Organization)

STATE SUPPORT AGREEMENT

BETWEEN

THE STATE OF TRIPURA

AND

ONGC TRIPURA POWER COMPANY PRIVATE LIMITED

Dated January 15 2007

STATE SUPPORT FOR THE PROJECT TO BE DEVELOPED BY ONGC TRIPURA POWER COMPANY PVT. LTD.

(3) Make best efforts to issue direction to the concerned departments / utilities so that adequate and suitable provisions for telephony, mobile telephony and internet access is made in and around the Power Plant.

(4) Make best efforts for inclusion of works related to strengthening of National Highway Number 44 with the Ministry of Road Transport and Highways, Government of India in their work plan for the year 2005-06.

3.6. **Power purchase**

3.6.1 The GOT acknowledges and covenants that it shall ensure and procure the off-take of 100 MW of power or any other quantity, as may be mutually agreed upon, from the Power Plant in terms of the Memorandum of Understanding for the purchase of power signed between Tripura Power Corporation and the PTC India.

3.7 **Water supply**

3.7.1 The GOT grants permission to the Company to draw 125 (One hundred and twenty five) Million liters per day (MLD) of raw water from the **'Intake Point'** specified by the Company on River Gumti to the Power Plant for a initial term of 30 (thirty) years commencing from the date of signing of this Agreement, on the terms and conditions herein contained. The permission hereby granted shall be subject to any executive orders issued in this behalf by the GOT from time to time and for the time being in force.

3.7.2 The Company shall pay GOT water rates for water drawn by it from the River Gumti at the rate of Re 0.10 (ten paisa) per kilolitre **('Water Charges')** for the raw water lifted from the river as per actual measurement by suitable water metre devices, to be installed at the Intake Point by the Company. The same rate would be applicable if the Company extracts water through installation of any device with due approval of the GOT for any use by the Company. The Water charges specified above would be revised in the event of revision in power tariff (per unit) for the Project, as approved by Central Regulatory Commission (CERC), in the following manner:

$W_R = W_P + W_P * (P_R - P_o) / P_o$

W_R = Revised water charges per kilolitre

W_P = Initial water charges i.e. Re 0.10 (ten paisa) per kilolitre

P_o = Initial power tariff (per unit) for the Project approved by CERC

P_R = Revised power tariff (per unit) for the Project approved by CERC

3.7.3 The Company shall be obliged to install pollution control devices meeting the specifications set out in the Water (Prevention & Control of Pollution) Act, 1974 (Central Act) and Tripura State Board (for the prevention and control of Water Pollution) Rules 1989 with upto date amendments on the point of discharge **('Discharge Point')** into River Gumti from the Power Plant at its own cost. The Company further agrees to pay cess @ 5 (Five) paisa per kilo litre to the Ministry of Environment & Forest, Government of India, through State Pollution Control Board as per sub-section (2) of section 3 of the Water (Prevention & Control of Pollution) Cess Act 1977 (36 of 1977) in terms of the notification issued by the Government of India, Ministry of Environment & Forest No. S.O.499 (E) dated 6.05.2003. In case of any revision in the cess payable to Ministry of Environment & Forest, Government of India, the Company would pay cess at the revised rate.

ONGC Tripura Power Company Limited

Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105, Phone: 0381-2363714, Fax: 0381-2363716

Ref: OTPC/UDP/Palatana/23-24/296 Date: 26.12.2023

To
The Executive Engineer,
Water resource Department,
Govt. of Tripura,
Gomati district, Udaipur.

Subject: Letter regarding insufficient water availability in river Gomati at OTPC river water intake pump house and **Permission to construct well type pump house at the upstream of Maharani barrage and laying of associated pipeline up to OTPC, Palatana.**

Kind Attn: Er. Mongsi Mog, Executive Engineer, water resource, Gomati district.

Dear Sir,

With reference to the above mentioned subject, you are already aware that the water level at our River water intake system (RWIS) has dropped on permanent basis and we are not getting any gravity flow to our intake channel to pump house. During rainy season only we get adequate water to our pump house. In remaining all other season, we have to deploy temporary pumps to withdraw water from the river to our pump house. Since plant water requirement is considerably more, trying to meet plant requirement by small temporary pumps is not being felt as feasible option even though we are doing as no other options are available. Moreover, during ponding operation at Maharani barrage, situation gets further aggravated to draw water in pump house.

Recently we came to know about the matter of dredging of the Gomati river from Udaipur to Sonamura for making the river navigable. As per our anticipation, after the dredging process river basin will further go down and we may not be able to draw water at all. This problem was discussed among various relevant technical and administrative forum but no permanent solution is visible as on date.

In view of the above scenario, it is requested to allow OTPC to construct well type pump house of suitable capacity at the upstream of the Maharani barrage along with laying of pipeline to OTPC, Palatana through Govt. owned land to mitigate the water scarcity problem on permanent basis.

Received 26/12/2023

ONGC Tripura Power Company Limited

Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105, Phone: 0381-2363714, Fax: 0381-2363716

Kindly be noted that OTPC is the major power supplier at north east which is supplying power to all north eastern states including Tripura and also Bangladesh gets power supply from Tripura. So OTPC bears the highest importance in maintaining grid security of northeast and also for maintaining bilateral relationship with neighbouring country. Water requirement of OTPC is paramount to maintain stable generation according to the fuel availability from ONGC. Kindly be noted that any reduction in power generation in OTPC will affect all the beneficiary state including Tripura.

We anticipate your favourable response on urgent basis for the critical requirement of OTPC.

Thanking You.

Yours Sincerely

26.12.23

Tapas Bhowmik
Head (Projects & Services)
OTPC, Palatana

CC.

1. DM & Collector, Gomati District, for kind information please.
2. MD, OTPC, for kind information please.
3. COO, OTPC, for kind information please.

ONGC Tripura Power Company Limited

Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105, Phone: 0381-2363714, Fax: 0381-2363716

Ref: OTPC/UDP/Palatana/2023-24/452 Date:05.03.2024

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05-3-24

(Tapas Bhowmik)
Head (Projects & Services)
OTPC, Palatana

ONGC TRIPURA POW... COMPANY LTD.
PALATANA
RECEIVED
DATE 05/03/24 NO. 452
TIME 3:12 P
Remarks: Contents ... been read
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Regd. Office: Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura-799 105, Phone: 0381-2363714, Fax: 0381-2363716
Head Office: Admin Block, OTPC Power Plant, Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105
Phone: 0381-2363711 (D), Fax: 0381-236-3715, CIN: U40101TR2004PLC007544, Website: www.otpcindia.in
(An ISO 9001, ISO 14001 and OHSAS 18001 Certified Organization)

OTPC

ONGC Tripura Power Company Limited

Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105, Phone: 0381-2363714, Fax: 0381-2363716

Ref: OTPC/UDP/Palatana/23-24/296

Date: 26.12.2023

To
The Executive Engineer,
Water resource Department,
Govt. of Tripura,
Gomati district, Udaipur.

EXECUTIVE ENGINEER
26/12/23

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ONGC Tripura Power Company Limited

Udaipur-Kakraban Road, Palatana P.O., District Gomati, Tripura - 799105, Phone: 0381-2363714, Fax: 0381-2363716

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Thanking You.

Yours Sincerely

26.12.23

Tapas Bhowmik
Head (Projects & Services)
OTPC, Palatana

CC.

1. DM & Collector, Gomati District, for kind information please.
2. MD, OTPC, for kind information please.
3. COO, OTPC, for kind information please.

ONGC-Tripura Power Company Ltd.

ONGC TRIPURA POWER COMPANY LIMITED
INTERNAL AUDIT REPORT (DRAFT)
For the Quarter ended 30th September 2024

T R Chadha & Co LLP
Chartered Accountants

To Management
ONGC Tripura Power Company Limited
Corporate Office, Scope Minar, Core 4
New Delhi – 110092, India

Dear Sir,

ONGC Tripura Power Company Limited engaged us to conduct the Internal Audit for the period 1st July 2024 to 30th September 2024.

The Scope of the Internal Audit, Executive Summary, Detailed observations, Action steps, and Recommendations are included in the attached report. Our Final report, based on the information supplied and explanations provided by the management of ONGC Tripura Power Company Limited is presented herewith for your perusal.

It is important to recognize that there are inherent limitations in any auditing process wherein material errors, fraud, and other illegal acts having a direct and material financial impact if they exist, may not be detected. Also, because of the characteristics of fraud, particularly those involving concealment through collusion and falsified documentation (including forgery), an internal audit may not detect material fraud. We will communicate to you as appropriate, any illegal act, material errors, or evidence that fraud may exist, identified during our work.

We value the opportunity to work with you and sincerely appreciate the cooperation and assistance provided to us during the course of the audit.

Should you require any further information/clarifications from our side, please do not hesitate to contact us.

This report is intended solely for the information and use of the management of the company.

Thanking you and assuring you of the best of our professional services at all times.

Yours Faithfully
T R Chadha & Co LLP
Chartered Accountants
Firm Regn. No. 06711N/N500028

(Neena Goel)
Partner
Membership Number - 057986
UDIN No:

Table of Content

Section 1 Executive Summary

A. Scope of work, Objective & Work Performed
B. Our Approach
C. Disclaimer
D. Internal Audit Status

Section 2 Executive Summary of Key Observations

Section 3 Detailed Internal Audit Observations of all department

Section 4 Recommendation / Improvement Points

Section 5 Action taken Report of Previous Auditor's Report

Section 6 Audit Risk Rating Criteria

Section 7 Annexures (Separate File)

A. Scope of work, Objective & Work Performed

Scope of work

- Spares, Stores & Consumables
- IT Security
- Salary Wages and Attendance records
- Loan & Advances, Imprest, Bonus to Employees
- Fixed Assets
- Payments including travelling expenses
- Supply Chain Management
- Statutory Compliance
- Review and Checking of CSR expenses as per policy and enactment
- Reconciliation of the reading in ONGC and OTPC gas custody meters on quarterly basis
- Review of Internal Financial Controls

Objective

The objectives of our audit were:

- Review of internal controls of sub-processes identified in the scope.
- Test the related controls.
- Assess the level of compliance with the existing policies and procedures
- Provide observations and recommendations to enhance controls and where appropriate, to improve process performance.

Work performed

- Obtained an understanding of various policies and procedures in the company.
- Interviewed process owners to gain an understanding of the processes and internal controls.
- Reviewed transactions on a sample basis to verify compliance with various checks and controls designed.

B. Our Approach

Process overview

Interview with process owners to obtain process understanding

Data acquisition & analysis

Obtain data relevant to the scope of the period under review. (wherever applicable and available)

Analysis of the data obtained and identification of preliminary observations

Discussion of the preliminary observations with process owners.

Findings

Identify control gaps and process non-compliance exceptions

Recommendations

Action steps

C. Disclaimer – Coverage and Limitations of the Review

Report period:

- This report is primarily based on data analysis and testing of transactions effected during the period Jul'24 to Sep'24. However, where applicable, we have also used data pertaining to the periods prior to Jul'24 as well as post Sep'24 to establish and corroborate trends and control gaps.

Scope limitations:

- As it is practically not possible to study all aspects of a process in its entirety during the limited time frame of an audit, based on our methodology for conducting internal audits, we conducted a review of the process and held discussions with the process owners and other key people in the process during the planning stage of audit which helped us in identifying specific areas where control weaknesses and process gaps may exist, opportunities for process improvement and/or cost reduction are available. Our subsequent test work, the study of issues in detail and developing action plans are directed toward the issues identified. Therefore, this report may not necessarily comment on all the function/process-related matters perceived as important by the management.

- The issues identified and proposed action plans in this report are based on our discussions with the people engaged in the process, review of relevant documents/records and our physical observation of the activities in the process. We made specific efforts to verify the accuracy and authenticity of the information gathered only in those cases where it was felt necessary. The work carried out and the analysis thereof is based on the interviews with the personnel and the records provided by them.

- The identification of the issues in the report is mainly based on the review of records, sample verification of documents/ transactions and physical observation of the events. As the basis of sample selection is purely judgmental in view of the time available, the outcome of the analysis may not be exhaustive and represent all possibilities, though we have taken reasonable care to cover the major eventualities.

- This report is meant for **ONGC Tripura Power Co. Ltd** management only & should not be quoted or referred to without our prior written consent.

D. Internal Audit Observations Status Q2 FY 2024-25

S. No.	Department Covered	Risk Rating			Total Observations
		High	Medium	Low	
1	Payments				
2	Human Resource				
3	Fixed Assets				
4	Travelling expenses				
5	Supply Chain Management				
6	Statutory Compliance				
7	IT Security				
8	Spares, Stores & Consumables				
9	Review and Checking of CSR expenses as per policy and enactment				
10	Reconciliation of the reading in ONGC and OTPC gas custody meters on quarterly basis				
11	Review of Internal Financial Controls				
Total Observations					
Recommendation / Improvement Points					

Executive Summary of Key Observations

Executive Summary of Key Observations

#	Key Observation	Implications & Recommendations	Management Comments	Ref
Payments				
1				

OTPC
ONGC-Tripura Power Company Ltd.
A JV Company of ONGC, IL&FS and Government of Tripura

Detailed Internal Audit Observations

ONGC-Tripura Power Company Ltd.
A JV Company of ONGC, IL&FS and Government of Tripura

Operation & Maintenance

Detailed Observation

HIGH

Point No: 1

Low Plant Availability Factor (PAF) as per CERC Norms

As per the CERC norms, a power plant's Plant Availability Factor (PAF) should not be less than 85% of the plant's designed capacity.

Upon reviewing the generation parameters for the period Jul'24 to Sep'24, it has been observed that the average PAF of the plant was 56% during the quarter. Details are provided below:

Month	No. of Days	Average of PAF	Max of PAF	Min of PAF
Jul'24	31	51%	71%	45%
Aug'24	31	57%	73%	42%
Sep'24	30	60%	67%	46%

Further, we noted that PAF was at 47% (very low) from 26th July 2024 to 27th July 2024 due to the tripping of unit-2 as ACDB control power failed. Similarly, PAF was at 46% on 5th September 2024 due to shutdown in unit-2 taken for rectification of the GT-2 diffuser compartment hotspot.

Note: There was a scheduled shutdown in Unit-1 for the period 1st July 2024 to 20th July 2024 and in Unit-2 from 5th August 2024 to 18th August 2024.

Details are given in **Annexure A**.

Department : Operation & Maintenance

Implication

Low Plant Availability Factor leads to revenue loss due to reduced power generation.

Recommendation

Company should take required action to maintain the PAF level as per the CERC norms.

Management comments

Detailed Observation

HIGH

Point No: 2

Operational & Financial loss due to short-supply of Gas from ONGC

We observed that ONGC is continuously supplying less gas to the OTPC plant as compared to the nominated quantity. Due to less supply of gas, the company is facing operational and financial losses as gas turbines are not running in the normal mode of operation resulting in increased maintenance costs.

We noted that on average, 6.70 Lakhs SCM of gas is short-supplied by ONGC daily resulting in an average short supply of 25% of total OTPC nominated quantity during the period Jul'24 to Sep'24.

Due to the short supply of gas, OTPC is incurring a loss of approx. **351 MUs** amounting to revenue losses of **INR 115.81 Cr** during the period Jul'24 to Sep'24. Details are provided in the next slide.

From a commercial perspective, the break-even point for OTPC is at a 64% Plant Load Factor (PLF). However, due to the reduced gas supply, the plant is operating at an average PLF of 55% leading to financial losses to OTPC.

Details are attached in **Annexure B.**

Department : Operation & Maintenance

Implication

Due to the short supply of gas, the company is incurring operations & financial losses.

Recommendation

Company should regularly follow up with ONGC for the supply of required gas as per the nominated quantity.

Management comments

Short Supply of Gas

HIGH

Month	OTPC Gas Nomination (SCM)	Actual Gas supplied (SCM)	Short supply of gas by ONGC	Average of % of short supply of Gas
July	7,09,05,500	5,65,83,467	1,43,22,032	20%
August	8,22,49,228	6,49,04,108	1,73,45,119	21%
September	9,53,98,200	6,54,32,000	2,99,66,200	31%
Total	**24,85,52,928**	**18,69,19,576**	**6,16,33,352**	**25%**

Month`1	Total Generation loss (MUs)	Revenue loss @ INR 3.30 per unit
July	58	19,22,40,518
August	107	35,39,67,670
September	186	61,18,92,079
Total	**351**	**1,15,81,00,267**

Detailed Observation

HIGH

Point No: 3	Department: Operation & Maintenance
Difference in gas meter reading as per ONGC custody meter vs. OTPC meter	**Implication**
As per GSPA with ONGC, the gas billing is to be done based on the gas flow meter reading, installed at ONGC terminal. Daily deviation tracking is being done for ONGC meter readings and OTPC meter readings available at the Gas Turbine end. Earlier, when stream A USM at ONGC side was in service, the difference was nominal. However after the stream changeover from A to B in Feb'24 (on account of sending A USM of ONGC for calibration), and having sent OTPC check meter for calibration, the difference has increased. Reading as per the ONGC meter is always more than the OTPC meter resulting in an **excess reading of an average of 18,251 SCM per day** resulting in an excess outflow of INR 1.79 Crores during the period Jul'24 to Sep'24. Details are attached in **Annexure C.** As per the management reply given in the last quarter, calibration of the meter is complete by Jul'24, however, till our review date 3rd October 2024, the calibrated meter has not yet been received. OTPC vide letter dated 12th August 2024, requested ONGC regarding the difference in meter reading and to adjust the excess amount (differential reading) in subsequent invoices.	Mismatch in the readings results in excess funds flow. **Recommendations** ➢ OTPC should periodically reconcile the difference quantity and communicate to ONGC. ➢ OTPC should ask ONGC to calibrate meter B USM after the installation of A USM. **Management comments**

Detailed Observation

MEDIUM

Point No: 4

High Auxiliary Power Consumption (APC)

As per the CERC norms, the Auxiliary Power Consumption in the case of a Combined Cycle Gas Station should be 3.50%.

During the period under review Jul'24 to Sep'24, it has been observed that the Plant Auxiliary Power Consumption (APC) was significantly higher than the agreed level. The average APC for the current period was 4.66%, compared to the CERC norm of 3.50%.

Due to the high APC level, the company has a generation loss of **10.48 MUs** amounting to a revenue loss of **INR 3.46 Cr (Actual vs CERC).** Details are given in the next slide.

Further, designed Auxiliary Power Consumption (APC) is not defined in the O&M agreement where PLF is below 60% and we noted 61 days during our audit period where PLF is below 60%.

Details are attached in **Annexures D & E.**

Department: Operation & Maintenance

Implication

Due to the High APC level, the company has a generation loss.

Recommendation

The company should make necessary efforts to maintain the Auxiliary Power Consumption (APC) within prescribed limit by CERC.

Management comments

MEDIUM

Period	Average of AUX power consumption (in %)	Average of AUX as per CERC	Total generation (in MU)	Loss of Units	Revenue Loss @3.30 P.U
Jul'24	4.46	3.50	274.41	26,34,336	86,93,309
Aug'24	4.58	3.50	306.23	33,07,284	1,09,14,037
Sep'24	4.94	3.50	315.09	45,37,296	1,49,73,077
Total	**4.66**	**3.50**	**895.73**	**1,04,78,916**	**3,45,80,423**

Detailed Observation

MEDIUM

Point No: 5

High generation losses due to downtime

On reviewing of power generation data for the period Jul'24 to Sep'24, we noted a generation loss of 13.72 MU in GT-1 and 90.49 MU in GT-2 totaling 104.21 MU (**which is 11.63% of total generation units**) resulting in a revenue loss of approx. **INR 34.39 Cr** during this period other than generation loss due to Gas. Details are as under:

Reasons of loss	GT-1 (In MU)	GT-2 (In MU)
Generation loss forced SD (Forced)	1.85	68.40
Generation loss due to ambient condition (Planned)	3.80	12.24
Start up generation loss (Forced)	0.09	2.26
Start up generation loss (Planned)	2.77	2.90
Generation loss due to partial requisition & other reasons	5.21	4.69
Total	**13.72**	**90.49**
Total units generated	**449.60**	**446.13**
Loss % as of total units generated	**3.05%**	**20.28%**
Total units capacity	**741.13**	**741.13**
Loss % as of total capacity	**1.85%**	**12.20%**

In the above table, out of the total generation loss of 90.49 MUs in GT 2, a major loss of 68.40 MUs is due to an unplanned shutdown required as given in the next slide:

Details are attached in **Annexure F.**

Department : Operation & Maintenance

Implications

The generation loss directly translates into revenue loss for the company.

Recommendation

It is recommended to take proper preventive and corrective measures to minimize such losses.

Management comments

Reasons of loss	Period of shutdown	GT-2 (In MU)
Failure of UPS 1 & 2 resulting in failure of Unit-2 ACDB control power	25.07.24 – 28.07.24	**20.30**
High vibration shutdown and after the mode changeover from PPM to PM, load was increased and tripped due to high value of bearings.	15.08.24 – 19.08.24	**32.00**
GT-2 diffuser compartment hotspot rectification	04.09.24 – 06.09.24	**12.36**
CPD to APU inlet line joint rectification	14.09.24	**3.73**

Detailed Observation

MEDIUM

Point No: 6

Actual Plant Heat Rate is higher than the agreed rate

As per the O&M contract with STEAG Energy Services (India) Pvt. Ltd, the plant heat rate should be maintained based on different levels of Plant Load Factor (PLF).

For instance, at 100% load, the heat rate should be 1505.70 Kcal/KWh, at 99% load, the heat rate should be 1508.62 Kcal/KWh, and so on.

During the period under review Jul'24 to Sep'24, it was observed that the average actual plant heat rate is 1723.12 Kcal/KWh whereas the agreed level of Plant Heat rate should be 1673.58 Kcal/KWh as per actual PLF i.e. **higher Plant Heat Rate by 49.54 Kcal/KWh.** Details are as under:

Month	Average of Actual Heat Rate	Average of Designed Heat Rate	Difference in Actual VS Designed Heat Rate
Jul'24	1728.40	1672.83	55.57
Aug'24	1717.03	1666.35	50.68
Sep'24	1724.92	1681.55	42.37
Total	**1723.12**	**1673.58**	**49.54**

Further, the designed heat rate is not defined upon in the O&M agreement in case where PLF is below 60% and we noted 61 days during our audit period where PLF was below 60%.

Details are attached in **Annexures G & H.**

Department : Operation & Maintenance

Implications

Higher Plant heat rate leads to increased consumption of Gas and reduction in output, which ultimately results in lesser efficiency of the Plant.

Recommendation

Maintain the plant heat rate within the agreed level.

Management comments

Human Resource

Detailed Observation

MEDIUM

Point No: 7

Monthly fee paid to township doctor needs to be analyzed

OTPC has entered into a service order for medical consultancy service with M/S Dr. Goutam Roy Chowdhury on 25th April 2024 and the remuneration to be paid to the doctor is fixed at INR 540,000/- for 1 year (INR 45,000/- p.m.). The purpose of this service order is to provide medical consultancy to the employees and their families residing in OTPC township.

On reviewing the monthly payments and the track of number of patients attended by doctor for the period Jul'24 to Sep'24, we noted that the doctor attends only 12 to 14 number of patients on an average in a month that are residing in OTPC township i.e. approx. INR 4000/- per patient.

As per the patient appointment records, doctor even not attended a single patient in some of the days.

This raises concerns regarding the utilization of the doctor's services and the overall cost-effectiveness of the arrangement. As a recommendation it is advised to review the necessity by considering the requirement of doctor as per the past records of attended patients.

Department: Human Resource

Implication

Average cost per patient is too high, indicating inefficient utilization of the allocated resources.

Recommendations

- Conduct a thorough analysis to assess the necessity of a full-time doctor based on the past records of attended patients.
- Work order amount may be negotiated with doctor to save cost to the company.

Management comments

This is a an Employee Welfare program initiated at OTPC Township for the well-being of our employees and associates residing at township. Advisory and awareness emails being circulated on regular interval about our Doctor's presence so that they may avail the services on a regular manner instead of hovering outside in search of a medical practitioner. Lower number of patient recently is a good indication of Employee well being. Past records was more in number to enable us to continue the services. As stated in the audit point HR & Admin department had decided to continue awareness program frequently to increase the footfall.

Detailed Observation

MEDIUM

Point No: 8

Ambulance hire cost needs to be analyzed for cost saving to the company

OTPC has entered into an agreement for Ambulance hire service with M/s B.N. DAS & CO. which includes rental of ambulance and driver cost. An average amount of INR 90,000/- is paid for ambulance service on a monthly basis.

On analysis of ambulance records for the period Apr’24 to Sep’24, we noted that ambulance service was used only for two patients (one patient was outsider) during 6 months. i.e. kept only for 24x7 emergency. Accordingly, three drivers (3 shifts of 8hrs each) remains idle at OTPC health center. Also, ambulance drivers are working in other shifts for other vehicles.

As a recommendation, it is advisable to review the monthly fees paid to the vendor for ambulance service.

Department: Human Resource

Implication

Excessive cost to the company.

Recommendation

Consider renegotiating the third-party contract to optimize costs, or explore hiring an in-house driver or purchasing an ambulance rather than hiring.

Management comments

Ambulance Services is required at OHC as per Tripura Factories Act 1948. Now we are in the tendering process of hiring Ambulance on a long term basis to minimize the cost effect but current contract is for smaller period All ambulance driver are dedicated to this service as per rooster. If ambulance driver is seen in other vehicle may be due to lack of availability of alternative option to vendor in emergency. Ideally this is not in practice. Purchasing of Ambulance and hiring of in-house driver is a policy decision of the organization. HR & Admin department would try to minimize the cost as per policy.

Detailed Observation

Low

Point No: 9

Delay in renewal of AMC for Audio Video (AV) system

As per the best practice, the AMC should be renewed before its expiry. Also, the renewal process should be initiated at least 30 days before the expiry of ongoing AMC to ensure continuity of maintenance services.

OTPC Palatana plant has taken AMC for AV system which was expired on 31st March 2024. However on our review, we noted that the renewal process for renewing the AMC for AV system from the existing vendor **(GODREJ & BOYCE MFG. CO. LTD.)** was initiated on 29th May 2024 (after 2 months of expiry of AMC). Accordingly, work order for renewal of AMC was made and approved on 9th September 2024 i.e. **delay of more than 5 months.**

Work order No.	W/O Date	Description	Amount
1700002980	09-09-24	AMC for AV system	11,21,000

Department: Human Resource

Implication

In the event of breakdown/fault during the period of expiry and renewal of contract, the company would have to rectify the fault on chargeable basis.

Recommendation

The AMC renewal process should be initiated before the expiry and the AMC should be renewed on time.

Management comments

AMC Renewal process gets initiated 60 days ahead of renewal date as per normal practice. This year when the AFE for renewal was raised it was been flagged by our IT team that certain equipment's covered under AMC of AV System had gone obsolete and respective OEM had stopped support services of those item. Hence, a identification process was initiated to omit those items and since the AMC clause and rate was finalized with initial PO, so inspection, rate finalization and acceptance of new rates from vendor side and from ours took the aforesaid duration to complete the renewal. But maintenance support of the AV system was never stopped by Godrej on good faith.

Statutory Compliance

Detailed Observation

HIGH

Point No: 10

INR 13.51 Lakhs still not recovered for excess payment made to PF authority

On reviewing the GL code 2550007 as on our review date of 27th September 2024, we noted that an amount of INR 13.51 Lakhs is standing as recoverable in the books of account. As discussed with the concerned official, it was explained to us that at the time of depositing the PF liability for the month of Nov'22, payment was made twice due to some payment error. Later on, payment was deducted from the bank twice.

As per the mail communication, OTPC is following up with the PF authorities however the amount has not been recovered till date. Details are as under:

G/L Account 2550007 Receivable from Provident Fund
Company Code OTPC

St	Assignment	Pstng Date	DocumentNo	BusA	Type	Doc. Date	PK	Amount in local cur.	LCurr	Tx	Clrng doc.	Text
✓		15.12.2022	4422000545		SA	15.12.2022	40	1,351,447.00	INR			EPF Payment Dec 2022
*								1,351,447.00	INR			
**								1,351,447.00	INR			

Department: Statutory Compliance

Implication

Notional interest loss to the company.

Recommendation

Company should continuously follow up with the PF authorities for recovery of amount.

Management comments

File is cleared by EPFC Dwarka and has been transferred the matter to the cash section at RPFC Wazirpur & we have been asked to wait till next week to get the approval from RPFC Wazirpur.

Payments

Detailed Observation

MEDIUM

Point No: 11

TDS amount of INR 86,158/- not recovered from NSIC

We noted that an amount of INR 86,158/- related to TDS recoverable from NSIC is pending since 2020. NSIC deducted TDS amount and not deposited due to which company debited such amount in the name of NSIC for TDS recovery.

Details are as under:

G/L Account	Document Number	Posting Date	Amount	Text	Vendor	Vendor Name
2540308	2619000130	17-04-2020	**86,158**	Amount receivable towards TDS difference	220422	The National Small Industries Corporation (NSIC)

Department: Payments

Implication

Notional interest loss or amount may not be recovered if not settled timely.

Recommendation

It is recommended to regularly follow up from NSIC to ensure recovery of TDS amount.

Management comments

HO

Detailed Observation

Low

Point No: 12

INR 2.94 lakhs reflecting in Down payments clearing A/c since 2018

On reviewing the GL code 2450202 “Down payments clearing A/c” as on 25th September 2024, we noted that credit amount of INR 2,94,133/- is reflecting in account for the entries done in the period 2018 to 2020.

These down payments had been recorded in SAP system, but no adjustments made related to such entries. The lack of regular review process allowed these transactions to remain unresolved.

Details of the cases are given as under.

Document No.	Posting Date	Amount	Vendor	Vendor Name
2617002985	09-02-2018	**-13,221**	110013	BHEL Trichy
2618000062	06-04-2018	**-2,65,742**	110010	BHEL Haridwar
2120000185	31-12-2020	**-15,170**	110013	BHEL Trichy

Department: Payments

Implication

Delayed clearing of down payments can result in inaccurate financial statements, as the liabilities are overstated.

Recommendation

Implement a review process to regularly monitor and clear outstanding down payments.

Management comments

GL is under review for clearing.

Fixed Assets

Detailed Observation

HIGH

Point No: 13

Amount of INR 1.30 crores reflecting in CWIP A/c since Jan'23

As per the work order dated 31st December 2022, OTPC plant agreed with vendor BHEL-Bangalore for supply of **"DAVR PC of excitation system of STG and switchyard SCADA PC for 2*363.3 MW gas based plant"** including supply of commissioning engineer, technicians, uninstallation of old system, etc.

As per the delivery terms of approved work order, vendor agreed to complete the scope of work within 2 months from the date of work order. An advance of INR 1,30,39,643/- was paid to the vendor in Feb'23 by capitalizing the amount in CWIP A/c.

As per the records, GRN for the material was done on 23rd March 2023 and issued from the store on 23rd August 2024 i.e**. after 519 days from the date of GRN.**

According to the standards, cost attributed to CWIP should be transferred to fixed assets but upon our review on 26th September 2024, we noted that an amount of INR 1,30,39,643/- has not been capitalized in the books of account.

Details of the cases are as under:

Asset	Asset Class	Description	Capitalized on	Plant	Amount
910000000080	Z9901	CWIP-DAVR PC for STG	19-01-2023	2000	61,40,967
910000000081	Z9901	CWIP-SCADA PC In Switchyard	19-01-2023	2000	68,98,675

Department: Fixed Assets

Implication

Delay in capitalization of fixed assets

Recommendation

It is recommended to timely review the amount reflecting in CWIP A/c.

Management comments

Capitalization done for CWIP-910000000080 & 81 during Q2, FY-24-25. Documents shared with Auditor.

Detailed Observation

MEDIUM

Point No: 14

Capital advance of INR 7.62 Lakhs given to BHEL in year 2016 still not settled

On reviewing the GL 2450001 "**Capital advance"** as on 27th September 2024, we noted that an advance of INR 41.45 Lakhs was paid to BHEL in year 2016 against which material (spares) of INR 33.83 Lakhs was received till 2017.

Accordingly, an amount of INR 7.62 Lakhs is still reflecting in the books of account as capital advance to BHEL which means that advance has not been properly utilized and settled on time.

Detail of case is as under

Document No.	Document Date	Amount	Text	Vendor
9915000266	31-03-2016	**7,62,187**	Advance to BHEL for spares	130007

Department: Fixed Assets

Implication

Material or spares not received against the advance given to the vendor.

Recommendation

Regular follow-up requests for recovering capital advance or deliver the spares.

Management comments

The amount of advances related to BHEL shall be adjusted after reconciliation and contract closure.

Supply Chain Management

Detailed Observation

HIGH

Point No: 15

Open Purchase Orders from Apr'23 to Aug'24

Extended open purchase orders can raise contractual and legal concerns. Breach of terms and conditions could result in financial penalties or legal disputes.

Upon review of open POs as on our review date 25th September 2024, we noted that during the period from Apr'23 to Aug'24, there were **63** Purchase Orders amounting to **Rs. 3.17Cr** whose delivery period had expired (i.e. upto Aug'24).

Details are given in **Annexure I.**

Summarised details of open POs is as under:

Ageing in days	Number of POs	Amount
0-90	33	95,41,387
91-180	16	1,07,42,950
181-360	10	1,13,74,869
More than 360	4	97,582
Grand Total	**63**	**3,17,86,788**

Department: Supply Chain Management

Implication

May lead to operational issues if material or services not received within time.

Recommendation

Open POs should be closed timely and periodically reviewed for closure.

Management comments

The delay analysis of the PO/WO as stated in the report has been done and is attached herewith in the attached file. It was also noted that in case of the WO's, maximum of the same had already been completed and now are in process of payment and closure. Materials for the maximum PO's are either in transit or are scheduled to be dispatched shortly. Wherever delay is found to be unreasonable, liquidated damages as per contract provisions shall be deducted in due course of payment processing.

Spares, Stores & Consumables

Detailed Observation

High

Point No: 16

Major value of inventory lying under SLOB report

We noted that an amount of INR 56.76 crores of OPEX inventory is lying at the store as of 17th September 2024. On reviewing the movement of inventory, we noted that the major value of inventory amounting to INR 37.36 crores (66% of total inventory) is lying idle with no movement from the past 3 years. Details of inventory are as under:

Category	Movement	Value of inventory (INR Cr.)	%
Active	<1 Year	9.43	16.61
Moving	1-3 Year	9.97	17.56
Slow-moving	3-5 Year	**6.20**	**10.92**
Non-moving	More than 5 Year	**31.16**	**54.90**
Total		**56.76**	**100**

Details are given in **Annexure J.** As per the current process, store department on a monthly basis share the SLOB report to the user department for status. The prolonged retention of SLOB inventory leads to inefficient use of storage space and increased carrying costs.

- **Inventory of INR 37.85 lakhs purchased during the year 23-24 despite having such inventory in stock:**

On review of the Inventory aging report as on 24th September 2024, we noted that inventory of INR 37.85 lakhs was purchased during the year 23-24 despite having such inventory already kept in store as slow-moving or non-moving. This indicates that stock levels were either improperly monitored or not considered before initiating new purchase orders.

Details are given in **Annexure K.**

Department: Stores

Implication

Blockage of working capital, high carrying cost, etc.

Recommendation

Rigorous plan should be taken to take necessary action for SLOB items and to be adjusted in the books of account.

Management comments

Detailed Observation

Medium

Point No: 17

Manual gate entry process for material received at gate

As per the current process, gate entry of material received at the gate is manually done and a manual register is prepared by the security guards for recording gate entry. Further, store department on a daily basis prepare DMR sheet and sent to the user department for inspection. However, no real time tracking is done to know the cases where inspection and GRN is pending for the material where gate entry was done.

In the absence of automated gate entry through SAP system, the following risks may be associated:

- Possibility of Human errors due to manual intervention.
- Difficulty in maintaining audit trails of material movement.
- Difficult for users to know the cases where GRN is not posted against the material or GRN is posted with a delay.

It is recommended to do the gate entry of material through SAP system to automate the tracking of materials and to know the cases where GRN is not posted against a particular gate entry. Also if manual process is followed, then store department should update the DMR sheet by adding the details of GE number and GRN number corresponding to each material.

Department: Stores

Implication

Difficult to know the cases in real time where GRN is not posted against the material.

Recommendation

Implement an automated gate entry system integrated with SAP or update the DMR sheet.

Management comments

Provision of Gate Entry directly through SAP is currently not available due to limitations of user licenses in current module & also lack of trained personnel to operate SAP system in TSR, who are currently manning the gate entry/exit. However, as an improvement and in line with the suggestions made in the report we have incorporated the manual Gate Entry number and the GRN number in the DMR (Daily Material Receipt) report from 1st Oct,2024 onwards.

Detailed Observation

Medium

Point No: 18

GRN (Goods Receipt Note) process needs to be strengthen

- **<u>Delay in preparing GRN by Store department:</u>**

As per the company's practice, GRN should be prepared within 7 days from the date of gate entry. On reviewing the GRN data for the period Jul'24 to Sep'24, we noted 23 GRNs (out of a total of 101 material-related GRNs), where GRN was prepared after 7 days from the date of gate entry.

Details are given in **<u>Annexure L.</u>**

- **<u>Manual system for approving GRN by the Operation head:</u>**

Currently, GRN is authorized by the Manager-stores and finally approved by the Operation head. GRN is manually signed by the approver. This manual process may result in a delay in the approval of GRNs, and the possibility of missing signatures on GRN copies.

On reviewing the GRN documents on a sample basis, we noted cases where the approver signature was taken after the GRN date. As a best practice, GRN should be authorized and approved through the SAP system by getting automatic notifications to the approver for action. Automated systems will also reduce paperwork and time saving to the plant.

The screenshot is attached to the next slide.

Department: Stores

Implication

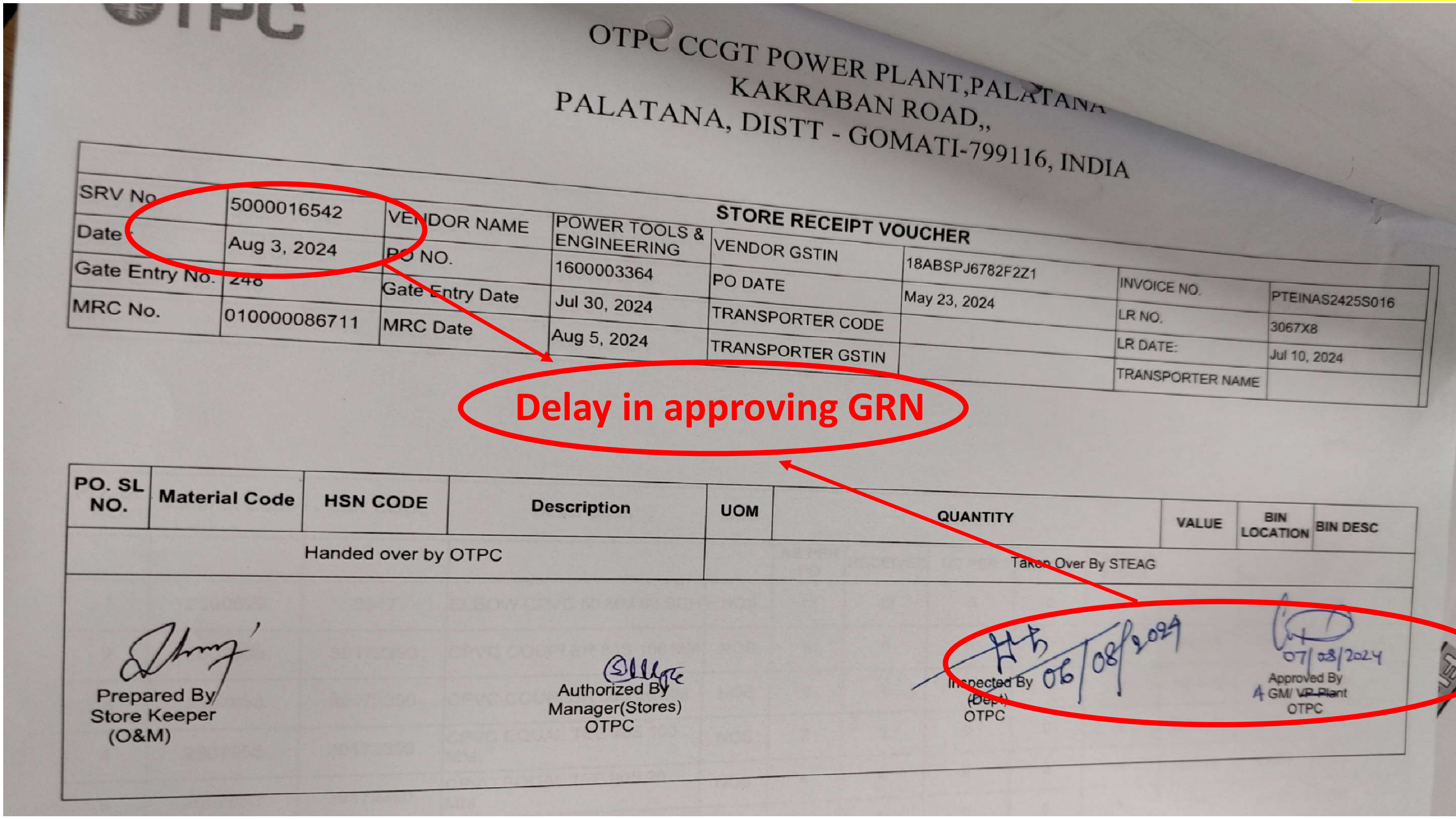
Delay in preparing GRNs disrupts the timely updating of inventory records and hampers the flow of materials in operations.

Recommendations

- GRN preparation should be done on a timely basis.
- GRN approval system should be implemented in SAP system.

- ***MIS for every month with materials inspection status are being ggenerated. Reasons for late inspection if any are also given in the Annexure as attached.***

Medium



OTPC CCGT POWER PLANT,PALATANA
KAKRABAN ROAD,,
PALATANA, DISTT - GOMATI-799116, INDIA

STORE RECEIPT VOUCHER

SRV No	5000016542	VENDOR NAME	POWER TOOLS & ENGINEERING	VENDOR GSTIN	18ABSPJ6782F2Z1	INVOICE NO.	PTEINAS2425S016
Date	Aug 3, 2024	PO NO.	1600003364	PO DATE	May 23, 2024	LR NO.	3067X8
Gate Entry No.	248	Gate Entry Date	Jul 30, 2024	TRANSPORTER CODE		LR DATE:	Jul 10, 2024
MRC No.	010000086711	MRC Date	Aug 5, 2024	TRANSPORTER GSTIN		TRANSPORTER NAME	

PO. SL NO.	Material Code	HSN CODE	Description	UOM	QUANTITY	VALUE	BIN LOCATION	BIN DESC
Handed over by OTPC				Taken Over By STEAG				

Prepared By
Store Keeper
(O&M)

Authorized By
Manager(Stores)
OTPC

06/08/2024
Inspected By
(Dept)
OTPC

07/08/2024
Approved By
GM/ ~~VP-Plant~~
OTPC

1000

Detailed Observation

Medium

Point No: 19

Issues noted related to quality inspection

- **Quality inspection not being performed for certain materials:**

On comparing the GRN and quality inspection data as reflected in the MB51 report (movement type 101 and 321) for the period Jul'24 to Sep'24, we observed 52 materials where quality inspection of certain materials was not done as per the report. However, manual inspection is done for such materials. Details are given in **Annexure M.**

Further, no quality inspection of "**Diesel**" was done in SAP system.

- **Manual system for approving material inspection reports:**

On reviewing the material inspection process, we noted that currently users prepare material inspection reports, give remarks for approval or rejection of material, and finally sign the report manually rather than being generated through an automated system (SAP).

Manual systems possess the risk of potential human error in data entry, unnecessary delay in processes, and leads to wastage of paper.

As per the best practice, a quality inspection checklist should be uploaded in SAP related to each item, and the quality department should approve or reject the material based on parameters defined in SAP system.

Department: Stores

Implications

- Quality analysis may have been omitted if inspection process is done manually.
- Manual inspection report can lead to delay in decision-making.

Recommendations

- Inspection must be conducted for all the materials received at store.
- Quality inspection should be implemented in SAP system.

Management comments

- ***We have reviewed the inspection in our material list, QM view inspection was not set up for these materials in creation stage.***

Detailed Observation

Medium

Point No: 20

Scrap should be maintained properly in scrap yard

As per **clause 2.13 of "Stores & Inventory manual-2020",** all scrap items shall be stored in the separately identified and properly fenced scrap yard under secured conditions. Each category of scrap will be stored as a separate lot and identified with a lot number.

Also, scrap shall be given to stores through MRN (Material Return Note) which shall be generated through SAP, and the store person should ensure proper accounting of receipts and sale of scrap and a separate ledger shall be maintained in SAP system.

On physical inspection at stores on **19th September 2024**, we observed discrepancies in scrap management such as:

- Scrapped items at the store are not categorized and no lot number is allocated for scrap. Even IT scrap and other scrap are kept together.
- Material return note is prepared manually and no records are maintained through SAP system.
- Scrap items are kept with good items at the store's open area.
- IT-related scrap was not properly stored and was dumped in a container which can be seen in the screenshot attached in the next slide. This issue leads to adverse human health effects and environmental pollution.

Department: Stores

Implications

- Non-compliance with manual related to scrap management.
- IT e-waste may affects environmental pollution if not stored or disposed properly.
- Possibility of mismanagement in scrap handling if records are not maintained through SAP system.

Recommendations

- A designated scrap yard should be allocated for the storage of scrap.
- MRN should be prepared through SAP system and manual clause should be followed strictly.

Management comments

Designated Scrapyard has already been allocated for both hazardous & non hazardous scrap in the plant. All scrap lying in other areas had also being cleared now. IT items and non-IT items are also segregated from the container. Now, all the items are packed in box. Picture is attached below.

Medium

Detailed Observation

Medium

Point No: 21

MIS process should be followed consistently as per the manual

As per chapter 4 of "Stores & Inventory Manual", the following MIS should be prepared and submitted to the respective authority:

- **GRN and SIV reports** should be generated over a week in the prescribed format and submitted to the head of the user department, head of material, and store finance. However, the store manager is submitting MIS monthly rather than a weekly basis.

- Gate entry register is verified by the store incharge periodically for not more than a month and reconciled with the GRNs issued for that month. Discrepancies if any should be noted and after the reconciliation, the store incharge should mention in the gate entry register about the material received against the gate.

We noted that presently there is no reconciliation prepared by the store incharge related to **GE vs. GRN** of material.

Department: Stores

Implications

In the absence of reconciliation between GE and GRNs, there is possibility of omission or human error.

Recommendation

MIS process should be followed consistently as per the stores & inventory manual.

Management comments

- ***We have started preparing GRN and SIV reports on a weekly basis.***

- ***We will start GE vs. GRN reconciliation with effect from Oct 2024.***

Detailed Observation

Medium

Point No: 22

Material issuance process from store need to be improved

On comparing the MB25 report (Reservation report) and MB51 report for the period Jul'24 to Sep'24, we noted the following discrepancies:

- We noted 37 reservations (out of a total of 279 reservations) where no or short material was issued from the store. Details are given in **Annexure N.**
- We noted 74 reservations where material was issued with a delay from the date of requisition. We had reported those cases where the delay was more than 3 days. Details are given in **Annexure O.**

Department: Stores

Implication

Operational disruptions, leading to potential production downtimes.

Recommendation

It is recommended to issue the material on time from the store.

Management comments

Reservations are created by the indenting departments in advance keeping in view the scheduled maintenance schedules. Hence, issue is being done with a lag on the actual maintenance activity being undertaken which is a standard practice.

Detailed Observation

Low

Point No: 23

Issues related to Returnable gate pass (RGP)

- **Manual system for approving RGPs:**

We observed that RGP is manually prepared and approved by the O&M head for material out from the gate. Manual processes may result in significant delays in processing and tracking open RGPs. There should be an automated system of preparing and managing RGPs which will make the process easier and transparent.

- **Delay in receipt of material sent on RGPs:**

On reviewing RGP for the period Jul'24 to Sep'24, we observed 4 cases where there was a delay in the receipt of material from the vendor as compared to the expected date of return.

Material Description	Qty	RGP number	RGP date	Expected date of Return	Receipt date	Delay
Cast Iron Weight 20 kg	42	RGP/OTPC/316	01-08-2024	15-08-2024	03-09-2024	19
Aragonite Cylinders	13	RGP/OTPC/311	08-06-2024	15-09-2024	24-09-2024	9
Sacffolding Pipe- 6mtr	8	RGP/OTPC/319	03-09-2024	10-09-2024	13-09-2024	3
Spanner- Ring 25/26	8	RGP/OTPC/320	03-09-2024	10-09-2024	13-09-2024	3

Department: Stores

Implication

Delay in RGP processing may result in late returns of materials, disrupting maintenance schedules.

Recommendations

- It is recommended to implement an automated system for preparing and approving RGPs.
- RGPs should be closed within time.

Management comments

- ***Cast iron weight-*** ***Material was sent to township for lift load test purpose through Steag's vehicle. After completing the load test, material was not collected from township due to shutdown time and vehicles were engaged in other works.***
- ***Aragonite Cylinders-*** ***Due to bad weather, material came to OTPC on 24th September 2024.***
- ***Scaffolding pipe and Spanner Ring-*** ***These materials were sent to township for WTP clean and repairing purpose. After completion of job, materials were send to OTPC.***

IT Security

Detailed Observation

High

Point No: 24

Offsite data backup is not maintained at the Disaster Recovery (DR) site

According to the Risk & control matrix of IT department, **“the company has a disaster recovery plan and off-site Data backup is taken once a month”.**

Offsite data backup should be maintained at the DR site to ensure data availability and business continuity in case of a disaster such as floods, earthquake, system failure, or cyber attack.

On inquiry from the concerned official, it was explained to us that currently no DR site is maintained for data restoration or recovery in case of disaster. However, daily backup of data is maintained onsite but not at the DR site.

Further, DR site (offsite) process is in implementation stage.

Department: IT Security

Implication

The absence of offsite data backup increases the risk of data loss in the event of a disaster, system failure, or cyber-attack.

Recommendation

DR site should be maintained and a regular schedule for offsite data backups should be implemented to the DR site.

Management comments

DR (Disaster Recovery) was being done through offsite backup where every 15 days interval we used to send Data Tape to the State Data Centre Agartala. The last Data Tape has been sent to the State Data Centre on 23rd Aug 2024. DR process temporarily kept on hold due to DC upgradation activities. Offsite backup for DR is started since 28th Sept 2024.

Detailed Observation

High

Point No: 25	Department: IT Security

No camera backup footage maintained for camera installed in IT server room at Palatana Plant

During our physical inspection on 18th September 2024, we noted that currently 1 camera was installed in the IT server room for capturing the footage inside the server room.

As per the SOP of the IT department, backup footage of 90 days is to be maintained for cameras. On requesting the backup footage of camera installed in IT server room, it was explained to us that no backup is maintained for this camera and only live recording is maintained.

This lack of recording capability means there is no historical footage available for review in case of incidents and creates a risk of untraceable security issues, making it difficult to address potential theft, altering or unauthorized access.

Implication

Risk of security issues, or unauthorized access to the server room.

Recommendation

Adequate backup footage should be maintained for camera installed in server room.

Management comments

Regarding non-availability of CCTV footage storage system has already been informed to the HO and M/S Orbit and It is under follow-up with the M/S Orbit who has setup new Data Centre. Storage system will be installed by Nov 2024.

48

Detailed Observation

High

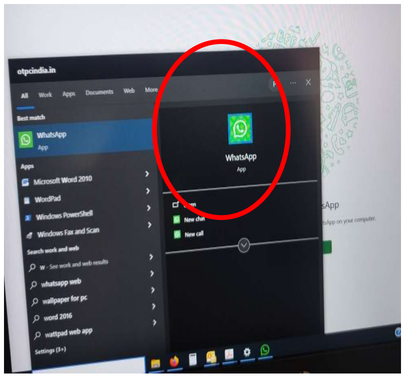
Point No: 26

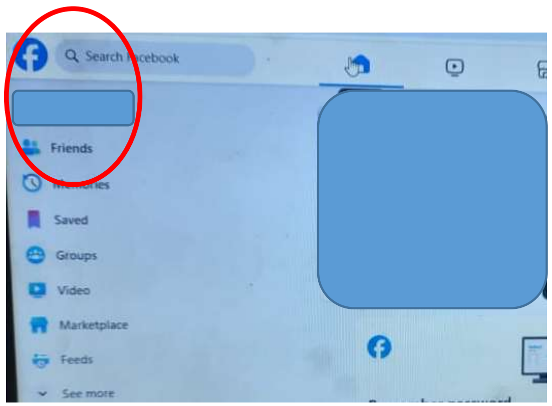
Use of unauthorized Software / Application in official computers

As per the SOP of the IT department, the company should ensure that no pirated, cracked, demo, unlicensed, or unauthorized application is installed on the official computer. Further, as per the SOP authorized list of software is given that can be installed in the system.

During our physical inspection of official laptops on a sample basis, we noted that employees were using WhatsApp, Facebook in the official laptops which can lead to breach of confidentiality, and loss of data.

Further, we noted that social media applications such as WhatsApp, Facebook, Linkedin, etc. can be accessed without any restrictions in laptops of HO and plant employees. For security purpose, the company should restrict these sites and include the restriction clause in the SOP.





Department: IT Security

Implication

Risk of data security, confidentiality.

Recommendation

It is recommended to restrict un-authorized application for installation and use in official laptops.

Management comments

Delhi IT Team may would like to comment it.

Detailed Observation

Medium

Point No: 27

Fixed asset tagging should be done for all IT assets

Asset tagging is crucial for tracking, maintaining, and securing critical assets, enhancing accountability and operational efficiency.

During our physical inspection of the IT server room on 18th September 2024, we observed that there is no fixed asset tagging on the assets/equipment lying in the IT server and UPS room. Major IT assets are stored in the IT server room.

Asset	Description	Capitalized on	Quantity	Value
610000800175	Data Centre at Palatana Plant	30-03-2024	1	**3,60,22,915**

Department: IT Security

Implication

The absence of asset tagging makes it difficult to track and manage the assets.

Recommendation

Implement asset tagging for all IT equipment's.

Management comments

Asset Tagging is completed.

Detailed Observation

Medium

Point No: 28

Security updates must be UP TO DATE in all official laptops

As per the SOP of IT department, all critical and important security updates are configured on all the official laptops.

During our physical inspection of employee laptops on a sample basis on 23rd September 2024, we noted 6 laptops (out of 7 laptops inspected), where security updates were not up to date and shows the status that "**Your device is missing important security and quality fixes".** Similar cases were also noted at HO.

Failure to apply critical patches and updates significantly increases the risk of malware infections, ransomware attacks, and unauthorized access to sensitive data.

Screenshot is attached to the next slide.

Department: IT Security

Implication

Risk of cyber security threats, impact on system working, etc.

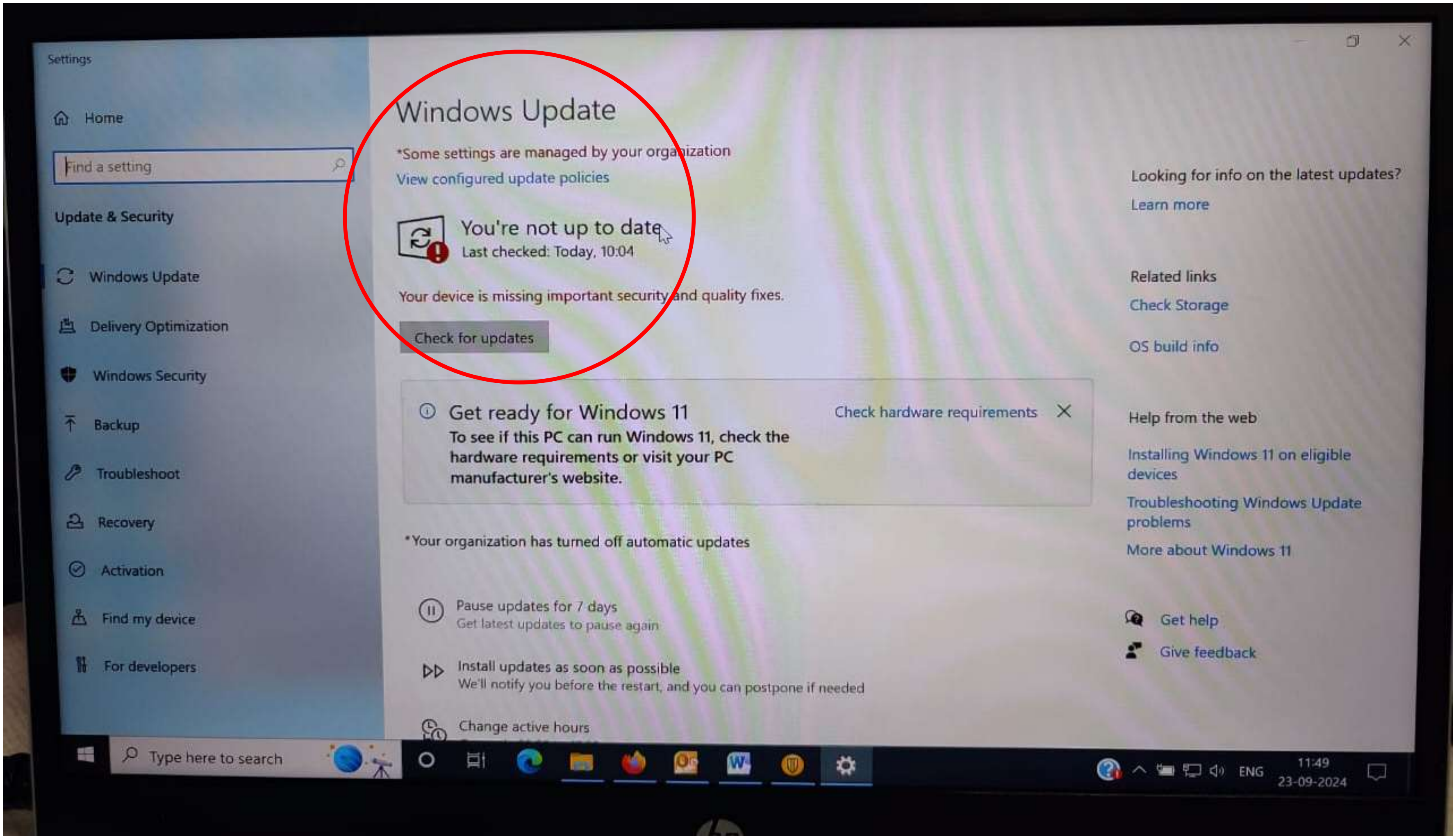
Recommendation

IT department should periodically ensure that all security updates are up to date in all the official desktops/laptops.

Management comments

Delhi IT Team may would like to comment it.

Medium


Settings
Home
Find a setting
Update & Security
Windows Update
Delivery Optimization
Windows Security
Backup
Troubleshoot
Recovery
Activation
Find my device
For developers
Windows Update
*Some settings are managed by your organization
View configured update policies
You're not up to date
Last checked: Today, 10:04
Your device is missing important security and quality fixes.
Check for updates
Get ready for Windows 11
Check hardware requirements
To see if this PC can run Windows 11, check the hardware requirements or visit your PC manufacturer's website.
*Your organization has turned off automatic updates
Pause updates for 7 days
Get latest updates to pause again
Install updates as soon as possible
We'll notify you before the restart, and you can postpone if needed
Change active hours
Looking for info on the latest updates?
Learn more
Related links
Check Storage
OS build info
Help from the web
Installing Windows 11 on eligible devices
Troubleshooting Windows Update problems
More about Windows 11
Get help
Give feedback
Type here to search
ENG
11:49
23-09-2024

Corporate Social Responsibility (CSR)

Detailed Observation

High

Point No: 29

CSR Amount not fully spent for FY 2021-22 to 2023-24

- During the audit, we noted that an amount of INR 5.49 lakhs is lying in the bank account related to CSR for FY 21-22. Similarly, INR 55,800/- is lying in the bank account related to CSR for FY 22-23.

As per the board report, OTPC has already spent the mandatory amount required as per the Act. However, such an amount is still lying in the bank account of CSR FY 21-22 and 22-23.

- For FY 23-24, 4 projects are ongoing till our review date amounting to INR 68.64 lakhs approx. for which amount has not been spent yet.

Also, we noted 3 projects amounting to INR 28 Lakhs where advance payment was already paid for these projects in Feb'24 and the expected delivery date had already elapsed. As discussed with the concerned official, it was explained to us that such projects are still in process i.e. utilization certificate (UC) not received.

Details of such cases are given in the next slide.

Department : Corporate Social Responsibility (CSR)

Implication

Delay in closure of CSR project.

Recommendation

Work Order made related to CSR expenditure should be closed within the agreed timeline.

Management comments

High

Particular	Party Name	PO Date	Expected Delivery Date	PO Amount	Expenditure done till 30th September 2024	Balance (In Lakhs)
AMC for Solar Street Projects	Energy Effeciency Services Ltd.	20-09-2023	31-03-2024	4.19	0	**4.19**
MHU Gomati & Sepahijala	Hindustan Latex Family Planning Promotion Trust	15-03-2024	NA	74.67	13.57	**61.10**
Girls hygiene project	Arpan Society	24-01-2024	28-11-2024	14.68	11.74	**2.94**
Coaching for Under privileged Meritorious students.	Maa Usha Charitable Trust	26-09-2023	30-09-2024	4.9	4.49	**0.41**
Total				**98.44**	**29.80**	**68.64**

Name of the Project	Party Name	PO Amount (In Lakhs)	PO date	Expected Delivery Date	Advance payment date
Girls Toilet at Murapara School	DM & Collector, Gomti District	5	02-02-2024	31-03-2024	26-02-2024
Assistance for Sports personnel	DM & Collector, West Tripura	15	29-12-2023	15-01-2024	23-01-2024
Kitchen Shed construction in different Aganwadi Centre	DM & Collector, Gomti District	8	05-02-2024	31-03-2024	26-02-2024
Total		**28**			

Detailed Recommendations

Detailed Recommendation

Point No: 1

Periodical physical verification of inventory should be introduced

As per clause 2.12 of "Stores & Inventory manual-2020", physical stock verification of inventory is done regularly internally by the custodian to identify the item-wise discrepancies for adjustment/ write-off of inventory.

As discussed with the concerned official, presently the store department conducts physical verification on an annual basis by constituting an internal committee. No periodical inventory count is done by the custodian during the year. In the absence of periodical physical verification, it is difficult to detect item-wise discrepancies, shortage or excess quantity, etc.

As per the inventory records as of 31st August 2024, **an approximate value of INR 56.59 crores is stored related to all the departments.** Since the number of items in a store is too large to carry out physical verification, therefore, it is recommended to conduct the PV as per the possibility such as department-wise, high-value items, critical items, etc.

Department: Stores

Recommendation

It is recommended that the store department enhance its current physical verification policy by incorporating monthly verification and adjustment of discrepancies if any.

Management comments

We will start periodical inventory check.

Detailed Recommendation

Point No: 2

Asset transfer form should be created in case of transfer of fixed assets

An asset transfer form should be prepared while transferring assets from one location to another (Plant to HO and vice-versa).

On conducting physical verification of IT assets, we found two laptops were missing at Palatana plant and after discussion with concerned official, it was explained to us that such laptops were already transferred to Delhi HO.

We noted that there is no practice for maintaining asset transfer form while transferring IT assets from one location to another. In the absence of maintaining asset transfer form, it is difficult to track the exact location, accountability and records of IT assets. Based on approved asset transfer form, location of asset must be updated in FAR maintained in SAP. Details of laptops transferred to Delhi HO are as follows:

Asset Code	Accessories	WDV as on 31.08.24
610000800160/2	Mouse- CN-05GD8Y-PRC00-19B-00DJ-A05 (Dell MS 3320W) Adapter-CN-0KPVMF-DES00-22D-77C7-A00	2,270
610000800160/7	Mouse- CN-05GD8Y-PRC00-19B-006U-A05 (Dell MS 3320W) Adapter-CN-0KPVMF-DES00-22D-70DI-A00	2,270

Department: IT Security

Recommendation

Implement a system for maintaining asset transfer form.

Management comments

Detailed Recommendation

Point No: 3

Attendance regularization should be approved periodically

As per clause 3 of SOP for the management and operation of biometric attendance system, the HR&A department shall be responsible to generate daily/monthly attendance reports. Based on the generated report, any discrepancy in attendance of any employee(s) must be rectified or regularized by concerned employees through the respective reporting line officer with intimation to the HR department.

On reviewing the attendance regularization process, we noted that HR & Admin department extract the attendance report on a monthly basis and intimate the discrepancies in attendance to the employees for submission of approved regularization forms.

This approach limits the ability to track employee attendance in real-time and delays the identification of any issues, such as absenteeism, late arrivals, or attendance discrepancies. As a recommendation, company should follow the attendance regularization process periodically.

Department: Human Resource

Recommendation

Company should follow the attendance regularization process periodically.

Management comments

Detailed Recommendation

Point No: 4

Inconsistencies in Smart Track access report

Smart Track system is installed in the IT server room for capturing the logs of access to smart racks (data server room). This report helps user to know the details of unauthorized access, access timings to rack, etc.

On reviewing the smart track access report for the month of September'24, we noted cases in the report, where **"Door closed"** status was also captured by the smart track system. However, door closed status for each access granted was not in the report. As discussed with the concerned official, it was explained to us that smart track system only captures the record of access granted and unauthorized access if any.

Screenshot is attached to the next slide.

Department: IT Security

Recommendation

Investigate and address the causes of the discrepancies in the Smart Track access logs and ask vendor to provide the door close status in the report.

Management comments

The Smart Rack Door access control system implemented with capturing auto door opening and unauthorized logs. "Door Closed" log is showing in the report due to Testing/Dummy data. Testing/Dummy Data has been removed. Now Door opening and unauthorized log is showing in the report.

We are in conversation with M/S Orbit TechSol India Pvt Ltd regarding non-capturing door closing log. The vendor is working on it whether the Smart Rack is feasible for integrating hardware /software for capturing door closing logs.

Employee Name	Card Number	Controller Name	Location Name	Reader Name	Area Name	Rack Name	Door Name	Transaction Time	Channel No	Event Message Name
Ronel Debbarma	0000101157	SmartRow Controller	PALATANA DATA CENTER	Reader 2	SERVER ROOM	SmartRack 2	Front Door	22-09-2024 17:11:15	2	AccessGranted
Ronel Debbarma	0000101157	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	22-09-2024 17:10:51	1	AccessGranted
Ram Goswami	0000000001	SmartRow Controller	PALATANA DATA CENTER	Reader 2	SERVER ROOM	SmartRack 2	Front Door	21-09-2024 22:33:54	2	AccessGranted
Ram Goswami	0000000001	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	21-09-2024 22:33:35	1	AccessGranted
	0000000000	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	21-09-2024 22:33:23	1	UnauthorizedUser
	0000000000	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	20-09-2024 09:45:09	1	Door Closed
Ram Goswami	0000000001	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	20-09-2024 09:45:05	1	AccessGranted
	0000000000	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	18-09-2024 11:49:22	1	Door Closed
Panna Roy	0000000033	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	18-09-2024 11:49:18	1	AccessGranted
Chinmoy Datta	0000101303	SmartRow Controller	PALATANA DATA CENTER	Reader 2	SERVER ROOM	SmartRack 2	Front Door	16-09-2024 12:57:27	2	AccessGranted
	0000000000	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	12-09-2024 10:19:21	1	Door Closed
Ram Goswami	0000000001	SmartRow Controller	PALATANA DATA CENTER	Reader 2	SERVER ROOM	SmartRack 2	Front Door	12-09-2024 10:19:18	2	AccessGranted
	0000000000	SmartRow Controller	PALATANA DATA CENTER	Reader 1	SERVER ROOM	SmartRack 1	Front Door	12-09-2024 10:18:32	1	Door Closed
Ram Goswami	0000000001	SmartRow Controller	PALATANA DATA CENTER	Reader 2	SERVER ROOM	SmartRack 2	Front Door	12-09-2024 10:18:29	2	AccessGranted

Action Taken Report of Previous Auditor's Report

Action taken Report of Previous Auditor's Report

	Current Status of Observations	Management Comments
1	**A. <u>Liquidation damages of INR 325.73 Crores receivable since long from ONGC:</u>** Amount of INR 325.73 crores is outstanding for the period from FY 2015-2016 to FY 2023-2024. No regular follow-up made for the recovery of said damages. **B. <u>Issues noted related to Calibration & health checkup of meters:</u>** OTPC has requested ONGC several times to calibrate ONGC side of USM at the earliest and reconcile the excess quantity. As discussed with the concerned official it was explained to us that two meters of ONGC and one check meter of OTPC is of same brand and specifications installed in year 2014. Accordingly, one meter of ONGC and OTPC was sent for calibration in Feb'24. As per the work order, expected date of return of meters is in July'24.	
2	**<u>Recommendation for Safety issues at ONGC Palatana Gas Terminal:</u>** 1.The fencing near the entrance gate is broken, which could lead to unauthorized entries and pose a security risk. 2. Fire buckets kept at the metering area are not in good condition. Further, there are no sheds upon it to prevent it from rainwater. Also, in the Scrubber filter area only 2 fire buckets are placed instead of 5 indicating non-compliance with fire safety protocol. 3. There is a water hydrant placed just nearer to the metering area, but the same is not in good condition and is broken & can't be used during emergencies.	
3	**<u>Recommendations related to Preventive Maintenance:</u>** 1. Annual Preventive Maintenance (PM) schedule should be uploaded in the SAP system 2. PM checklist should be maintained in SAP by the Electrical and C&I department 3. Recommendation for updating Equipment no. in annual PM schedule	
4	**<u>Recommendations related to Occupational Health Centre (OHC):</u>** 1. During the review of the OHC, it was noted that the current nursing staff comprises with no female nurses onboard. 2. Recommended to have surveillance camera in the OHC to record the footage of the centre.	

Action taken Report of Previous Auditor's Report

#	Current Status of Observations	Management Comments
1	**A. Long Outstanding Vendor:** On the review of GL a/c 1324001, noted that an EMD of INR 50,000 was payable to PWC in May'2017 but the same has not been returned yet. **B. Short-Term Provision MRC payable (GL Code 1322002):** The aggregate amount of INR 24.73 lakhs appears in the ledger from 2016 to 2017 as a provision and neither such provision is settled nor written back as income in the books of account. **C. Liability on hold (GL Code 1327202)** The amount of INR 14.63 lakhs has been on hold for more than 3 years on account of PBG not submitted, LD, Excess GST, SD, etc. Such an amount was neither settled by payment to vendors nor booked as income in the books.	
2	**A. Long-Term Retention Money Payable (GL Code 1220001):** Amount of INR 20.70 lakh from FY 2015-16 to FY 22-23 is appearing in the long-term retention money ledger which is not refunded by the company. **B. Short-Term Retention Money payable (GL Code 1322001) :** Amount of INR 40.76 lakh from FY 2015-16 to FY 22-23 is appearing in the short-term retention money ledger which is not refunded by the company.	
3	**A. S/Cr – Cap Ex-Ere & Con payable (GL Code 1323101):** Sundry creditors amounting to INR 3.56 lakhs are appearing in the S/Crs-Cap Ex- Ere & Con ledger since FY 16-17 which is not adjusted by the company. **B. Short-Term Loan & Advance received (GL Code 2540001):** Advance receivable amounting of INR 2.65 Cr from FY 2017-18 to 2022-23 which is not adjusted by the company since long.	

Action taken Report of Previous Auditor's Report

<table>
<tr><th>#</th><th>Current Status of Observations</th><th>Management Comments</th></tr>
<tr><td>4</td><td><u>GST charged by vendor even GST registration is cancelled:</u>

We noted that company has paid the GST amount of INR 8.11 Lacs to the vendor on the invoices raised by vendor which is not paid to Govt.</td><td></td></tr>
<tr><td>5</td><td><u>Short Term Security Deposit payable outstanding since long (GL Code 1324002):</u>

Amount of INR 3.33 lakhs is available in the short-term security deposit ledger which is not refunded by the company.
<table>
<tr><th>Vendor Code</th><th>Vendor Name</th><th>Grand Total</th></tr>
<tr><td>210010</td><td>Abhijit Das</td><td>(11,500)</td></tr>
<tr><td>220006</td><td>DELOITTE TOUCHE TOHMATSU INDIA LLP</td><td>(304,200)</td></tr>
<tr><td>310146</td><td>DEEP ENTERPRISES</td><td>(3,553)</td></tr>
<tr><td>310427</td><td>ARPAN SOCIETY</td><td>(14,050)</td></tr>
</table></td><td></td></tr>
<tr><td>6</td><td><u>Open Purchase Requisitions (Apr'22 to Jun'24):</u>

There are 169 open PRs which are open from Apr'24 to Jun'24 and against which no PO has been raised as on our review date 30-09-2024.
Open PR</td><td></td></tr>
<tr><td>7</td><td><u>CSR amount not paid of FY 17-18:</u>

On scrutiny of ledger 1310301, noted that the payment of INR 23.29 lakhs is still pending to the CSR vendor 220223 for Boundary wall CSR 17-18.</td><td></td></tr>
</table>

Action taken Report of Previous Auditor's Report

#	Current Status of Observations	Management Comments
8	**<u>Expired Laptop/Desktop kept in IT Department:</u>** We have observed that there are few systems of which useful life has been expired but such device are used by employees in case of emergency condition or some systems are kept as spare at IT department.	
9	**<u>Monitoring and Control of PAF:</u>** Monitoring and control of PAF is required as per CERC requirement. But plant availability is effected by demand raised by NERLD and supply of NG by ONGC.	
10	**<u>Outdated CCTV camera's in Plant area:</u>** We noted during the visit, the camera's used in plant operation area's as well as non operational area are based on analogue technology. These camera's are declared obsolete long back. We also checked the images which is not clear.	

Audit Risk Rating Criteria

The Internal Audit Risk Rating criteria are as per predetermined parameters which are as follows:

High	Significant Control Design Deficiency with inadequate compensating, preventive and detective controls. Instances of Non-compliance of policy/control having high impact
Medium	Deviations from controls, which may impact adversely or some weakness in controls or non-compliance with processes/ Regulations.
Low	All other observations not falling under above categories

THANK YOU

THE FACTORIES ACT, 1948

ARRANGEMENT OF SECTIONS

CHAPTER I

PRELIMINARY

SECTIONS

1. Short title, extent and commencement.

2. Interpretation.

3. References to time of day.

4. Power to declare different departments to be separate factories or two or more factories to be a single factory.

5. Power to exempt during public emergency.

6. Approval, licensing and registration of factories.

7. Notice by occupier.

CHAPTER II

THE INSPECTING STAFF

7A. General duties of the occupier.

7B. General duties of manufacturers, etc., as regards articles and substances for use in factories.

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9. Powers of Inspectors.

10. Certifying surgeons.

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14. Dust and fume.

15. Artificial humidification.

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25. Self-acting machines.

26. Casing of new machinery.

27. Prohibition of employment of women and children near cotton-openers.

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29. Lifting machines, chains, ropes and lifting tackles.

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31. Pressure plant.

32. Floors, stairs and means of access.

33. Pits, sumps openings in floors, etc.

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35. Protection of eyes.

36. Precautions against dangerous fumes, gases, etc.

36A. Precautions regarding the use of portable electric light.

37. Explosive or inflammable dust, gas, etc.

38. Precautions in case of fire.

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40A. Maintenance of buildings.

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45. First-aid appliances.

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47. Shelters, rest rooms and lunch rooms.

48. Creches.

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50. Power to make rules to supplement this Chapter.

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53. Compensatory holidays.

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55. Intervals for rest.

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59. Extra wages for overtime.

60. Restriction on double employment.

61. Notice of periods of work for adults.

62. Register of adult workers.

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65. Power to make exempting orders.

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100. [*Repealed*.]

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109. Service of notices.

110. Returns.

111. Obligations of workers.

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113. Powers of Centre to give directions.

114. No charge for facilities and conveniences.

115. Publication of rules.

116. Application of Act to Government factories.

117. Protection to persons acting under this Act.

118. Restrictions on disclosure of information.

118A. Restriction on disclosure of information.

119. Act to have effect notwithstanding anything contained in Act 37 of 1970.

120. Repeal and savings.

THE FIRST SCHEDULE.

THE SECOND SCHEDULE.

THE THIRD SCHEDULE.

THE FACTORIES ACT, 1948

ACT NO. 63 OF 1948[1]

[23*rd September,* 1948.]

An Act to consolidate and amend the law regulating labour in factories.

WHEREAS it is expedient to consolidate and amend the law regulating labour in factories;

It is hereby enacted as follows:—

CHAPTER I

PRELIMINARY

1. Short title, extent and commencement.—(*1*) This Act may be called the Factories Act, 1948.

[2][(*2*) It extends to the whole of India [3]***.]

(*3*) It shall come into force on the 1st day of April 1949.

2. Interpretation.—In this Act, unless there is anything repugnant in the subject or context,—

(*a*) "adult" means a person who has completed his eighteenth year of age;

(*b*) "adolescent" means a person who has completed his fifteenth year of age but has not completed his eighteenth year;

[4][(*bb*) "calendar year" means the period of twelve months beginning with the first day of January in any year;]

(*c*) "child" means a person who has not completed his fifteenth year of age;

[5][(*ca*) "competent person", in relation to any provision of this Act, means a person or an institution recognised as such by the Chief Inspector for the purposes of carrying out tests, examinations and inspections required to be done in a factory under the provisions of this Act having regard to—

(*i*) the qualifications and experience of the person and facilities available at his disposal; or

(*ii*) the qualifications and experience of the persons employed in such institution and facilities available therein,

with regard to the conduct of such tests, examinations and inspections, and more than one person or institution can be recognised as a competent person in relation to a factory;

(*cb*) "hazardous process" means any process or activity in relation to an industry specified in the First Schedule where, unless special care is taken, raw materials used therein or the intermediate or finished products, bye-products, wastes or effluents thereof would—

(*i*) cause material impairment to the health of the persons engaged in or connected therewith, or

(*ii*) result in the pollution or the general environment:

Provided that the State Government may, by notification in the Official Gazette, amend the First Schedule by way of addition, omission or variation of any industry specified in the said Schedule;]

(*d*) "young person" means a person who is either a child or an adolescent;

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1. The Act has been extended to Dadra and Nagar Haveli by Reg. 6 of 1963, s. 2 and the First Schedule; Pondicherry by Reg. 7 of 1963, s. 3 and the First Schedule, Goa, Daman and Diu by Reg. 11 of 1963, s. 3 and the Schedule and Laccadive, Minicoy and Amindivi Islands by Reg. 8 of 1965, s. 3 and the Schedule.
2. Subs. by the A.O. 1950, for sub-section (*2*).
3. The words "except the state of Jammu and Kashmir" omitted by Act 51 of 1970, s. 2 and the Schedule (w.e.f. 1-9-1971).
4. Ins. by Act 25 of 1954, s. 2 (w.e.f. 7-5-1954).
5. Ins. by Act 20 of 1987, s. 2 (w.e.f. 1-12-1987).

(*e*) "day" means a period of twenty-four hours beginning at midnight;

(*f*) "week" means a period of seven days beginning at midnight on Saturday night or such other night as may be approved in writing for a particular area by the Chief Inspector of Factories;

(*g*) "power" means electrical energy, or any other form of energy which is mechanically transmitted and is not generated by human or animal agency;

(*h*) "prime mover" means any engine, motor or other appliance which generates or otherwise provides power;

(*i*) "transmission machinery" means any shaft, wheel, drum, pulley, system of pulleys, coupling, clutch, driving belt or other appliance or device by which the motion of a prime mover is transmitted to or received by any machinery or appliance;

(*j*) "machinery" includes prime movers, transmission machinery and all other appliances whereby power is generated, transformed, transmitted or applied;

(*k*) "manufacturing process" means any process for—

(*i*) making, altering, repairing, ornamenting, finishing, packing, oiling, washing, cleaning, breaking up, demolishing, or otherwise treating or adapting any article or substance with a view to its use, sale, transport, delivery or disposal; or

[1][(*ii*) pumping oil, water, sewage or any other substance; or]

(*iii*) generating, transforming or transmitting power; or

[2][(*iv*) composing types for printing, printing by letter press, lithography, photogravure or other similar process or book binding; [3][or]]

(*v*) constructing, reconstructing, repairing, refitting, finishing or breaking up ships or vessels; [3][or]

[3][(*vi*) preserving or storing any article in cold storage;]

(*l*) "worker" means a person [4][employed, directly or by or through any agency (including a contractor) with or without the knowledge of the principal employer, whether for remuneration or not], in any manufacturing process, or in cleaning any part of the machinery or premises used for a manufacturing process, or in any other kind of work incidental to, or connected with, the manufacturing process, or the subject of the manufacturing process [3][but does not include any member of the armed forces of the Union];

(*m*) "factory" means any premises including the precincts thereof—

(*i*) whereon ten or more workers are working, or were working on any day of the preceding twelve months, and in any part of which a manufacturing process is being carried on with the aid of power, or is ordinarily so carried on, or

(*ii*) whereon twenty or more workers are working, or were working on any day of the preceding twelve months, and in any part of which a manufacturing process is being carried on without the aid of power, or is ordinarily so carried on,—

but does not include a mine subject to the operation of [5][the Mines Act, 1952 (35 of 1952)], or [6][a mobile mobile unit belonging to the armed forces of the Union, railway running shed or a hotel, restaurant or eating place].

1. Subs. by Act 94 of 1976, s. 2, for sub-clause (*ii*) (w.e.f. 26-10-1976).
2. Subs. by Act 25 of 1954, s. 2, for sub-clause (*iv*) (w.e.f. 7-5-1954).
3. Ins. by Act 94 of 1976, s. 2 (w.e.f. 26-10-1976).
4. Subs. by s. 2, *ibid.*, for "employed, directly or through any agency, whether for wages or not" (w.e.f. 26-10-1976).
5. Subs. by Act 25 of 1954, s. 2, for "the Indian Mines Act, 1923 (4 of 1923)" (w.e.f. 7-5-1954).
6. Subs. by Act 94 of 1976, s. 2, for "a railway running shed" (w.e.f. 26-10-1976).

[1][*Explanation* [2][I]—For computing the number of workers for the purposes of this clause all the workers in [3][different groups and relays] in a day shall be taken into account;]

[4][*Explanation* II.—For the purposes of this clause, the mere fact that an Electronic Data Processing Unit or a Computer Unit is installed in any premises or part thereof, shall not be construed to make it a factory if no manufacturing process is being carried on in such premises or part thereof;]

(*n*) "occupier" of a factory means the person who has ultimate control over the affairs of the factory [5]***.

[4][Provided that—

(*i*) in the case of a firm or other association of individuals, any one of the individual partners or members thereof shall be deemed to be the occupier;

(*ii*) in the case of a company, any one of the directors shall be deemed to be the occupier;

(*iii*) in the case of a factory owned or controlled by the Central Government or any State Government, or any local authority, the person or persons appointed to manage the affairs of the factory by the Central Government, the Stale Government or the local authority, as the case may be, shall be deemed to be the occupier:]

[1][[6][Provided further that] in the case of a ship which is being repaired, or on which maintenance work is being carried out, in a dry dock which is available for hire,—

(*1*) the owner of the dock shall be deemed to be the occupier for the purposes of any matter provided for by or under—

(*a*) section 6, section 7, [4][section 7A, section 7B,] section 11 or section 12;

(*b*) section 17, in so far as it relates to the providing and maintenance of sufficient and suitable lighting in or around the dock;

(*c*) section 18, section 19, section 42, section 46, section 47 or section 49, in relation to the workers employed on such repair or maintenance;

(*2*) the owner of the ship or his agent or master or other officer-in-charge of the ship or any person who contracts with such owner, agent or master or other officer-in-charge to carry out the repair or maintenance work shall be deemed to be the occupier for the purposes of any matter provided for by or under section 13, section 14, section 16 or section 17 (save as otherwise provided in this proviso) or Chapter IV (except section 27) or section 43, section 44 or section 45, Chapter VI, Chapter VII, Chapter VIII or Chapter IX or section 108, section 109 or section 110, in relation to—

(*a*) the workers employed directly by him, or by or through any agency; and

(*b*) the machinery, plant or premises in use for the purpose of carrying out such repair or maintenance work by such owner, agent, master or other officer-in-charge or person;

[7]* * * * *

(*p*) "prescribed" means prescribed by rules made by the State Government under this Act;

[8]* * * * *

(*r*) where work of the same kind is carried out by two or more sets of workers working during different periods of the day, each of such sets is called a [9]["group" or "relay"] and each of such periods is called a "shift".

1. Ins. by Act 94 of 1976, s. 2 (w.e.f. 26-10-1976).
2. The *Explanation* renumbered as *Explanation* I by Act 20 of 1987, s. 2 (w.e.f. 1-12-1987).
3. Subs. by s. 2, *ibid.*, for "different relays" (w.e.f. 1-12-1987).
4. Ins. by s. 2, *ibid.* (w.e.f. 1-12-1987).
5. Certain words omitted by s. 2, *ibid.* (w.e.f. 1-12-1987).
6. Subs. by s. 2, *ibid.*, for "Provided that" (w.e.f. 1-12-1987).
7. Omitted by s. 2, *ibid.* (w.e.f. 1-12-1987).
8. Omitted by the A. O. 1950.
9. Subs. by Act 20 of 1987, s. 2, for "relay" (w.e.f. 1-12-1987).

3. References to time of day.—In this Act references to time of day are references to Indian Standard Time, being five and a half hours ahead of Greenwich Mean Time:

Provided that for any area in which Indian Standard Time is not ordinarily observed the State Government may make rules—

(*a*) specifying the area,

(*b*) defining the local mean time ordinarily observed therein, and

(*c*) permitting such time to be observed in all or any of the factories situated in the area.

[1]**[4. Power to declare different departments to be separate factories or two or more factories to be a single factory.—**The State Government may, [2][on its own or] on an application made in this behalf by an occupier, direct, by an order in writing [2][and subject to such conditions as it may deem fit that for all or any of the purposes of this Act different departments or branches of a factory of the occupier specified in the application shall be treated as separate factories or that two or more factories of the occupier specified in the application shall be treated as a single factory:]

[3][Provided that no order under this section shall be made by the State Government on its own motion unless an opportunity of being heard is given to the occupier.]

5. Power to exempt during public emergency.—In any case of public emergency the State Government may, by notification in the Official Gazette, exempt any factory or class or description of factories from all or any of the provisions of this Act [4][except section 67] for such period and subject to such conditions as it may think fit:

Provided that no such notification shall be made for a period exceeding three months at a time.

[5][*Explanation*.**—**For the purposes of this section "public emergency" means a grave emergency whereby the security of India or of any part of the territory thereof is threatened, whether by war or external aggression or internal disturbance.]

6. Approval, licensing and registration of factories.—(*1*) The State Government may make rules**—**

[6][(*a*) requiring, for the purposes of this Act, the submission of plans of any class or description of factories to the Chief Inspector or the State Government;]

[7][(*aa*)] requiring, the previous permission in writing of the State Government or the Chief Inspector to be obtained for the site on which the factory is to be situated and for the construction or extension of any factory or class or description of factories;

(*b*) requiring for the purpose of considering applications for such permission the submission of plans and specifications;

(*c*) prescribing the nature of such plans and specifications and by whom they shall be certified;

(*d*) requiring the registration and licensing of factories or any class or description of factories, and prescribing the fees payable for such registration and licensing and for the renewal of licences;

(*e*) requiring that no licence shall be granted or renewed unless the notice specified in section 7 has been given.

(*2*) If on an application for permission referred to in [8][clause (*aa*)] of sub-section (*1*) accompanied by the plans and specifications required by the rules made under clause (*b*) of that sub-section, sent to the State Government or Chief Inspector by registered post, no order is communicated to the applicant within three months from the date on which it is so sent, the permission applied for in the said application shall be deemed to have been granted.

1. Subs. by Act 25 of 1954, s. 3, for section 4 (w.e.f. 7-5-1954).
2. Ins. by Act 20 of 1987, s. 3 (w.e.f. 1-12-1987).
3. Added by s. 3, *ibid.* (w.e.f. 1-12-1987).
4. Ins. by the A.O. 1950.
5. Ins. by Act 94 of 1976, s. 3 (w.e.f. 26-10-1976).
6. Ins. by s. 4, *ibid.* (w.e.f. 26-10-1976).
7. Clause (*a*) re-lettered as clause (*aa*) by s. 4, *ibid.* (w.e.f. 26-10-1976).
8. Subs. by s. 4, *ibid.*, for "clause (*a*)" (w.e.f. 26-10-1976).

(*3*) Where a State Government or a Chief Inspector refuses to grant permission to the site, construction or extension of a factory or to the registration and licensing of a factory, the applicant may within thirty days of the date of such refusal appeal to the Central Government if the decision appealed from was of the State Government and to the State Government in any other case.

Explanation.—A factory shall not be deemed to be extended within the meaning of this section by reason only of the replacement of any plant or machinery, or within such limits as may be prescribed, of the addition of any plant or machinery [1][if such replacement or addition does not reduce the minimum clear space required for safe working around the plant or machinery or adversely affect the environmental conditions from the evolution or emission of steam, heat or dust or fumes injurious to health].

7. Notice by occupier.—(*1*) The occupier shall, at least fifteen days before he begins to occupy or use any premises as a factory, send to the Chief Inspector a written notice containing—

(*a*) the name and situation of the factory;

(*b*) the name and address of the occupier;

[2][(*bb*) the name and address of the owner of the premises or building (including the precincts thereof) referred to in section 93;]

(*c*) the address to which communications relating to the factory may be sent;

(*d*) the nature of the manufacturing process—

(*i*) carried on in the factory during the last twelve months in the case of factories in existence on the date of the commencement of this Act; and

(*ii*) to be carried on in the factory during the next twelve months in the case of all factories;

[3][(*e*) the total rated horse power installed or to be installed in the factory, which shall not include the rated horse power of any separate stand-by plant;]

(*f*) the name of the manager of the factory for the purposes of this Act;

(*g*) the number of workers likely to be employed in the factory;

(*h*) the average number of workers per day employed during the last twelve months in the case of a factory in existence on the date of the commencement of this Act;

(*i*) such other particulars as may be prescribed.

(*2*) In respect of all establishments which come within the scope of the Act for the first time, the occupier shall send a written notice to the Chief Inspector containing the particulars specified in sub-section (*1*) within thirty days from the date of the commencement of this Act.

(*3*) Before a factory engaged in a manufacturing process which is ordinarily carried on for less than one hundred and eighty working days in the year resumes working, the occupier shall send a written notice to the Chief Inspector containing the particulars specified in sub-section (*1*) [4][at least thirty days] before the date of the commencement of work.

(*4*) Whenever a new manager is appointed, the occupier shall send to the [5][Inspector a written notice and to the Chief Inspector a copy thereof] within seven days from the date on which such person takes over charge.

(*5*) During any period for which no person has been designated as manager of a factory or during which the person designated does not manage the factory, any person found acting as manager, or if no such person is found, the occupier himself, shall be deemed to be the manager of the factory for the purposes of this Act.

1. Ins. by Act 94 of 1976, s. 4 (w.e.f. 26-10-1976).
2. Ins. by Act 25 of 1954, s. 4 (w.e.f. 7-5-1954).
3. Subs. by Act 94 of 1976, s. 5, for clause (*e*) (w.e.f. 26-10-1976).
4. Subs. by Act 40 of 1949, s. 3 and the Second Schedule, for "within thirty days" (w.e.f. 1-5-1949).
5. Subs. by Act 25 of 1954, s. 4, for "Chief Inspector a written notice" (w.e.f. 7-5-1954).

CHAPTER II

THE INSPECTING STAFF

[1][**7A. General duties of the occupier.—**(*1*) Every occupier shall ensure, so far as is reasonably practicable, the health, safety and welfare of all workers while they are at work in the factory.

(*2*) Without prejudice to the generality of the provisions of sub-section (*1*), the matters to which such duty extends, shall include—

(*a*) the provision and maintenance of plant and systems of work in the factory that are safe and without risks to health;

(*b*) the arrangements in the factory for ensuring safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances;

(*c*) the provisions of such information, instruction, training and supervision as are necessary to ensure the health and safety of all workers at work;

(*d*) the maintenance of all places of work in the factory in a condition that is safe and without risks to health and the provision and maintenance of such means of access to, and egress from, such places as are safe and without such risks;

(*e*) the provision, maintenance or monitoring of such working environment in the factory for the workers that is safe, without risks to health and adequate as regards facilities and arrangements for their welfare at work.

(*3*) Except in such cases as may be prescribed, every occupier shall prepare, and, as often as may be appropriate, revise, a written statement of his general policy with respect to the health and safety of the workers at work and the organisation and arrangements for the time being in force for carrying out that policy, and to bring the statement and any revision thereof to the notice of all the workers in such manner as may be prescribed.

***7B. General duties of manufacturers, etc., as regards articles and substances for use in factories.—**(*1*) Every person who designs, manufactures, imports or supplies any article for use in any factory, shall—

(*a*) ensure, so far as is reasonably practicable, that the article is so designed and constructed as to be safe and without risks to the health of the workers when properly used;

(*b*) carry out or arrange for the carrying out of such tests and examination as may be considered necessary for the effective implementation of the provisions of clause (*a*);

(*c*) take such steps as may be necessary to ensure that adequate information will be available—

(*i*) in connection with the use of the article in any factory;

(*ii*) about the use for which it is designed and tested; and

(*iii*) about any conditions necessary to ensure that the article, when put to such use, will be safe, and without risks to the health of the workers:

Provided that where an article is designed or manufactured outside India, it shall be obligatory on the part of the importer to see—

(*a*) that the article conforms to the same standards if such article is manufactured in India, or

(*b*) if the standards adopted in the country outside for the manufacture of such article is above the standards adopted in India, that the article conforms to such standards.

(*2*) Every person, who undertakes to design or manufacture any article for use in any factory, may carry out or arrange for the carrying out of necessary research with a view to the discovery and, so far as is reasonably practicable, the elimination or minimisation of any risks to the health or safety of the workers to which the design or article may give rise.

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1. Ins. by Act 20 of 1987, s. 4 (w.e.f. 1-12-1987).
*. Ins. by s. 4, *ibid*. (w.e.f. 1-6-1988).

(*3*) Nothing contained in sub-sections (*1*) and (*2*) shall be construed to require a person to repeat the testing, examination or research which has been carried out otherwise than by him or at his instance in so far as it is reasonable for him to rely on the results thereof for the purposes of the said sub-sections.

(*4*) Any duty imposed on any person by sub-sections (*1*) and (*2*) shall extend only to things done in the course of business carried on by him and to matters within his control.

(*5*) Where a person designs, manufactures, imports or supplies an article on the basis of a written undertaking by the user of such article to take the steps specified in such undertaking to ensure, so far as is reasonably practicable, that the article will be safe and without risks to the health of the workers when properly used, the undertaking shall have the effect of relieving the person designing, manufacturing, importing or supplying the article from the duty imposed by clause (*a*) of sub-section (*1*) to such extent as is reasonable having regard to the terms of the undertaking.

(*6*) For the purposes of this section, an article is not to be regarded as properly used if it is used without regard to any information or advice relating to its use which has been made available by the person who has designed, manufactured, imported or supplied the article.

Explanation.—For the purposes of this section, "article" shall include plant and machinery.]

8. Inspectors.—(*1*) The State Government may, by notification in the Official Gazette, appoint such persons as possess the prescribed qualification to be Inspectors for the purposes of this Act and may assign to them such local limits as it may think fit.

(*2*) The State Government may, by notification in the Official Gazette, appoint any person to be a Chief Inspector who shall, in addition to the powers conferred on a Chief Inspector under this Act, exercise the powers of an Inspector throughout the State.

[1][(*2A*) The State Government may, by notification in the Official Gazette, appoint as many Additional Chief Inspectors, Joint Chief Inspectors and Deputy Chief Inspectors and as many other officers as it thinks fit to assist the Chief Inspector and to exercise such of the powers of the Chief Inspector as may be specified in such notification.

(*2B*) Every Additional Chief Inspector, Joint Chief Inspector, Deputy Chief Inspector and every other officer appointed under sub-section (*2A*) shall, in addition to the powers of a Chief Inspector specified in the notification by which he is appointed, exercise the power of an Inspector throughout the State.]

(*3*) No person shall be appointed under sub-section (*1*), sub-section (*2*) [1][, sub-section (*2A*)] or sub-section (*5*) or, having been so appointed, shall continue to hold office, who is or becomes directly or indirectly interested in a factory or in any process or business carried on therein or in any patent or machinery connected therewith.

(*4*) Every District Magistrate shall be an Inspector for his district.

(*5*) The State Government may also, by notification as aforesaid, appoint such public officers as it thinks fit to be additional Inspectors for all or any of the purposes of this Act, within such local limits as it may assign to them respectively.

(*6*) In any area where there are more Inspectors than one the State Government may, by notification as aforesaid, declare the powers, which such Inspectors shall respectively exercise and the Inspector to whom the prescribed notices are to be sent.

(*7*) [2][Every Chief Inspector, Additional Chief Inspector, Joint Chief Inspector, Deputy Chief Inspector, Inspector and every other officer appointed under this section] shall be deemed to be a public servant within the meaning of the Indian Penal Code (45 of 1860), and shall be officially subordinate to such authority as the State Government may specify in this behalf.

1. Ins. by Act 94 of 1976, s. 6 (w.e.f. 26-10-1976).
2. Subs. by s. 6, *ibid.*, for "every Chief Inspector and Inspector" (w.e.f. 26-10-1976).

9. Powers of Inspectors.—Subject to any rules made in this behalf, an Inspector may, within the local limits for which he is appointed,—

(*a*) enter, with such assistants, being persons in the service of the Government, or any local or other public authority, [1][or with an expert] as he thinks fit, any place which is used, or which he has reason to believe is used, as a factory;

[2][(*b*) make examination of the premises, plant, machinery, article or substance;

(*c*) inquire into any accident or dangerous occurrence, whether resulting in bodily injury, disability or not, and take on the spot or otherwise statements of any person which he may consider necessary for such inquiry;

(*d*) require the production of any prescribed register or any other document relating to the factory;

(*e*) seize, or take copies of, any register, record or other document or any portion thereof, as he may consider necessary in respect of any offence under this Act, which he has reason to believe, has been committed;

(*f*) direct the occupier that any premises or any part thereof, or anything lying therein, shall be left undisturbed (whether generally or in particular respects) for so long as is necessary for the purpose of any examination under clause (*b*);

(*g*) take measurements and photographs and make such recordings as he considers necessary for the purpose of any examination under clause (*b*), taking with him any necessary instrument or equipment;

(*h*) in case of any article or substance found in any premises, being an article or substance which appears to him as having caused or is likely to cause danger to the health or safety of the workers, direct it to be dismantled or subject it to any process or test (but not so as to damage or destroy it unless the same is, in the circumstances necessary, for carrying out the purposes of this Act), and take possession of any such article or substance or a part thereof, and detain it for so long as is necessary for such examination;

(*i*) exercise such other powers as may be prescribed.]

10. Certifying surgeons.—(*1*) The State Government may appoint qualified medical practitioners to be certifying surgeons for the purposes of this Act within such local limits or for such factory or class or description of factories as it may assign to them respectively.

(*2*) A certifying surgeon may, with the approval of the State Government, authorise any qualified medical practitioner to exercise any of his powers under this Act for such period as the certifying surgeon may specify and subject to such conditions as the State Government may think fit to impose, and references in this Act to a certifying surgeon shall be deemed to include references to any qualified medical practitioner when so authorised.

(*3*) No person shall be appointed to be, or authorised to exercise the powers of, a certifying surgeon, or having been so appointed or authorised, continue to exercise such powers, who is or becomes the occupier of a factory or is or becomes directly or indirectly interested therein or in any process or business carried on therein on in any patent or machinery connected therewith or is otherwise in the employ of the factory:

[3][Provided that the State Government may, by order in writing and subject to such conditions as may be specified in the order, exempt any person or class of persons from the provisions of this sub-section in respect of any factory or class or description of factories.]

(*4*) The certifying surgeon shall carry out such duties as may be prescribed in connection with—

(*a*) the examination and certification of young persons under this Act;

1. Ins. by Act 20 of 1987, s. 5 (w.e.f. 1-12-1987).
2. Subs. by s. 5, *ibid.*, for clauses (*b*) and (*c*) (w.e.f. 1-12-1987).
3. Ins. by Act 94 of 1976, s. 7 (w.e.f. 26-10-1976).

(*b*) the examination of persons engaged in factories in such dangerous occupations or processes as may be prescribed;

(*c*) the exercising of such medical supervision as may be prescribed for any factory or class or description of factories where—

(*i*) cases of illness have occurred which it is reasonable to believe are due to the nature of the manufacturing process carried on, or other conditions of work prevailing, therein;

(*ii*) by reason of any change in the manufacturing process carried on or in the substances used therein or by reason of the adoption of any new manufacturing process or of any new substance for use in a manufacturing process, there is a likelihood of injury to the health of workers employed in that manufacturing process;

(*iii*) young persons are, or are about to be, employed in any work which is likely to cause injury to their health.

Explanation.—In this section "qualified medical practitioner" means a person holding a qualification granted by an authority specified in the Schedule to the Indian Medical Degrees Act, 1916 (7 of 1916), or in the Schedules to the Indian Medical Council Act, 1933 (27 of 1933)[1].

CHAPTER III

HEALTH

11. Cleanliness.—(*1*) Every factory shall be kept clean and free from effluvia arising from any drain, privy or other nuisance, and in particular—

(*a*) accumulation of dirt and refuse shall be removed daily by sweeping or by any other effective method from the floors and benches of workrooms and from staircases and passages, and disposed of in a suitable manner;

(*b*) the floor of every workroom shall be cleaned at least once in every week by washing, using disinfectant, where necessary, or by some other effective method;

(*c*) where a floor is liable to become wet in the course of any manufacturing process to such extent as is capable of being drained, effective means of drainage shall be provided and maintained;

(*d*) all inside walls and partitions, all ceilings or tops of rooms and all walls, sides and tops of passages and staircases shall—

(*i*) where they are [2][painted otherwise than with washable water-paint] or varnished, be repainted or revarnished at least once in every period of five years;

[3][(*ia*) where they are painted with washable water-paint, be repainted with at least one coat of such paint at least once in every period of three years and washed at least once in every period of six months;]

(*ii*) where they are painted or varnished or where they have smooth impervious surfaces, be cleaned at least once in every period of fourteen months by such method as may be prescribed;

(*iii*) in any other case, be kept whitewashed, or colourwashed, and the whitewashing or colourwashing shall be carried out at least once in every period of fourteen months;

[3][(*dd*) all doors and window frames and other wooden or metallic framework and shutters shall be kept painted or varnished and the painting or varnishing shall be carried out at least once in every period of five years;]

(*e*) the dates on which the processes required by clause (*d*) are carried out shall be entered in the prescribed register.

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1. *See now* the Indian Medical Council Act, 1956 (102 of 1956).
2. Subs. by Act 94 of 1976, s. 8, for "painted" (w.e.f. 26-10-1976).
3. Ins. by s. 8, *ibid*. (w.e.f. 26-10-1976).

(*2*) If, in view of the nature of the operations carried on [1][in a factory or class or description of factories or any part of a factory or class or description of factories], it is not possible for the occupier to comply with all or any of the provisions of subsection (*1*), the State Government may by order exempt such factory or class or description of factories [2][or part] from any of the provisions of that sub-section and specify alternative methods for keeping the factory in a clean stale.

12. Disposal of wastes and effluents.—[3][(*1*) Effective arrangements shall be made in every factory for the treatment of wastes and effluents due to the manufacturing process carried on therein, so as to render them innocuous, and for their disposal.]

(*2*) The State Government may make rules prescribing the arrangements to be made under sub-section (*1*) or requiring that the arrangements made in accordance with sub-section (*1*) shall be approved by such authority as may be prescribed.

13. Ventilation and temperature.—(*1*) Effective and suitable provision shall be made in ever factory for securing and maintaining in every workroom**—**

(*a*) adequate ventilation by the circulation of fresh air, and

(*b*) such a temperature as will secure to workers therein reasonable conditions of comfort and prevent injury to health;

and in particular,**—**

(*i*) walls and roofs shall be of such material and so designed that such temperature shall not be exceeded bill kept as tow as practicable;

(*ii*) where the nature of the work carried on in the factory involves, or is likely to involve the production of excessively high temperatures, such adequate measures as are practicable shall be taken to protect the workers therefrom, by separating the process which produces such temperatures from the workroom, by insulating the hot parts or by other effective means.

(*2*) The State Government may prescribe a standard of adequate ventilation and reasonable temperature for any factory or class or description of factories or parts thereof and direct that [4][proper measuring instruments, at such places and in such position as may be specified, shall be provided and such records, as may be prescribed, shall be maintained.]

[5][(*3*) If it appears to the Chief Inspector that excessively high temperatures in any factory can be reduced by the adoption of suitable measures, he may, without prejudice to the rules made under sub-section (*2*), serve on the occupier, an order in writing specifying the measures which, in his opinion, should be adopted, and requiring them to be carried out before a specified date.]

14. Dust and fume.—(*1*) In every factory in which, by reason of the manufacturing process carried on, there is given off any dust or fume or other impurity of such a nature and to such an extent as is likely to be injurious or offensive to the workers employed therein, or any dust in substantial quantities, effective measures shall be taken to prevent its inhalation and accumulation in any workroom, and if any exhaust appliance is necessary for this purpose, it shall be applied as near as possible to the point of origin of the dust, fume or other impurity, and such point shall be enclosed so far as possible.

(*2*) In any factory no stationary internal combustion engine shall be operated unless the exhaust is conducted into the open air, and no other internal combustion engine shall be operated in any room unless effective measures have been taken to prevent such accumulation of fumes therefrom as are likely to be injurious to workers employed in the room.

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1. Subs. by Act 94 of 1976, s. 8, for "in a factory" (w.e.f. 26-10-1976).
2. Ins. by s. 8, *ibid*. (w.e.f. 26-10-1976).
3. Subs. by s. 9, *ibid.*, for sub-section (*1*) (w.e.f. 26-10-1976).
4. Subs. by Act 20 of 1987, s. 6, for certain words (w.e.f. 1-12-1987).
5. Subs. by s. 6, *ibid.*, for sub-section (*3*) (w.e.f. 1-12-1987).

15. Artificial humidification.—(*1*) In respect of all factories in which the humidity of the air is artificially increased, the State Government may make rules,—

(*a*) prescribing standards of humidification;

(*b*) regulating the methods used for artificially increasing the humidity of the air;

(*c*) directing prescribed tests for determining the humidity of the air to be correctly carried out and recorded;

(*d*) prescribing methods to be adopted for securing adequate ventilation and cooling of the air in the workrooms.

(*2*) In any factory in which the humidity of the air is artificially increased, the water used for the purpose shall be taken from a public supply, or other source of drinking water, or shall be effectively purified before it is so used.

(*3*) If it appears to an Inspector that the water used in a factory for increasing humidity which is required to be effectively purified under sub-section (*2*) is not effectively purified he may serve on the manager of the factory an order in writing, specifying the measures which in his opinion should be adopted, and requiring them to be carried out before specified date.

16. Overcrowding.—(*1*) No room in any factory shall be overcrowded to an extent injurious to the health of the workers employed therein.

(*2*) Without prejudice to the generality of sub-section (*1*) there shall be in every workroom of a factory in existence on the date of the commencement of this Act at least [1][9.9 cubic metres] and of a factory built after the commencement of this Act at least [2][14.2 cubic metres] of space for every worker employed therein, and for the purposes of this sub-section no account shall be taken of any space which is more than [3][4.2 metres] above the level of the floor of the room.

(*3*) If the Chief Inspector by order in writing so requires, there shall be posted in each workroom of a factory a notice specifying the maximum number of workers who may, in compliance with the provisions of this section, be employed in the room.

(*4*) The Chief Inspector may by order in writing exempt, subject to such conditions, if any, as he may think fit to impose, any workroom from the provisions of this section, if he is satisfied that compliance therewith in respect of the room is unnecessary in the interest of the health of the workers employed therein.

17. Lighting.—(*1*) In every part of a factory where workers are working of passing there shall be provided and maintained sufficient and suitable lighting, natural or artificial, or both.

(*2*) In every factory all glazed windows and skylights used for the lighting of the workrooms shall be kept clean on both the inner and outer surfaces and, so far as compliance with the provisions of any rules made under sub-section (*3*) of section 13 will allow, free from obstruction.

(*3*) In every factory effective provision shall, so far as is practicable, be made for the prevention of—

(*a*) glare, either directly from a source of light or by reflection from a smooth or polished surface:

(*b*) the formation of shadows to such an extent as to cause eye-strain or the risk of accident to any worker.

(*4*) The State Government may prescribe standards of sufficient and suitable lighting for factories or for any class or description of factories or for any manufacturing process.

18. Drinking water.—(*1*) In every factory effective arrangements shall be made to provide and maintain at suitable points conveniently situated for all workers employed therein a sufficient supply of wholesome drinking water.

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1. Subs. by Act 20 of 1987, s. 7, for “three hundred and fifty cubic feet” (w.e.f. 1-12-1987).
2. Subs. by s. 7, *ibid.*, for “five hundred cubic feet” (w.e.f. 1-12-1987).
3. Subs. by s. 7, *ibid.*, for “fourteen feet” (w.e.f. 1-12-1987).

(*2*) All such points shall be legibly marked "drinking water" in a language understood by a majority of the workers employed in the factory, and no such point shall be situated within [1][six metres of any washing place, urinal, latrine, spittoon, open drain carrying sullage or effluent or any other source of contamination] unless a shorter distance is approved in writing by the Chief Inspector.

(*3*) In every factory wherein more than two hundred and fifty workers are ordinarily employed, provision shall be made for cool drinking water during hot weather by effective means and for distribution thereof.

(*4*) In respect of all factories or any class or description of factories the State Government may make rules for securing compliance with the provisions of sub-sections (*1*), (*2*) and (*3*) and for the examination by prescribed authorities of the supply and distribution of drinking water in factories.

19. Latrines and urinals.—(*1*) In every factory**—**

(*a*) sufficient latrine and urinal accommodation of prescribed types shall be provided conveniently situated and accessible to workers at all times while they are at factory;

(*b*) separate enclosed accommodation shall be provided for male and female workers;

(*c*) such accommodation shall be adequately lighted and ventilated, and no latrine or urinal shall, unless specially exempted in writing by the Chief Inspector, communicate with any work room except through an intervening open space or ventilated passage;

(*d*) all such accommodation shall be maintained in a clean and sanitary condition at all times;

(*e*) sweepers shall be employed whose primary duty it would be to keep clean latrines, urinals and washing places.

(*2*) In every factory wherein more than two hundred and fifty workers are ordinarily employed**—**

(*a*) all latrine and urinal accommodation shall be of prescribed sanitary types;

(*b*) the floors and internal walls, up to a height of [2][ninety centimetres], of the latrines and urinals and the sanitary blocks shall be laid in glazed tiles or otherwise finished to provide a smooth polished impervious surface;

(*c*) without prejudice to the provisions of clauses (*d*) and (*e*) of sub-section (*1*), the floors, portions of the walls and blocks so laid or finished and the sanitary pans of latrines and urinals shall be thoroughly washed and cleaned at least once in every seven days with suitable detergents or disinfectants or with both.

(*3*) The State Government may prescribe the number of latrines and urinals to be provided in any factory in proportion to the numbers of male and female workers ordinarily employed therein, and provide for such further mailers in respect of sanitation in factories, including the obligation of workers in this regard, as it considers necessary in the interest of the health of the workers employed therein.

20. Spittoons.—(*1*) In every factory there shall be provided a sufficient number of spittoons in convenient places and they shall be maintained in a clean and hygienic condition.

(*2*) The State Government may make rules prescribing the type and the number of spittoons to be provided and their location in any factory and provide for such further matters relating to their maintenance in a clean and hygienic condition.

1. Subs. by Act 20 of 1987, s. 8, for "twenty feet of any washing place, urinal or latrine" (w.e.f. 1-12-1987).
2. Subs. by s. 9, *ibid.*, for "three feet" (w.e.f. 1-12-1987).

(*3*) No person shall spit within the premises of a factory except in the spittoons provided for the purpose and a notice containing this provision and the penalty for its violation shall be prominently displayed at suitable places in the premises.

(*4*) Whoever spits in contravention of sub-section (*3*) shall be punishable with fine not exceeding five rupees.

CHAPTER IV

SAFETY

21. Fencing of machinery.—(*1*) In every factory the following, namely:—

(*i*) every moving part of a prime mover and every flywheel connected to a prime mover, whether the prime mover or flywheel is in the engine house or not;

(*ii*) the headrace and tailrace of every water-wheel and water turbine:

(*iii*) any part of a stock-bar which projects beyond the head stock of a lathe; and

(*iv*) unless they are in such position or of such construction as to be safe to every person employed in the factory as they would be if they were securely fenced, the following, namely:—

(*a*) every part of an electric generator, a motor or rotary converter;

(*b*) every part of transmission machinery; and

(*c*) every dangerous part of any other machinery;

shall be securely fenced by safeguards of substantial construction which [1][shall be constantly maintained and kept in position] while the parts of machinery the y are fencing are in motion or in use:

[2][Provided that for the purpose of determining whether any part of machinery is in such position or is of such construction as to be safe as aforesaid, account shall not be taken of any occasion when—

(*i*) it is necessary to make an examination of any part of the machinery aforesaid while it is in motion or, a s a result of such examination, to carry out lubrication or other adjusting operation while the machinery is in motion, being an examination or operation which it is necessary to be carried out while that part of the machinery is in motion, or

(*ii*) in the case of any part of a transmission machinery used in such process as may be prescribed (being a process of a continuous nature the carrying on of which shall be, or is likely to be, substantially interfered with by the stoppage of that part of the machinery), it is necessary to make an examination of such part of the machinery while it is in motion or, as a result of such examination, to carry out any mounting or shipping of belts or lubrication or other adjusting operation while the machinery is in motion,

and such examination or operation is made or carried out in accordance with the provisions of sub-section (*1*) of section 22.]

(*2*) The State Government may by rules prescribe such further precautions as it may consider necessary in respect of any particular machinery or part thereof, or exempt, subject to such condition as may be prescribed, for securing the safety of the workers, any particular machinery or part thereof from the provisions of this section.

22. Work on or near machinery in motion.—(*1*) [3][Where in any factory it becomes necessary to examine any part of machinery referred to in section 21, while the machinery is in motion, or, as a result of such examination, to carry out—

(*a*) in a case referred to in clause (*i*) of the proviso to sub-section (*1*) of section 21, lubrication or other adjusting operation; or

1. Subs. by Act 94 of 1976, s. 10, for "shall be kept in position" (w.e.f. 26-10-1976).
2. Subs. by s. 10, *ibid.*, for the proviso (w.e.f. 26-10-1976).
3. Subs. by s. 11, *ibid.*, for the opening paragraph and clause (*a*) (w.e.f. 26-10-1976).

(*b*) in a case referred to in clause (*ii*) of the proviso aforesaid, any mounting or shipping of belts or lubrication or other adjusting operation,

while the machinery is in motion, such examination or operation shall be made or carried out only by a specially trained adult male worker wearing tight fitting clothing (which shall be supplied by the occupier) whose name has been recorded in the register prescribed in this behalf and who has been furnished with a certificate of this appointment, and while he is so engaged,—

(*a*) such worker shall not handle a belt at a moving pulley unless—

(*i*) the belt is not more than fifteen centimetres in width;

(*ii*) the pulley is normally for the purpose of drive and not merely a fly-wheel or balance wheel (in which case a belt is not permissible);

(*iii*) the belt joint is either laced or flush with the belt;

(*iv*) the belt, including the joint and the pulley rim, are in good repair;

(*v*) there is reasonable clearance between the pulley and any fixed plant or structure;

(*vi*) secure foothold and, where necessary, secure handhold, are provided for the operator; and

(*vii*) any ladder in use for carrying out any examination or operation aforesaid is securely fixed or lashed or is firmly held by a second person;]

(*b*) without prejudice to any other provision of this Act relating to the fencing of machinery, every set screw, bolt and key on any revolving shaft, spindle, wheel or pinion, and all spur, worm and other toothed or friction gearing in motion with which such worker would otherwise be liable to come into contact, shall be securely fenced to prevent such contact.

[1][(*2*) No woman or young person shall be allowed to clean, lubricate or adjust any part of a prime mover or of any transmission machinery while the prime mover or transmission machinery is in motion, or to clean, lubricate or adjust any part of any machine if the cleaning, lubrication or adjustment thereof would expose the woman or young person to risk of injury from any moving part either of that machine or of any adjacent machinery.]

(*3*) The State Government may, by notification in the Official Gazette, prohibit, in any specified factory or class or description of factories, the cleaning, lubricating or adjusting by any person of specified parts of machinery when those parts are in motion.

23. Employment of young persons on dangerous machines.—(*1*) No young person [2][shall be required or allowed to work] at any machine to which this section applies, unless he has been fully instructed as to the dangers arising in connection with the machine and the precautions to be observed and—

(*a*) has received sufficient training in work at the machine, or

(*b*) is under adequate supervision by a person who has a thorough knowledge and experience of the machine.

(*2*) Sub-section (*1*) shall apply to such machines as may be prescribed by the State Government, being machines which in its opinion are of such a dangerous character that young persons ought not to work at them unless the foregoing requirements are complied with.

24. Striking gear and devices for cutting off power.—(*1*) In every factory—

(*a*) suitable striking gear or other efficient mechanical appliance shall be provided and maintained and used to move driving belts to and from fast and loose pulleys which form part of the transmission machinery, and such gear or appliances shall be so constructed, placed and maintained as to prevent the belt from creeping back on the fast pulley;

(*b*) driving belts when not in use shall not be allowed to rest or ride upon shafting in motion.

1. Subs. by Act 25 of 1954, s. 6, for sub-section (*2*) (w.e.f. 7-5-1954).
2. Subs. by Act 20 of 1987, s. 10, for "shall work" (w.e.f. 1-12-1987).

(*2*) In every factory suitable devices for cutting off power in emergencies from running machinery shall be provided and maintained in every workroom:

Provided that in respect of factories in operation before the commencement of this Act, the provisions of this sub-section shall apply only to workrooms in which electricity is used as power.

[1][(*3*) When a device, which can inadvertently shift from "off" to "on" position, is provided in a factory to cut off power, arrangements shall be provided for locking the device in safe position to prevent accidental starting of the transmission machinery or other machines to which the device is fitted].

25. Self-acting machines.—No traversing part of a self-acting machine in any factory and no material carried thereon shall, if the space over which it runs is a space over which any person is liable to pass, whether in the course of his employment or otherwise, be allowed to run on its outward or inward traverse within a distance of [2][forty-five centimetres] from any fixed structure which is not part of the machine:

Provided that the Chief Inspector may permit the continued use of a machine installed before the commencement of this Act which does not comply with the requirements of this section on such conditions for ensuring safety as he may think fit to impose.

26. Casing of new machinery.—(*1*) In all machinery driven by power and installed in any factory after the commencement of this Act,**—**

(*a*) every set screw, bolt or key on any revolving shaft, spindle, wheel or pinion shall be so sunk, encased or otherwise effectively guarded as to prevent danger;

(*b*) all spur, worm and other toothed or friction gearing which does not require frequent adjustment while in motion shall be completely encased, unless it is so situated as to be as safe as it would be if it were completely encased.

(*2*) Whoever sells or lets on hire or, as agent of a seller or hirer, causes or procures to be sold or let on hire, for use in a factory any machinery driven by power which does not comply with the provisions of [3][sub-section (*1*) or any rules made under sub-section (*3*)], shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to five hundred rupees or with both.

[4][(*3*) The State Government may make rules specifying further safeguards to be provided in respect of any other dangerous part of any particular machine or class or description of machines.]

27. Prohibition of employment of women and children near cotton-openers.—No woman or child shall be employed in any part of a factory for pressing cotton in which a cotton opener is at work:

Provided that if the feed-end of a cotton-opener is in a room separated from the delivery end by a partition extending to the roof or to such height as the Inspector may in any particular case specify in writing, women and children may be employed on the side of the partition where the feed-end is situated.

28. Hoists and lifts.—(*1*) In every factory**—**

(*a*) every hoist and lift shall be**—**

(*i*) of good mechanical construction, sound material and adequate strength;

(*ii*) properly maintained, and shall be thoroughly examined by a competent person at least once in every period of six months, and a register shall be kept containing the prescribed particulars of very such examination;

1. Ins. by Act 94 of 1976, s. 12 (w.e.f. 26-10-1976).
2. Subs. by Act 20 of 1987, s. 11, for "eighteen inches" (w.e.f. 1-12-1987).
3. Subs. by Act 25 of 1954, s. 7, for "sub-section (*1*)" (w.e.f. 7-5-1954).
4. Subs. by s. 7, *ibid.*, for sub-section (*3*) (w.e.f. 7-5-1954).

(*b*) every hoist way and lift way shall be sufficiently protected by an enclosure fitted with gates, and the hoist or lift and every such enclosure shall be so constructed as to prevent any person or thing from being trapped between any part of the hoist or lift and any fixed structure or moving part;

(*c*) the maximum safe working load shall be plainly marked on every hoist or lift, and no load greater than such load shall be carried thereon;

(*d*) the cage of every hoist or lift used for carrying persons shall be fitted with a gate on each side from which access is afforded to a landing;

(*e*) every gate referred to in clause (*b*) or clause (*d*) shall be fitted with interlocking or other efficient device to secure that the gate cannot be opened except when the cage is at the landing and that the cage cannot be moved unless the gate is closed.

(*2*) The following additional requirement shall apply to hoists and lifts used for carrying persons and installed or reconstructed in a factory after the commencement of this Act, namely:—

(*a*) where the cage is supported by rope or chain, there shall be at least two ropes of chains separately connected with the cage and balance weight, and each rope or chain with its attachments shall be capable of carrying the whole weight of the cage together with its maximum load;

(*b*) efficient devices shall be provided and maintained capable of supporting the cage together with its maximum load in the event of breakage of the ropes, chains or attachments;

(*c*) an efficient automatic device shall be provided and maintained to prevent the cage from over-running.

(*3*) The Chief Inspector may permit the continued, use of a hoist of lift installed in a factory before the commencement of this Act which does not fully comply with the provisions of sub-section (*1*) upon such conditions for ensuring safely as he may think fit to impose.

(*4*) The State Government may, if in respect of any class or description of hoist or lift, it is of opinion that it would be unreasonable to enforce any requirement of sub-sections (*1*) and (*2*), by order direct that such requirement shall not apply to such class or description of hoist or lift.

[1][*Explanation.*—For the purposes of this section, no lifting machine or appliance shall be deemed to be a hoist or lift unless it has a platform or cage, the direction or movement of which is restricted by a guide or guides.]

[2][**29. Lifting machines, chains, ropes and lifting tackles.**—(*1*) In any factory the following provisions shall be complied with in respect of every lifting machine (other than a hoist and lift) and every chain, rope and lifting tackle for the purpose of raising or lowering persons, goods or materials:—

(*a*) all parts, including the working gear, whether fixed or movable, of every lifting machine and every chain, rope or lifting tackle shall be—

(*i*) of good construction, sound material and adequate strength and free from defects;

(*ii*) properly maintained; and

(*iii*) thoroughly examined by a competent person at least once in every period of twelve months, or at such intervals as the Chief Inspector may specify in writing; and a register shall be kept containing the prescribed particulars of every such examination;

(*b*) no lifting machine and no chain, rope or lifting tackle shall, except for the purpose of test be loaded beyond the safe working load which shall be plainly marked thereon together with an identification mark and duly entered in the prescribed register; and where this is not practicable, a table showing the safe working loads of every kind and size of lifting machine or chain, rope or lifting tackle in use shall be displayed in prominent positions on the premises;

1. Ins. by Act 20 of 1987, s. 12 (w.e.f. 1-12-1987).
2. Subs. by Act 25 of 1954, s. 8, for section 29 (w.e.f. 7-5-1954).

(*c*) while any person is employed or working on or near the wheel track of a travelling crane in any place where he would be liable to be struck by the crane, effective measures shall be taken to ensure that the crane does not approach within [1][six metres] of that place.

(*2*) The State Government may make rules in respect of any lifting machine or any chain, rope or lifting tackle used in factories—

(*a*) prescribing further requirements to be complied with in addition to those set out in this section;

(*b*) providing for exemption from compliance with all or any of the requirements of this section, where in its opinion, such compliance is unnecessary or impracticable.

(*3*) For the purposes of this section a lifting machine or a chain, rope or lifting tackle shall be deemed to have been thoroughly examined if a visual examination supplemented, if necessary, by other means and by the dismantling of parts of the gear, has been carried out as carefully as the conditions permit in order to arrive at a reliable conclusion as to the safely of the parts examined.

Explanation.—In this section.—

(*a*) "lifting machine" means a crane, crab, winch, teagle, pulley block, gin wheel, transporter or runway;

[2][(*b*) "lifting tackle" means any chain sling, rope sling, hook, shackle, swivel, coupling, socket, clamp, tray or similar appliance, whether fixed or movable, used in connection with the raising or lowering of persons, or loads by use of lifting machines.]

30. Revolving machinery.—(*1*) [3][In every factory] in which the process of grinding is carried on there shall be permanently affixed to or placed near each machine in use a notice indicating the maximum safe working peripheral speed of every grindstone or abrasive wheel, the speed of the shaft or spindle upon which the wheel is mounted, and the diameter of the pulley upon such shaft or spindle necessary to secure such safe working peripheral speed.

(*2*) The speeds indicated in notices under sub-section (*1*) shall not be exceeded.

(*3*) Effective measures shall be taken in every factory to ensure that the safe working peripheral speed of every revolving vessel, cage, basket, fly-wheel, pulley, disc or similar appliance driven by power is not exceeded.

31. Pressure plant.—[4][(*1*) If in any factory, any plant or machinery or any part thereof is operated at a pressure above atmospheric pressure, effective measures shall be taken to ensure that the safe working pressure of such plant or machinery or part is not exceeded.]

(*2*) The State Government may make rules providing for the examination and testing of any plant or machinery such as is referred to in sub-section (*1*) and prescribing such other safety measures in relation thereto as may in its opinion be necessary in any factory or class or description of factories.

[5][(*3*) The State Government may, by rules, exempt, subject to such conditions as may be specified therein, any part of any plant or machinery referred to in sub-section (*1*) from the provisions of this section.]

32. Floors, stairs and means of access.—In every factory—

(*a*) all floors, steps, stairs, passages and gangways shall be of sound construction and properly maintained [6][and shall be kept free from obstructions and substances likely to cause persons to slip], and where it is necessary to ensure safety, steps, stairs, passages and gangways shall be provided with substantial handrails;

1. Subs. by Act 20 of 1987, s. 13, for "twenty feet" (w.e.f. 1-12-1987).
2. Subs. by s. 13, *ibid.*, for clause (*b*) (w.e.f. 1-12-1987).
3. Subs. by s. 14, *ibid.*, for "in every room in a factory" (w.e.f. 1-12-1987).
4. Subs. by s. 15, *ibid.*, for sub-section (*1*) (w.e.f. 1-12-1987).
5. Ins. by Act 94 of 1976, s. 13 (w.e.f. 26-10-1976).
6. Ins. by s. 14, *ibid.* (w.e.f. 26-10-1976).

(*b*) there shall, so far as is reasonably practicable, be provided and maintained safe means of access to every place at which any person is at any time required to work.

[1][(*c*) when any person has to work at a height from where he is likely to fall, provision shall be made, so far as is reasonably practicable, by fencing or otherwise, to ensure the safety of the person so working.]

33. Pits, sumps openings in floors, etc.—(*1*) In every factory every fixed vessel, sump, tank, pit or opening in the ground or in a floor which, by reason of its depth, situation, construction or contents, is or may be a source of danger, shall be either securely covered or securely fenced.

(*2*) The State Government may, by order in writing, exempt, subject to such conditions as may be prescribed, any factory or class or description of factories in respect of any vessel, sump, tank, pit or opening from compliance with the provisions of this section.

34. Excessive weights.—(*1*) No person shall be employed in any factory to lift, carry or move any load so heavy as to be likely to cause him injury.

(*2*) The State Government may make rules prescribing the maximum weights which may be lifted, carried or moved by adult men, adult women, adolescents and children employed in factories or in any class or description of factories or in carrying or any specified process.

35. Protection of eyes.—In respect of any such manufacturing process carried on in any factory as may be prescribed, being a process which involves—

(*a*) risk of injury to the eyes from particles or fragments thrown off in the course of the process, or

(*b*) risk to the eyes by reason of exposure to excessive light, the State Government may by rules require that effective screens or suitable goggles shall be provided for the protection of persons employed on, or in the immediate vicinity of, the process.

[2][**36. Precautions against dangerous fumes, gases, etc.—**(*1*) No person shall be required or allowed to enter any chamber, tank, vat, pit, pipe, flue or other confined space in any factory in which any gas, fume vapour or dust is likely to be present to such an extent as to involve risk to persons being overcome thereby, unless it is provided with a manhole of adequate size or other effective means of egress.

(*2*) No person shall be required or allowed to enter any confined space as is referred to in sub-section (*1*), until all practicable measures have been taken to remove any gas, fume, vapour or dust, which may be present so as to bring its level within the permissible limits and to prevent any ingress of such gas, fume, vapour or dust and unless—

(*a*) a certificate in writing has been given by a competent person, based on a test carried out by himself that the space is reasonably free from dangerous gas, fume, vapour or dust; or

(*b*) such person is wearing suitable breathing apparatus and a belt securely attached to a rope the free end of which is held by a person outside the confined space.]

[3][**36A. Precautions regarding the use of portable electric light.—**In any factory—

(*a*) no portable electric light or any other electric appliance of voltage exceeding twenty-four volts shall be permitted for use inside any chamber, tank, vat, pit, pipe, flue or other confined space [4][unless adequate safety devices are provided]; and

(*b*) if any inflammable gas, fume or dust is likely to be present in such chamber, tank, vat, pit, pipe, flue or other confined space, no lamp or light other than that flame-proof construction shall be permitted to be used therein.]

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1. Subs. by Act 20 of 1987, s. 16, for clause (*c*) (w.e.f. 1-12-1987).
2. Subs. by s. 17, *ibid.*, for section 36 (w.e.f. 1-12-1987).
3. Ins. by Act 94 of 1976, s. 16 (w.e.f. 26-10-1976).
4. Ins. by Act 20 of 1987, s. 18 (w.e.f. 1-12-1987).

37. Explosive or inflammable dust, gas, etc.—(*1*) Where in any factory any manufacturing process produces dust, gas, fume or vapour of such character and to such extent as to be likely to explode on ignition, all practicable measure shall be taken to prevent any such explosion by—

(*a*) effective enclosure of the plant or machinery used in the process;

(*b*) removal or prevention of the accumulation of such dust, gas, fume or vapour;

(*c*) exclusion or effective enclosure of all possible sources of ignition.

(*2*) Where in any factory the plant or machinery used in a process such as is referred to in sub-section (*1*) is not so constructed as to withstand the probable pressure which such an explosion as aforesaid would produce, all practicable measures shall be taken to restrict the spread and effects of the explosion by the provision in the plant or machinery of chokes, baffles, vents or other effective appliances.

(*3*) Where any part of the plant or machinery in a factory contains any explosive or inflammable gas or vapour under pressure greater than atmospheric pressure, that part shall not be opened except in accordance with the following provisions, namely:—

(*a*) before the fastening of any joint of any pipe connected with the part or the fastening of the cover of any opening into the part is loosened, any flow of the gas or vapour into the part of any such pipe shall be effectively stopped by a stop-valve or other means;

(*b*) before any such fastening as aforesaid is removed, all practicable measures shall be taken to reduce the pressure of the gas or vapour in the part or pipe to atmospheric pressure;

(*c*) where any such fastening as aforesaid has been loosened or removed effective measures shall be taken or prevent any explosive or inflammable gas or vapour from entering the part or pipe until the fastening has been secured, or the case may be, securely replaced;

Provided that the provisions of this sub-section shall not apply in the case of plant or machinery installed in the open air.

(*4*) No plant, tank or vessel which contains or has contained any explosive or inflammable substance shall be subjected in any factory to any welding, brazing, soldering or cutting operation which involves the application of heat unless adequate measures have first been taken to remove such substance and any fumes arising therefrom or to render such substance and fumes non-explosive or non-inflammable, and no such substance shall be allowed to enter such plant, tank or vessel after any such operation until the metal has cooled sufficiently to prevent any risk of igniting the substance.

(*5*) The State Government may by rules exempt, subject to such conditions as may be prescribed, any factory or class or description of factories from compliance with all or any of the provisions of this section.

[1][**38. Precautions in case of fire.—**(*1*) In every factory, all practicable measures shall he taken to prevent outbreak of fire and its spread, both internally and externally, and to provide and maintain—

(*a*) safe means of escape for all persons in the event of a fire, and

(*b*) the necessary equipment and facilities for extinguishing fire.

(*2*) Effective measures shall be taken to ensure that in every factory all the workers are familiar with the means of escape in case of fire and have been adequately trained in the routine to be followed in such cases.

(*3*) The State Government may make rules, in respect of any factory or class or description of factories, requiring the measures to be adopted to give effect to the provisions of sub-sections (*1*) and (*2*).

1. Subs. by Act 20 of 1987, s. 19, for section 38 (w.e.f. 1-12-1987).

(*4*) Notwithstanding anything contained in clause (*a*) of sub-section (*1*) or sub-section (*2*), if the Chief Inspector, having regard to the nature of the work carried on in any factory, the construction of such factory, special risk to life or safety, or any other circumstances, is of the opinion that the measures provided in the factory, whether as prescribed or not, for the purposes of clause (*a*) of sub-section (*1*) or sub-section (*2*), are inadequate, he may, by order in writing, require that such additional measures as he may consider reasonable and necessary, be provided in the factory before such date as is specified in the order.]

39. Power to require specifications of defective parts or tests of stability.—If it appears to the Inspector that any building or part of a building or any part of the ways, machinery or plant in a factory is in such a condition that it may be dangerous to human life or safety, he may serve on [1][the occupier or manger or both] of the factory an order in writing requiring him before a specified date**—**

(*a*) to furnish such drawings, specifications and other particulars as may be necessary to determine whether such building, ways, machinery or plant can be used with safety, or

(*b*) to carry out such tests in such manner as may be specified in the order, and to inform the Inspector of the results thereof.

40. Safety of buildings and machinery.—(*1*) If it appears to the Inspector that any building or part of a building or any part of the ways, machinery or plant in a factory is in such a condition that it is dangerous to human life or safety, he may serve on [1][the occupier or manager or both] of the factory an order in writing specifying the measures which in his opinion should be adopted, and requiring them to be carried out before a specified date.

(*2*) If it appears to the Inspector that the use of any building or part of a building or any part of the ways, machinery or plant in a factory involves imminent danger to human life or safety, he may serve on [1][the occupier or manager or both] of the factory an order in writing prohibiting its use until it has been properly repaired or altered.

[2][**40A. Maintenance of buildings.—**If it appears to the Inspector that any building or part of a building in a factory is in such a state of disrepair as is likely to lead to conditions detrimental to the health and welfare of the workers, he may serve on the occupier or manager or both of the factory an order in writing specifying the measures which in his opinion should be taken and requiring the same to be carried out before such date as is specified in the order.]

40B. Safety Officers.—(*1*) In every factory**—**

(*i*) wherein one thousand or more workers are ordinarily employed, or

(*ii*) wherein, in the opinion of the State Government, any manufacturing process or operation is carried on, which process or operation involves any risk of bodily injury, poisoning or disease, or any other hazard to health, to the persons employed in the factory,

the occupier shall, if so, required by the State Government by notification in the Official Gazette, employ such number of Safety Officers as may be specified in that notification.

(*2*) The duties, qualifications and conditions of service of Safety Officers shall be such as may be prescribed by the State Government.]

41. Power to make rules to supplement this Chapter.**—**The State Government may make rules requiring the provision in any factory or in any class or description of factories of such further [3][devices and measures] for securing the safety of persons employed therein as it may deem necessary.

1. Subs. by Act 94 of 1976, s. 18, for "the manager" (w.e.f. 26-10-1976).
2. Ins. by s. 19, *ibid.* (w.e.f. 26-10-1976).
3. Subs. by s. 20, *ibid.*, for "devices" (w.e.f. 26-10-1976).

[1][CHAPTER IVA

PROVISIONS RELATING TO HAZARDOUS PROCESSES

41A. Constitution of Site Appraisal Committee.—(*1*) The State Government may, for purposes of advising it to consider applications for grant of permission for the initial location of a factory involving a hazardous process or for the expansion of an such factory, appoint a Site Appraisal Committee consisting of—

(*a*) the Chief Inspector of the State who shall be its Chairman;

(*b*) a representative of the Central Board for the Prevention and Control of Water Pollution appointed by the Central Government under section 3 of the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974);

(*c*) a representative of the Central Board for the Prevention and Control of Air Pollution referred to in section 3 of the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981);

(*d*) a representative of the State Board appointed under section 4 of the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974);

(*e*) a representative of the State Board for the Prevention and Control of Air Pollution referred to in section 5 of the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981);

(*f*) a representative of the Department of Environment in the State;

(*g*) a representative of the Meteorological Department of the Government of India;

(*h*) an expert in the field of occupational health; and

(*i*) a representative of the Town Planning Department of the State Government,

and not more than five other members who may be co-opted by the State Government who shall be—

(*i*) a scientist having specialised knowledge of the hazardous process which will be involved in the factory,

(*ii*) a representative of the local authority within whose jurisdiction the factory is to be established, and

(*iii*) not more than three other persons as deemed fit by the State Government.

(*2*) The Site Appraisal Committee shall examine an application for the establishment of a factory involving hazardous process and make its recommendation to the State Government within a period of ninety days of the receipt of such application in the prescribed form.

(*3*) Where any process relates to a factory owned or controlled by the Central Government or to a corporation or a company owned or controlled by the Central Government, the State Government shall co-opt in the Site Appraisal Committee a representative nominated by the Central Government as a member of that Committee.

(*4*) The Site Appraisal Committee shall have power to call for any information from the person making an application for the establishment or expansion of a factory involving a hazardous process.

(*5*) Where the State Government has granted approval to an application for the establishment or expansion of a factory involving a hazardous process, it shall not be necessary for an applicant to obtain a further approval from the Central Board or the State Board established under the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974) and the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981).

1. Ins. by Act 20 of 1987, s. 20 (w.e.f. 1-12-1987).

41B. Compulsory disclosure of information by the occupier.—(*1*) The occupier of every factory involving a hazardous process shall disclose in the manner prescribed all information regarding dangers, including health hazards and the measures to overcome such hazards arising from the exposure to or handling of the materials or substances in the manufactures, transportation, storage and other processes, to the workers employed in the factory, the Chief Inspector, the local authority within whose jurisdiction the factory is situate and the general public in the vicinity.

(*2*) The occupier shall, at the time of registering the factory involving a hazardous process, lay down a detailed policy with respect to the health and safety of the workers employed therein and intimate such policy to the Chief Inspector and the local authority and, thereafter, at such intervals as may be prescribed, inform the Chief Inspector and the local authority of any change made in the said policy.

(*3*) The information furnished under sub-section (*1*) shall include accurate information as to the quantity, specification and other characteristics of wastes and the manner of their disposal.

(*4*) Every occupier shall, with the approval of the Chief Inspector, draw up an on-site emergency plan and detailed disaster control measures for his factory and make known to the workers employed therein and to the general public living in the vicinity of the factory the safety measures required to be taken in the event of an accident taking place.

(*5*) Every occupier of a factory shall,—

(*a*) if such factory engaged in a hazardous process on the commencement of the Factories (Amendment) Act, 1987 (20 of 1987), within a period of thirty days of such commencement; and

(*b*) if such factory proposes to engaged in a hazardous process at any time after such commencement, within a period of thirty days before the commencement of such process,

inform the Chief Inspector of the nature and details of the process in such form and in such manner as may be prescribed.

(*6*) Where any occupier of a factory contravenes the provisions of sub-section (*5*), the licence issued under section 6 to such factory shall, notwithstanding any penalty to which the occupier or factory shall be subjected to under the provisions of this Act, be liable for cancellation.

(*7*) The occupier of a factory involving a hazardous process shall, with the previous approval of the Chief Inspector, lay down measures for the handling, usage, transportation and storage of hazardous substances inside the factory premises and the disposal of such substances outside the factory premises and publicise them in the manner prescribed among the workers and the general public living in the vicinity.

41C. Specific responsibility of the occupier in relation to hazardous processes.—Every occupier of a factory involving any hazardous process shall—

(*a*) maintain accurate and up-to-date health records or, as the case may be, medical records, of the workers in the factory who are exposed to any chemical, toxic or any other harmful substances which are manufactured, stored, handled or transported and such records shall be accessible to the workers subject to such conditions as may be prescribed;

(*b*) appoint persons who possess qualifications and experience in handling hazardous substances and are competent to supervise such handling within the factory and to provide at the working place all the necessary facilities for protecting the workers in the manner prescribed:

Provided that where any question arises as to the qualifications and experience of a person so appointed, the decision of the Chief Inspector shall be final;

(*c*) provide for medical examination of every worker—

(*a*) before such worker is assigned to a job involving the handling of, or working with, a hazardous substance, and

(*b*) while continuing in such job, and after he has ceased to work in such job, at intervals not exceeding twelve months, in such manner as may be prescribed.

41D. Power of Central Government to appoint Inquiry Committee.—(*1*) The Central Government may, in the event of the occurrence of an extraordinary situation involving a factory engaged in a hazardous process, appoint an Inquiry Committee to inquire into the standards of health and safety observed in the factory with a view to finding out the causes of any failure or neglect in the adoption of any measures or standards prescribed for the health and safety of the workers employed in the factory or the general public affected, or likely to be affected, due to such failure or neglect and for the prevention and recurrence of such extraordinary situations in future in such factory or elsewhere.

(*2*) The Committee appointed under sub-section (*1*) shall consist of a Chairman and two other members and the terms of reference of the Committee and the tenure of office of its members shall be such as may be determined by the Central Government according to the requirements of the situation.

(*3*) The recommendations of the Committee shall be advisory in nature.

41E. Emergency standards.—(*1*) Where the Central Government is satisfied that no standards of safety have been prescribed in respect of a hazardous process or class of hazardous processes, or where the standards so prescribed are inadequate, it may direct the Director-General of Factory Advice Service and Labour Institutes or any institution specialised in matters relating to standards of safety in hazardous processes, to lay down emergency standards for enforcement of suitable standards in respect of such hazardous processes.

(*2*) The emergency standards laid down under sub-section (*1*) shall, until they are incorporated in the rules made under this Act, be enforceable and have the same effect as if they had been incorporated in the rules made under this Act.

***41F. Permissible limits of exposure of chemical and toxic substances.—**(*1*) The maximum permissible threshold limits of exposure of chemical and toxic substances in manufacturing processes (whether hazardous or otherwise) in any factory shall be of the value indicated in the Second Schedule.

(*2*) The Central Government may, at any time, for the purpose of giving effect to any scientific proof obtained from specialised institutions or experts in the field by notification in the Official Gazette, make suitable changes in the said Schedule.

41G. Workers' participation in safety management.—(*1*) The occupier shall, in every factory where a hazardous process takes place, or where hazardous substances are used or handled, set up a Safety Committee consisting of equal number of representatives of workers and management to promote co-operation between the workers and the management in maintaining proper safety and health at work and to review periodical the measures taken in that behalf:

Provided that the State Government may, by order in writing and for reasons to be recorded exempt the occupier of any factory or class of factories from setting up such Committee.

(*2*) The composition of the Safety Committee, the tenure of office of its members and their rights and duties shall be such as may be prescribed.

41H. Right of workers to warn about imminent danger.—(*1*) Where the workers employed in any factory engaged in a hazardous process have reasonable apprehension that there is a likelihood of imminent danger to their lives or health due to any accident, they may bring the same to the notice of the occupier, agent, manager or any other person who is in charge of the factory or the process concerned directly or through their representatives in the Safety Committee and simultaneously bring the same to the notice of the Inspector.

(*2*) It shall be the duty of such occupier, agent, manager or the person in charge of the factory or process to take immediate remedial action if he is satisfied about the existence of such imminent danger and send a report forthwith of the action taken to the nearest Inspector.

(*3*) If the occupier, agent, manager or the person in charge referred to in sub-section (*2*) is not satisfied about the existence of any imminent danger as apprehended by the workers, he shall, nevertheless, refer the matter forthwith to the nearest Inspector whose decision on the question of the existence of such imminent danger shall be final.]

* Ins. by Act 20 of 1987, s. 20 (w.e.f. 1-6-1988).

CHAPTER V

WELFARE

42. Washing facilities.—(*1*) In every factory**—**

(*a*) adequate and suitable facilities for washing shall be provided and maintained for the use of the workers therein;

(*b*) separate and adequately screened facilities shall be provided for the use of male and female workers;

(*c*) such facilities shall be conveniently accessible and shall be kept clean.

(*2*) The State Government may, in respect of any factory or class or description of factories or of any manufacturing process, prescribe standards of adequate and suitable facilities for washing.

43. Facilities for storing and drying clothing.—The State Government may, in respect of any factory or class or description of factories, make rules requiring the provision therein of suitable places for keeping clothing not worn daring working hours and for the drying of wet clothing.

44. Facilities for sitting.—(*1*) In every factory suitable arrangements for sitting shall be provided and maintained for all workers obliged to work in a standing position, in order that they may take advantage of any opportunities for rest which may occur in the course of their work.

(*2*) If, in the opinion of the Chief Inspector, the workers in any factory engaged in a particular manufacturing process or working in a particular room are able to do their work efficiently in a sitting position, he may, by order in writing, require the occupier of the factory to provide before a specified date such seating arrangements as may be practicable for all workers so engaged or working.

(*3*) The State Government may, by notification in the Official Gazette, declare that the provisions of sub-section (*1*) shall not apply to any specified factory or class or description of factories or to any specified manufacturing process.

45. First-aid appliances.—(*1*) There shall in every factory be provided and maintained so as to be readily accessible during all working hours first-aid boxes or cupboards equipped with the prescribed contents, and the number of such boxes or cupboards to be provided and maintained shall not be less than one for every one hundred and fifty workers ordinarily employed [1][at any one time] in the factory.

[2][(*2*) Nothing except the prescribed contents shall be kept in a first-aid box or cupboard.

(*3*) Each first-aid box or cupboard shall be kept in the charge of a separate responsible person [3][who holds a certificate in first-aid treatment recognised by the State Government] and who shall always be readily available during the working hours of the factory.]

[4][(*4*)] In every factory wherein more than five hundred workers are [5][ordinarily employed] there shall be provided and maintained an ambulance room of the prescribed size, containing the prescribed equipment and in the charge of such medical and nursing staff as may be prescribed [6][and those facilities shall always be made readily available during the working hours of the factory].

46. Canteens.—(*1*) The State Government may make rules requiring that in any specified factory wherein more than two hundred and fifty workers are ordinarily employed, a canteen or canteens shall be provided and maintained by the occupier for the use of the workers.]

(*2*) Without prejudice to the generality of the foregoing power, such rules may provide for**—**

(*a*) the date by which such canteen shall be provided;

1. Ins. by Act 25 of 1954, s. 9 (w.e.f. 7-5-1954).
2. Subs. by s. 9, *ibid.*, for sub-section (*2*) (w.e.f. 7-5-1954).
3. Subs. by Act 94 of 1976, s. 21, for "who is trained in first-aid treatment" (w.e.f. 26-10-1976).
4. Sub-section (*3*) renumbered as sub-section (*4*) by Act 25 of 1954, s. 9 (w.e.f. 7-5-1954).
5. Subs. by Act 94 of 1976, s. 21, for "employed" (w.e.f. 26-10-1976).
6. Ins. by s. 21, *ibid.* (w.e.f. 26-10-1976).

(*b*) the standards in respect of construction, accommodation, furniture and other equipment of the canteen;

(*c*) the foodstuffs to be served therein and the charges which may be made therefor;

(*d*) the constitution of a managing committee for the canteen and representation of the workers in the management of the canteen;

[1][(*dd*) the items of expenditure in the running of the canteen which are not to be taken into account in fixing the cost of foodstuffs and which shall be borne by the employer;]

(*e*) the delegation to the Chief Inspector, subject to such conditions as may be prescribed, of the power to make rules under clause (*c*).

47. Shelters, rest rooms and lunch rooms.—(*1*) In every factory wherein more than one hundred and fifty workers are ordinarily employed, adequate and suitable shelters or rest rooms and a suitable lunch room, with provision for drinking water, where workers can eat meals brought by them, shall be provided and maintained for the use of the workers:

Provided that any canteen maintained in accordance with the provisions of section 46 shall be regarded as part of the requirements of this sub-section:

Provided further that where a lunch room exists no worker shall eat any food in the work room.

(*2*) The shelters or rest rooms or lunch rooms to be provided under sub-section (*1*) shall be sufficiently lighted aid ventilated and shall be maintained in a cool and clean condition.

(*3*) The State Government may—

(*a*) prescribe the standards in respect of construction, accommodation, furniture and other equipment of shelters, rest rooms and lunch rooms to be provided under this section;

(*b*) by notification in the Official Gazette, exempt any factory or class or description of factories from the requirements of this section.

48. Creches.—(*1*) In every factory wherein more than [2][thirty women workers] are ordinarily employed there shall be provided and maintained a suitable room or rooms for the use of children under the age of six years of such women.

(*2*) Such rooms shall provide adequate accommodation, shall be adequately lighted and ventilated, shall be maintained in a clean and sanitary condition and shall be under the charge of women trained in the care of children and infants.

(*3*) The State Government may make rules—

(*a*) prescribing the location and the standards in respect of construction, accommodation, furniture and other equipment of rooms to be provided under this section;

(*b*) requiring the provision in factories to which this section applies of additional facilities for the care of children belonging to women workers, including suitable provision of facilities for washing and changing their clothing;

(*c*) requiring the provision in any factory of free milk or refreshment or both for such children;

(*d*) requiring that facilities shall be given in any factory for the mothers of such children to feed them at the necessary intervals.

49. Welfare officers.—(*1*) In every factory wherein five hundred or more workers are ordinarily employed the occupier shall employ in the factory such number of welfare officers as may be prescribed.

(*2*) The State Government may prescribe the duties, qualifications and conditions of service of officers employed under sub-section (*1*).

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1. Ins. by Act 94 of 1976, s. 22 (w.e.f. 26-10-1976).
2. Subs. by s. 23, *ibid.*, for "fifty women workers" (w.e.f. 26-10-1976).

50. Power to make rules to supplement this Chapter.—The State Government may make rules—

(*a*) exempting, subject to compliance with such alternative arrangements for the welfare of workers as may be prescribed, any factory or class or description of factories from compliance with any of the provisions of this Chapter;

(*b*) requiring in any factory or class or description of factories that representatives of the workers employed in the factory shall be associated with the management of the welfare arrangements of the workers.

CHAPTER VI

WORKING HOURS OF ADULTS

51. Weekly hours.—No adult worker shall be required or allowed to work in a factory for more than forty-eight hours in any week.

52. Weekly holidays.—(*1*) No adult worker shall be required or allowed to work in a factory on the first day of the week (hereinafter referred to as the said day), unless—

(*a*) he has or will have a holiday for a whole day on one of the three days immediately before or after the said day, and

(*b*) the manager of the factory has, before the said day or the substituted day under clause (*a*), whichever is earlier,—

(*i*) delivered a notice at the office of the Inspector of his intention to require the worker to work on the said day and of the day which is to be substituted, and

(*ii*) displayed a notice to that effect in the factory:

Provided that no substitution shall be made which will result in any worker working for more than ten days consecutively without a holiday for a whole day.

(*2*) Notices given under sub-section (*1*) may be cancelled by a notice delivered at the office of the Inspector and a notice displayed in the factory not later than the day before the said day or the holiday to be cancelled, whichever is earlier.

(*3*) Where, in accordance with the provisions of sub-section (*1*), any worker works on the said day and has had a holiday on one of the three days immediately before it, that said day shall, for the purpose of calculating his weekly hours of work, be included in the preceding week.

53. Compensatory holidays.—(*1*) Where, as a result of the passing of an order or the making of a rule under the provisions of this Act exempting a factory or the workers therein from the provisions of section 52, a worker is deprived of any of the weekly holidays for which provision is made in sub-section (*1*) of that section, he shall be allowed, within the month in which the holidays were due to him or within the two months immediately following that month, compensatory holidays of equal number to the holidays so lost.

(*2*) The State Government may prescribe the manner in which the holidays for which provision is made in sub-section (*1*) shall be allowed.

54. Daily hours.—Subject to the provisions of section 51, not adult worker shall be required or allowed to work in a factory for more than nine hours in any day:

[1][Provided that, subject to the previous approval of the Chief Inspector, the daily maximum specified in this section may be exceeded in order to facilitate the change of shifts.]

55. Intervals for rest.—[2][(*1*)] [3][The periods of work] of adult workers in a factory each day shall be so fixed that no period shall exceed five hours and that no worker shall work for more than five hours before he has had an interval for rest of at least half an hour.

1. Added by Act 25 of 1954, s. 10 (w.e.f. 7-5-1954).
2. Section 55 renumbered as sub-section (*1*) of that section by s. 11, *ibid.* (w.e.f. 7-5-1954).
3. Subs. by Act 40 of 1949, s. 3 and the Second Schedule, for "The period" (w.e.f. 1-5-1949).

[1][(*2*) The State Government or, subject to the control of the State Government, the Chief Inspector, may, by written order and for the reasons specified therein, exempt any factory from the provisions of sub-section (*1*) so, however, that the total number of hours worked by a worker without an interval does not exceed six.]

56. Spread over.—The periods of work of an adult worker in a factory shall be so arranged that inclusive of his intervals for rest under section 55, they shall not spread over more than ten and a half hours in any day:

Provided that the Chief Inspector may, for reasons to be specified in writing increase the [2][spread over up to twelve hours].

57. Night shifts.—Where a worker in a factory works on a shift which extends beyond midnight,—

(*a*) for the purposes of sections 52 and 53, a holiday for a whole day shall mean in his case a period of twenty-four consecutive hours beginning when his shift ends;

(*b*) the following day for him shall be deemed to be the period of twenty-four hours beginning when such shift ends, and the hours he has worked after midnight shall be counted in the previous day.

58. Prohibition of overlapping shifts.—(*1*) Work shall not be carried on in any factory by means of system of shifts so arranged that more than one relay of workers is engaged in work of the same kind at the same time.

[3][(*2*) The State Government or subject to the control of the State Government, the Chief Inspector, may, by written order and for the reasons specified therein, exempt on such conditions as may be deemed expedient, any factory or class or description of factories or any department or section of a factory or any category or description of workers therein from the provisions of sub-section (*1*).]

59. Extra wages for overtime.—(*1*) Where a worker works in a factory for more than nine hours in any day or for more than forty-eight hours in any week, he shall, in respect of overtime work, be entitled to wages at the rate of twice his ordinary rate of wages.

[4][(*2*) For the purposes of sub-section (*1*), "ordinary rate of wages" means the basic wages plus such allowances, including the cash equivalent of the advantage accruing through the concessional sale to workers of foodgrains and other articles, as the worker is for the time being entitled to, but does not include a bonus and wages for overtime work.

(*3*) Where any workers in a factory are paid on a piece rate basis, the time rate shall be deemed to be equivalent to the daily average of their full-time earnings for the days on which they actually worked on the same or identical job during the month immediately preceding the calendar month during which the overtime work was done, and such time rates shall be deemed to be ordinary rates of wages of those workers:

Provided that in the case of a worker who has not worked in the immediately preceding calendar month on the same or identical job, the time rate shall be deemed to be equivalent to the daily average of the earning of the worker for the days on which he actually worked in the week in which the overtime work was done.

Explanation.—For the purposes of this sub-section in computing the earnings for the days on which the worker actually worked such allowances, including the cash equivalent of the advantage accruing through the concessional sale to workers of foodgrains and other articles, as the worker is for the time being entitled to, shall be included but any bonus or wages for overtime work payable in relation to the period with reference to which the earnings are being computed shall be excluded.]

1. Added by Act 25 of 1954, s. 11 (w.e.f. 7-5-1954).
2. Subs. by Act 94 of 1976, s. 24, for "spread over to twelve hours" (w.e.f. 26-10-1976).
3. Subs. by Act 25 of 1954, s. 12, for sub-section (*2*) (w.e.f. 7-5-1954).
4. Subs. by Act 94 of 1976, s. 25, for sub-sections (*2*) and (*3*) (w.e.f. 26-10-1976).

[1][(*4*) The cash equivalent of the advantage accruing through the concessional sale to a worker of foodgrains and other articles shall be computed as often as may be prescribed on the basis of the maximum quantity of foodgrains and other articles admissible to a standard family.

Explanation 1.—"Standard family" means a family consisting of the worker, his or her spouse and two children below the age of fourteen years requiring in all three adult consumption units.

Explanation 2.—"Adult consumption unit" means the consumption unit of a male above the age of fourteen years; and the consumption unit of a female above the age of fourteen years and that of a child below the age of fourteen years shall be calculated at the rates of 8 and 6 respectively of one adult consumption unit.

(*5*) The State Government may make rules prescribing—

(*a*) the manner in which the cash equivalent of the advantage accruing through the concessional sale to a worker of foodgrains and other articles shall be computed; and

(*b*) the registers that shall be maintained in a factory for the purpose of securing compliance with the provisions of this section.]

60. Restriction on double employment.—No adult worker shall be required or allowed to work in any factory on any day on which he has already been working in any other factory, save in such circumstances as may be prescribed.

61. Notice of periods of work for adults.—(*1*) There shall be displayed and correctly maintained in every factory in accordance with the provisions of sub-section (*2*) of section 108, a notice of periods of work for adults, showing clearly for every day the periods during which adult workers may be required to work.

(*2*) The periods shown in the notice required by sub-section (*1*) shall be fixed beforehand in accordance with the following provisions of this section, and shall be such that workers working for those periods would not be working in contravention of any of the provisions of sections 51, 52, 54, [2][55, 56 and 58].

(*3*) Where all the adult workers in a factory are required to work during the same periods, the manager of the factory shall fix those periods for such workers generally.

(*4*) Where all the adult workers in a factory are not required to work during the same periods, the manager of the factory shall classify them into groups according to the nature of their work indicating the number of workers in each group.

(*5*) For each group which is not required to work on a system of shifts, the manager of the factory shall fix the periods during which the group may be required to work.

(*6*) Where any group is required to work on a system of shifts and the relays are not to be subject to predetermined periodical changes of shifts, the manager of the factory shall fix the periods during which each relay of the group may be required to work.

(*7*) Where any group is to work on a system of shifts and the relays are to be subject to predetermined periodical changes of shifts, the manager of the factory shall draw up a scheme of shifts where under the periods during which any relay of the group may be required to work and the relay which will be working at any time of the day shall be known for any day.

(*8*) The State Government may prescribe forms of the notice required by sub-section (*1*) and the manner in which it shall be maintained.

(*9*) In the case of a factory beginning work after the commencement of this Act, a copy of the notice referred to in sub-section (*1*) shall be sent in duplicate to the Inspector before the day on which work is begun in the factory.

1. Subs. by Act 25 of 1954, s. 13, for sub-section (*4*) (w.e.f. 7-5-1954).
2. Subs. by s. 14, *ibid.*, for "55 and 56" (w.e.f. 7-5-1954).

(*10*) Any proposed change in the system of work in any factory which will necessitate a change in the notice referred to in sub-section (*1*) shall be notified to the Inspector in duplicate before the change is made, and except with the previous sanction of the Inspector, no such change shall be made until one week has elapsed since the last change.

62. Register of adult workers.—(*1*) The manager of every factory shall maintain a register of adult workers, to be available to the Inspector at all times during working hours, or when any work is being carried on in the factory, showing—

(*a*) the name of each adult worker in the factory;

(*b*) the nature of his work;

(*c*) the group, if any, in which he is included;

(*d*) where his group works on shifts, the relay to which he is allotted;

(*e*) such other particulars as may be prescribed:

Provided that, if the Inspector is of opinion that any muster roll or register maintained as part of the routine of a factory gives in respect of any or all the workers in the factory the particulars required under this section, he may, by order in writing, direct that such muster roll or register shall to the corresponding extent be maintained in place of, and be treated as the register of adult workers in that factory.

[1][(*1A*) No adult worker shall be required or allowed to work in any factory unless his name and other particulars have been entered in the register of adult workers.]

(*2*) The State Government may prescribe the form of the register of adult workers, the manner in which it shall be maintained and the period for which it shall be preserved.

63. Hours of work to correspond with notice under section 61 and register under section 62.—No adult worker shall be required or allowed to work in any factory otherwise than in accordance with the notice of periods of work for adults displayed in the factory and the entries made beforehand against his name in the register of adult workers of the factory.

64. Power to make exempting rules.—(*1*) The State Government may make rules defining the persons who hold positions of supervision or management or are employed in a confidential position in a factory [2][or empowering the Chief Inspector to declare any person, other than a person defined by such rules, as a person holding position of supervision or management or employed in a confidential position in a factory if, in the opinion of the Chief Inspector, such person holds such position or is so employed], and the provisions of this Chapter, other than the provisions of clause (*b*) of sub-section (*1*) of section 66 and of the proviso to that sub-section, shall not apply to any person so defined [2][or declared]:

[2][Provided that any person so defined or declared shall, where the ordinary rate of wages of such person [3][does not exceed the wage limit specified in sub-section (*6*) of section 1 of the Payment of Wages Act, 1936 (4 of 1936), as amended from time to time], be entitled to extra wages in respect of overtime work under section 59.]

(*2*) The State Government may make rules in respect of adult workers in factories providing for the exemption, to such extent and subject to such conditions as may be prescribed—

(*a*) of workers engaged on urgent repairs, from the provisions of sections 51, 52, 54, 55 and 56;

(*b*) of workers engaged in work in the nature of preparatory or complementary work which must necessarily be carried on outside the limits laid down for the general working of the factory, from the provisions of sections 51, 54, 55 and 56;

(*c*) of workers engaged in work which is necessarily so intermittent that the intervals during which they do not work while on duty ordinarily amount to more than the intervals for rest required by or under section 55, from the provisions of sections 51, 54, 55 and 56;

1. Ins. by Act 94 of 1976, s. 26 (w.e.f. 26-10-1976).
2. Ins. by s. 27, *ibid.* (w.e.f. 26-10-1976).
3. Subs. by Act 20 of 1987, s. 21, for "does not exceed rupees seven hundred and fifty per month" (w.e.f. 1-12-1987).

(*d*) of workers engaged in any work which for technical reasons must be carried on continuously [1]*** from the provisions of sections 51, 52, 54, 55 and 56;

(*e*) of workers engaged in making or supplying articles of prime necessity which must be made or supplied every day, from the provisions of [2][section 51 and section 52];

(*f*) of workers engaged in a manufacturing process which cannot be carried on except during fixed seasons, from the provisions of [2][section 51, section 52 and section 54];

(*g*) of workers engaged in a manufacturing process which cannot be carried on except at times dependent on the irregular action of natural forces, from the provisions of sections 52 and 55;

(*h*) of workers engaged in engine-rooms or boiler-houses or in attending to power-plant or transmission machinery, from the provisions of [2][section 51 and section 52];

[3][(*i*) of workers engaged in the printing of newspapers, who are held up on account of the breakdown of machinery, from the provisions of sections 51, 54 and 56.

Explanation.—In this clause the expression "newspapers" has the meaning assigned to it in the Press and Registration of Books Act, 1867 (25 of 1867);

(*j*) of workers engaged in the loading or unloading of railway wagons, [4][or lorries or truck] from the provisions of sections 51, 52, 54, 55 and 56];

[4][(*k*) of workers engaged in any work, which is notified by the State Government in the Official Gazette as a work of national importance, from the provisions of section 51, section 52, section 54, section 55 and section 56.]

(*3*) Rules made under sub-section (*2*) providing for any exemption may also provide for any consequential exemption from the provisions of section 61 which the State Government may deem to be expedient, subject to such conditions as it may prescribe.

[5][(*4*) In making rules under this section, the State Government shall not exceed, except in respect of exemption under clause (*a*) of sub-section (*2*), the following limits of work inclusive of overtime:—

(*i*) the total number of hours of work in any day shall not exceed ten;

(*ii*) the spread over, inclusive of intervals for rest, shall not exceed twelve hours in any one day:

Provided that the State Government may, in respect of any or all of the categories of workers referred to in clause (*d*) of sub-section (*2*), make rules prescribing the circumstances in which, and the conditions subject to which, the restrictions imposed by clause (*i*) and clause (*ii*) shall not apply in order to enable a shift worker to work the whole or part of a subsequent shift in the absence of a worker who has failed to report for duty;

[4][(*iii*) the total number of hours of work in a week, including overtime, shall not exceed sixty;]

[6][(*iv*)] the total number of hours of overtime shall not exceed fifty for any one quarter.

Explanation.—"Quarter" means a period of three consecutive months beginning on the 1st of January, the 1st of April, the 1st of July or the 1st of October.]

(*5*) Rules made under this section shall remain in force for not more than [7][five years].

65. Power to make exempting orders.—(*1*) Where the State Government is satisfied that, owing to the nature of the work carried on or to other circumstances, it is unreasonable to require that the periods of work of any adult workers in any factory or class or description of factories should be fixed beforehand, it

1. The words "throughout the day" omitted by Act 25 of 1954, s. 15 (w.e.f. 7-5-1954).
2. Subs. by Act 94 of 1976, s. 27, for "section 52" (w.e.f. 26-10-1976).
3. Added by Act 25 of 1954, s. 15 (w.e.f. 7-5-1954).
4. Ins. by Act 94 of 1976, s. 27 (w.e.f. 26-10-1976).
5. Subs. by Act 25 of 1954, s. 15, for sub-section (*4*) (w.e.f. 7-5-1954).
6. Clause (*iii*) renumbered as clause (*iv*) by Act 94 of 1976, s. 27 (w.e.f. 26-10-1976).
7. Subs. by s. 27, *ibid.*, for "three years" (w.e.f. 26-10-1976).

may, by written order, relax or modify the provisions of section 61 in respect of such workers therein, to such extent and in such manner as it may think fit, and subject to such conditions as it may deem expedient to ensure control over periods of work.

(*2*) The State Government or, subject to the control of the Stale Government, the Chief Inspector may by written order exempt, on such conditions as it or he may deem expedient, any or all of the adult workers in any factory or group or class or description of factories from any or all of the provisions of sections 51, 52, 54 and 56 on the ground that the exemption is required to enable the factory or factories to deal with an exceptional press of work.

[1][(*3*) Any exemption granted under sub-section (*2*) shall be subject to the following conditions, namely:—

(*i*) the total number of hours of work in any day shall not exceed twelve;

(*ii*) the spread over, inclusive of intervals for rest, shall not exceed thirteen hours in any one day;

(*iii*) the total number of hours of work in any week, including overtime, shall not exceed sixty;

(*iv*) no worker shall be allowed to work overtime, for more than seven days at a stretch and the total number of hours of overtime work in any quarter shall not exceed seventy-five.

Explanation.—In this sub-section "quarter" has the same meaning as in sub-section (*4*) of section 64.]

[2]* * * * *

66. Further restrictions on employment of women.—(*1*) The provisions of this Chapter shall, in their application to women in factories, be supplemented by the following further restrictions, namely:—

(*a*) no exemption from the provisions of section 54 may be granted in respect of any woman;

(*b*) no woman shall be [3][required or allowed to work in any factory] except between the hours of 6 A.M. and 7 P.M.:

Provided that the State Government may, by notification in the Official Gazette, in respect of [4][any factory or group or class or description of factories,] very the limits laid down in clause (*b*), but so that no such variation shall authorise the employment of any woman between the hours of 10 P.M. and 5 A.M.:

[5][(*c*) there shall be no change of shifts except after a weekly holiday or any other holiday.]

(*2*) The State Government may make rules providing for the exemption from the restrictions set out in sub-section (*1*), to such extent and subject to such conditions as it may prescribe, of women working in fish-curing or fish-canning factories, where the employment of women beyond the hours specified in the said restrictions is necessary to prevent damage to, or deterioration in, any raw material.

(*3*) The rules made under sub-section (*2*) shall remain in force for not more than three years at a time.

CHAPTER VII

EMPLOYMENT OF YOUNG PERSONS

67. Prohibition of employment of young children.—No child who has not completed his fourteenth year shall be required or allowed to work in any factory.

68. Non-adult workers to carry tokens.—A child who has completed his fourteenth year or an adolescent shall not be required or allowed to work in any factory unless—

(*a*) a certificate of fitness granted with reference to him under section 69 is in the custody of the manager of the factory, and

1. Subs. by Act 94 of 1976, s. 28, for sub-section (*3*) (w.e.f. 26-10-1976).
2. Omitted by s. 28, *ibid.* (w.e.f. 26-10-1976).
3. Subs. by s. 29, *ibid.*, for "employed in any factory" (w.e.f. 26-10-1976).
4. Subs. by s. 29, *ibid.*, for "any class or description of factories" (w.e.f. 26-10-1976).
5. Ins. by Act 25 of 1954, s. 17 (w.e.f. 7-5-1954).

(*b*) such child or adolescent carries while he is at work a token giving a reference to such certificate.

69. Certificates of fitness.—(*1*) A certifying surgeon shall, on the application of any young person or his parent or guardian accompanied by a document signed by the manager of a factory that such person will be employed therein if certified to be fit for work in a factory, or on the application of the manager of the factory in which any young person wishes to work, examine such person and ascertain his fitness for work in a factory.

(*2*) The certifying surgeon, after examination, may grant to such young person, in the prescribed form, or may renew—

(*a*) a certificate of fitness to work in a factory as a child, if he is satisfied that the young person has completed his fourteenth year, that he has attained the prescribed physical standards and that he is fit for such work;

(*b*) a certificate of fitness to work in a factory as an adult, if he is satisfied that the young person has completed his fifteenth year, and is fit for a full day's work in a factory:

Provided that unless the certifying surgeon has personal knowledge of the place where the young person proposes to work and of the manufacturing process in which he will be employed, he shall not grant or renew a certificate under this sub-section until he has examined such place.

(*3*) A certificate of fitness granted or renewed under sub-section (*2*)—

(*a*) shall be valid only for a period of twelve months from the date thereof:

(*b*) may be made subject to conditions in regard to the nature of the work in which the young person may be employed, or requiring re-examination of the young person before the expiry of the period of twelve months.

(*4*) A certifying surgeon shall revoke any certificate granted or renewed under sub-section (*2*) if in his opinion the holder of it is no longer fit to work in the capacity stated therein in a factory.

(*5*) Where a certifying surgeon refuses to grant or renew a certificate or a certificate of the kind requested or revokes a certificate, he shall, if so requested by any person who could have applied for the certificate or the renewal thereof, state his reasons in writing for so doing.

(*6*) Where a certificate under this section with reference to any young person is granted or renewed subject to such conditions as are referred to in clause (*b*) of sub-section (*3*), the young person shall not be required or allowed to work in any factory except in accordance with those conditions.

(*7*) Any fee payable for a certificate under this section shall be paid by the occupier and shall not be recoverable from the young person, his parents or guardian.

70. Effect of certificate of fitness granted to adolescent.—(*1*) An adolescent who has been granted a certificate of fitness to work in a factory as an adult under clause (*b*) of sub-section (*2*) of section 69, and who while at work in a factory carries a token giving reference to the certificate, shall be deemed to be an adult for all the purposes of Chapter VI and VIII.

[1]* * * * *

[2][(*1A*) No female adolescent or a male adolescent who has not attained the age of seventeen years but who has been granted a certificate of fitness to work in a factory as an adult, shall be required or allowed to work in any factory except between 6 A.M. and 7 P.M.:

Provided that the State Government may, by notification in the Official Gazelle, in respect of any factory or group or class or description of factories,—

(*i*) vary the limits laid down in this sub-section so, however, that no such section shall authorise the employment of any female adolescent between 10 P.M. and 5 A.M.

1. The proviso and the *Explanation* omitted by Act 20 of 1987, s. 22 (w.e.f. 1-12-1987).
2. Ins. by s. 22, *ibid*. (w.e.f. 1-12-1987).

(*ii*) grant exemption from the provisions of this sub-section in case of serious emergency where national interest is involved.]

(*2*) An adolescent who has not been granted a certificate of fitness to work in a factory as an adult under the aforesaid clause (*b*) shall, notwithstanding his age, be deemed to be a child for all the purposes of this Act.

71. Working hours for children.—(*1*) No child shall be employed or permitted to work, in any factory—

(*a*) for more than four and a half hours in any day;

[1][(*b*) during the night.

Explanation.—For the purpose of this sub-section "night" shall mean a period of at least twelve consecutive hours which shall include the interval between 10 P.M. and 6 A.M.]

(*2*) The period of work of all children employed in a factory shall be limited to two shifts which shall not overlap or spread over more than five hours each; and each child shall be employed in only one of the relays which shall not, except with the previous permission in writing of the Chief Inspector, be changed more frequently than once in a period of thirty days.

(*3*) The provisions of section 52 shall apply also to child workers and no exemption from the provisions of that section may be granted in respect of any child.

(*4*) No child shall be required or allowed to work in any factory on any day on which he has already been working in another factory.

[2][(*5*) No female child shall be required or allowed to work in any factory except between 8 A.M. and 7 P.M.]

72. Notice of periods of work for children.—(*1*) There shall be displayed and correctly maintained in every factory in which children are employed, in accordance with the provisions of sub-section (*2*) of section 108 a notice of periods of work for children, showing clearly for every day the periods during which children may be required or allowed to work.

(*2*) The periods shown in the notice required by sub-section (*1*) shall be fixed beforehand in accordance with the method laid down for adult workers in section 61, and shall be such that children working for those periods would not be working in contravention of any of the provisions of section 71.

(*3*) The provisions of sub-sections (*8*), (*9*) and (*10*) of section 61 shall apply also to the notice required by sub-section (*1*) of this section.

73. Register of child workers.—(*1*) The manager of every factory in which children are employed shall maintain a register of child workers, to be available to the Inspector at all times during working hours or when any work is being carried on in a factory, showing—

(*a*) the name of each child worker in the factory,

(*b*) the nature of his work,

(*c*) the group, if any, in which he is included,

(*d*) where his group works on shifts, the relay to which he is allotted, and

(*e*) the number of his certificate of fitness granted under section 69.

[3][(*1A*) No child worker shall be required or allowed to work in any factory unless his name and other particulars have been entered in the register of child workers.]

(*2*) The State Government may prescribe the form of the register of child workers, the manner in which it shall be maintained and the period for which it shall be preserved.

1. Subs. by Act 25 of 1954, s. 19, for clause (*b*) (w.e.f. 7-5-1954).
2. Ins. by Act 20 of 1987, s. 23 (w.e.f. 1-12-1987).
3. Ins. by Act 94 of 1976, s. 30 (w.e.f. 26-10-1976).

74. Hours of work to correspond with notice under section 72 and register under section 73.—No child worker shall be employed in any factory otherwise than in accordance with the notice of periods of work for children displayed in the factory and the entries made beforehand against his name in the register of child workers of the factory.

75. Power to require medical examination.—Where an Inspector is of opinion**—**

(*a*) that any person working in a factory without a certificate of fitness is a young person, or

(*b*) that a young person working in a factory with a certificate of fitness is no longer fit to work in the capacity stated therein,

he may serve on the manager of the factory a notice requiring that such person or young person, as the case may be, shall be examined by a certifying surgeon, and such person or young person shall not, if the Inspector so directs, be employed, or permitted to work, in any factory until he has been so examined and has been granted a certificate of fitness or a fresh certificate of fitness, as the case may be, under section 69, or has been certified by the certifying surgeon examining him not to be a young person.

76. Power to make rules.—The State Government may make rules**—**

(*a*) prescribing the forms of certificates of fitness to be granted under section 69, providing for the grant of duplicates in the event of loss of the original certificates, and fixing the fees which may be charged for such certificates and renewals thereof and such duplicates;

(*b*) prescribing the physical standards to be attained by children and adolescents working in factories;

(*c*) regulating the procedure of certifying surgeons under this Chapter;

(*d*) specifying other duties which certifying surgeons may be required to perform in connection with the employment of young persons in factories, and fixing the fees which may be charged for such duties and the persons by whom they shall be payable.

77. Certain other provisions of law not barred.—The provisions of this Chapter shall be in addition to, and not in derogation of, the provisions of the Employment of Children Act, 1938 (26 of 1938).

[1][CHAPTER VIII

ANNUAL LEAVE WITH WAGES

78. Application of Chapter.—(*1*) The provisions of this Chapter shall not operate to the prejudice of any right to which a worker may be entitled under any other law or under the terms of any award, [2][agreement (including settlement)] or contract of service:

[3][Provided that if such award, agreement (including settlement) or contract of service provides for a longer annual leave with wages than provided in this Chapter, the quantum of leave, which the worker shall be entitled to, shall be in accordance with such award, agreement or contract of service, but in relation to matters not provided for in such award, agreement or contract of service or matters which are provided for less favourably therein, the provisions of sections 79 to 82, so far as may be, shall apply.]

(*2*) The provisions of this Chapter shall not apply to workers [4][in any factory] of any railway administered by the Government, who are governed by leave rules approved by the Central Government.

79. Annual leave with wages.—(*1*) Every worker who has worked for a period of 240 days or more in a factory during a calendar year shall be allowed during the subsequent calendar year, leave with wages for a number of days calculated at the rate of**—**

(*i*) if an adult, one day for every twenty days of work performed by him during the previous calendar year;

1. Subs. by Act 25 of 1954, s. 20 for Chapter VIII (w.e.f. 7-5-1954).
2. Subs. by Act 94 of 1976, s. 31, for "agreement" (w.e.f. 26-10-1976).
3. Subs. by s. 31, *ibid.*, for the proviso (w.e.f. 26-10-1976).
4. Subs. by s. 31, *ibid.*, for "in any workshop" (w.e.f. 26-10-1976).

(*ii*) if a child, one day for every fifteen days of work performed by him during the previous calendar year.

Explanation 1.—For the purpose of this sub-section—

(*a*) any days of lay off, by agreement or contract or as permissible under the standing orders;

(*b*) in the case of a female worker, maternity leave for any number of days not exceeding twelve weeks; and

(*c*) the leave earned in the year prior to that in which the leave is enjoyed,

shall be deemed to be days on which the worker has worked in a factory for the purpose of computation of the period of 240 days or more, but he shall not earn leave for these days.

Explanation 2.—The leave admissible under this sub-section shall be exclusive of all holidays whether occurring during or at either end of the period of leave.

(*2*) A worker whose service commences otherwise than on the first day of January shall be entitled to leave with wages at the rate laid down in clause (*i*) or, as the case may be, clause (*ii*) of sub-section (*1*) if he has worked for two-thirds of the total number of days in the remainder of the calendar year.

[1][(*3*) If a worker is discharged or dismissed from service or quits his employment or is superannuated or dies while in service, during the course of the calendar year, he or his heir or nominee, as the case may be, shall be entitled to wages in lieu of the quantum of leave to which he was entitled immediately before his discharge, dismissal, quitting of employment, superannuation or death calculated at the rates specified in sub-section (*1*), even if he had not worked for the entire period specified in sub-section (*1*) or sub-section (*2*) making him eligible to avail of such leave, and such payment shall be made—

(*i*) where the worker is discharged or dismissed or quits employment, before the expiry of the second working day from the date of such discharge, dismissal or quitting; and

(*ii*) where the worker is superannuated or dies while in service, before the expiry of two months from the date of such superannuation or death.]

(*4*) In calculating leave under this section, fraction of leave of half a day or more shall be treated as one full day's leave, and fraction of less than half a day shall be omitted.

(*5*) If a worker does not in any one calendar year take the whole of the leave allowed to him under sub-section (*1*) or sub-section (*2*), as the case may be, any leave not taken by him shall be added to the leave to be allowed to him in the succeeding calendar year:

Provided that the total number of days of leave that may be carried forward to a succeeding year shall not exceed thirty in the case of an adult or forty in the case of a child:

Provided further that a worker, who has applied for leave with wages but has not been given such leave in accordance with any scheme laid down in sub-sections (*8*) and (*9*) [2][or in contravention of sub-section (*10*)] shall be entitled to carry forward the [3][leave refused] without any limit.

(*6*) A worker may at any time apply in writing to the manager of a factory not less than fifteen days before the date on which he wishes his leave to begin, to take all the leave or any portion thereof allowable to him during the calendar year:

Provided that the application shall be made not less than thirty days before the date on which the worker wishes his leave to begin, if he is employed in a public utility service as defined in clause (*ii*) of section 2 of the Industrial Disputes Act. 1947 (14 of 1947):

Provided further that the number of times in which leave may be taken during any year shall not exceed three.

1. Subs. by Act 94 of 1976, s. 32, for sub-section (*3*) (w.e.f. 26-10-1976).
2. Ins. by s. 32, *ibid.* (w.e.f. 26-10-1976).
3. Subs. by s. 32, *ibid.*, for "unavailed leave" (w.e.f. 26-10-1976).

(*7*) If a worker wants to avail himself of the leave with wages due to him to cover a period of illness, he shall be granted such leave even if the application for leave is not made within the time specified in sub-section (*6*); and in such a case wages as admissible under section 81 shall be paid not later than fifteen days, or in the case of a public utility service not later than thirty days from the date of the application for leave.

(*8*) For the purpose of ensuring the continuity of work, the occupier or manager of the factory, in agreement with the Works Committee of the factory constituted under section 3 of the Industrial Disputes Act, 1947 (14 of 1947), or a similar Committee constituted under any other Act or if there is no such Works Committee or a similar Committee in the factory, in agreement with the representatives of the workers therein chosen in the prescribed manner, may lodge with the Chief Inspector a scheme in writing whereby the grant of leave allowable under this section may be regulated.

(*9*) A scheme lodged under sub-section (*8*) shall be displayed at some conspicuous and convenient places in the factory and shall be in force for a period of twelve months from the date on which it comes into force, and may thereafter be renewed with or without modification for a further period of twelve months at a time, by the manager in agreement with the Works Committee or a similar Committee, or as the case may be, in agreement with the representatives of the workers as specified in sub-section (*8*), and a notice of renewal shall be sent to the Chief Inspector before it is renewed.

(*10*) An application for leave which does not contravene the provisions of sub-section (*6*) shall not be refused, unless refusal is in accordance with the scheme for the time being in operation under sub-sections (*8*) and (*9*).

(*11*) If the employment of a worker who is entitled to leave under sub-section (*1*) or sub-section (*2*), as the case may be, is terminated by the occupier before he has taken the entire leave to which he is entitled, or if having applied for and having not been granted such leave, the worker quits his employment, before he has taken the leave, the occupier of the factory shall pay him the amount payable under section 80 in respect of the leave not taken, and such payment shall be made, where the employment of the worker is terminated by the occupier, before the expiry of the second working day after such termination, and where a worker who quits his employment, on or before the next pay day.

(*12*) The unavailed leave of a worker shall not be taken into consideration in computing the period of any notice required to be given before discharge or dismissal.

80. Wages during leave period.—(*1*) For the leave allowed to him under [1][section 78 or section 79, as the case may be,] a worker [2][shall be entitled to wages] at a rate equal to the daily average of his total full time earnings for the days on which [3][he actually worked] during the month immediately preceding his leave, exclusive of any overtime and bonus but inclusive of dearness allowance and the cash equivalent of the advantage accruing through the concessional sale to the worker of food grains and other articles:

[4][Provided that in the case of a worker who has not worked on any day during the calendar month immediately preceding his leave, he shall be paid at a rate equal to the daily average of his total full time earnings for the days on which he actually worked during the last calendar month preceding his leave, in which he actually worked, exclusive of any overtime and bonus but inclusive of dearness allowance and the cash equivalent of the advantage accruing through the concessional sale to the workers of food grains and other articles.]

(*2*) The cash equivalent of the advantage accruing through the concessional sale to the worker of food grains and other articles shall be computed as often as may be prescribed, on the basis of the maximum quantity of food grains and other articles admissible to a standard family.

Explanation 1.—"Standard family" means a family consisting of a worker, his or her spouse and two children below the age of fourteen years requiring in all three adult consumption units.

1. Subs. by Act 94 of 1976, s. 33, for "section 79" (w.e.f. 26-10-1976).
2. Subs. by Act 20 of 1987, s. 24, for "shall be paid" (w.e.f. 1-12-1987).
3. Subs. by Act 94 of 1976, s. 33, for "he worked" (w.e.f. 26-10-1976).
4. Ins. by Act 20 of 1987, s. 24 (w.e.f. 1-12-1987).

Explanation 2.—"Adult consumption unit" means the consumption unit of a male above the age of fourteen years; and the consumption unit of a female above the age of fourteen years and that of a child below the age of fourteen years shall be calculated at the rates of 8 and 6 respectively of one adult consumption unit.

(*3*) The State Government may make rules prescribing—

(*a*) the manner in which the cash equivalent of the advantage accruing through the concessional sale to a worker of food grains and other articles shall be computed; and

(*b*) the registers that shall be maintained in a factory for the purpose of securing compliance with the provisions of this section.

81. Payment in advance in certain cases.—A worker who has been allowed leave for not less than four days, in the case of an adult, and five days, in the case of a child, shall, before his leave begins be paid the wages due for the period of the leave allowed.

82. Mode of recovery of unpaid wages.—Any sum required to be paid by an employer, under his Chapter but not paid by him shall be recoverable as delayed wages under the provisions of the Payment of Wages Act, 1936 (4 of 1936).

83. Power to make rules.—The State Government may make rules directing managers of factories to keep registers containing such particulars as may be prescribed and requiring the registers to be made available for examination by Inspectors.

84. Power to exempt factories.—Where the State Government is satisfied that the leave rules applicable to workers in a factory provide benefits which in its opinion are not less favourable than those for which this Chapter makes provision it may, by written order; exempt the factory from all or any of the provisions of this Chapter subject to such conditions as may be specified in the order.]

[1][*Explanation*.—For the purposes of this section, in deciding whether the benefits which are provided for by any leave rules are less favourable than those for which this Chapter makes provision, or not, the totality of the benefits shall be taken into account.]

CHAPTER IX

SPECIAL PROVISIONS

85. Power to apply the act to certain premises.—(*1*) The State Government may, by notification in the Official Gazette, declare that all or any of the provisions of this Act shall apply to any place wherein a manufacturing process is carried on with or without the aid of power or is so ordinarily carried on, notwithstanding that—

(*i*) the number of persons employed therein is less than ten, if working with the aid of power and less than twenty if working without the aid of power, or

(*ii*) the persons working therein are not employed by the owner thereof but are working with the permission of, or under agreement with, such owner:

Provided that the manufacturing process is not being carried on by the owner only with the aid of his family.

(*2*) After a place is so declared, it shall be deemed to be a factory for the purposes of this Act, and the owner shall be deemed to be the occupier, and any person working therein, a worker.

Explanation.—For the purposes of this section, "owner" shall include a lessee or mortgage with possession of the premises.

86. Power to exempt public institutions.—The State Government may exempt, subject to such conditions as it may consider necessary, any workshop or workplace where a manufacturing process is carried on and which is attached to a public institution maintained for the purposes of education, [2][training, research] or reformation, from all or any of the provisions of this Act:

1. Ins. by Act 94 of 1976, s. 34 (w.e.f. 26-10-1976).
2. Subs. by s. 35, *ibid.*, for "training" (w.e.f. 26-10-1976).

Provided that no exemption shall be granted from the provisions relating to hours of work and holidays, unless the persons having the control of the institution submit, for the approval of the State Government, a scheme for the regulation of the hours of employment, intervals for meals, and holidays of the persons employed in or attending the institution or who are inmates of the institution, and the State Government is satisfied that the provisions of the scheme are not less favourable than the corresponding provisions of this Act.

87. Dangerous operations.—Where the State Government is of opinion that any [1][manufacturing process or operation] carried on in a factory exposes any persons employed in it to a serious risk of bodily injury, poisoning or disease, it may make rules applicable to any factory or class or description of factories in which the [1][manufacturing process or operation] is carried on—

(*a*) specifying the [1][manufacturing process or operation] and declaring it to be dangerous;

(*b*) prohibiting or restricting the employment of women, adolescents or children in the [1][manufacturing process or operation];

(*c*) providing for the periodical medical examination of persons employed, or seeking to be employed, in the [1][manufacturing process or operation], and prohibiting the employment or persons not certified as fit for such employment [2][and requiring the payment by the occupier of the factory of fees for such medical examination];

(*d*) providing for the protection of all persons employed in the [1][manufacturing process or operation] or in the vicinity of the places where it is carried on;

(*e*) prohibiting, restricting or controlling the use of any specified materials or processes in connection with the [1][manufacturing process or operation];

[2][(*f*) requiring the provision of additional welfare amenities and sanitary facilities and the supply of protective equipment and clothing, and laying down the standards thereof, having regard to the dangerous nature of the manufacturing process or operation.

[3]* * * * *

[4][**87A. Power to prohibit employment on account of serious hazard.—**(*1*) Where it appears to the Inspector that conditions in a factory or part thereof are such that they may cause serious hazard by way of injury or death to the persons employed therein or to the general public in the vicinity, he may, by order in writing to the occupier of the factory, state the particulars in respect of which he considers the factory or part thereof to be the cause of such serious hazard and prohibit such occupier from employing any person in the factory or any part thereof other than the minimum number of persons necessary to attend to the minimum tasks till the hazard is removed.

(*2*) Any order issued by the Inspector under sub-section (*1*) shall have effect for a period of three days until extended by the Chief Inspector by a subsequent order.

(*3*) Any person aggrieved by an order of the Inspector under sub-section (*1*), and the Chief Inspector under sub-section (*2*), shall have the right to appeal to the High Court.

(*4*) Any person whose employment has been affected by an order issued under sub-section (*1*), shall be entitled to wages and other benefits and it shall be the duty of the occupier to provide alternative employment to him wherever possible and in the manner prescribed.

(*5*) The provisions of sub-section (*4*) shall be without prejudice to the rights of the parties under the Industrial Disputes Act, 1947 (14 of 1947).]

1. Subs. by Act 94 of 1976, s. 36, for "operation" (w.e.f. 26-10-1976).
2. Ins. by s. 36, *ibid.* (w.e.f. 26-10-1976).
3. Omitted by Act 20 of 1987, s. 25 (w.e.f. 1-12-1987).
4. Ins. by s. 26, *ibid.* (w.e.f. 1-12-1987).

88. Notice of certain accidents.—[1][(*1*)] Where in any factory an accident occurs which causes death, or which causes any bodily injury by reason of which the person injured is prevented from working for a period of forty-eight hours or more immediately following the accident, or which is of such nature as may be prescribed in this behalf, the manager of the factory shall send notice thereof to such authorities, and in such form and within such time, as may be prescribed.

[2][(*2*) Where a notice given under sub-section (*1*) relates to an accident causing death, the authority to whom the notice is sent shall make an inquiry into the occurrence within one month of the receipt of the notice or, if such authority is not the Inspector, cause the Inspector to make an inquiry within the said period.

(*3*) The State Government may make rules for regulating the procedure at inquiries under this section.]

[3][**88A. Notice of certain dangerous occurrences.—**Where in a factory any dangerous occurrence of such nature as may be prescribed occurs, whether causing any bodily injury or disability or not, the manager of the factory shall send notice thereof to such authorities, and in such form and within such time, as may be prescribed.]

89. Notice of certain diseases.—(*1*) Where any worker in a factory contracts any disease specified in [4][the Third Schedule], the manager of the factory shall send notice thereof to such authorities, and in such form and within such time, as may be prescribed.

(*2*) If any medical practitioner attends on a person who is or has been employed in a factory, and who is, or is believed by the medical practitioner to be, suffering from any disease specified in [4][the Third Schedule], the medical practitioner shall without delay send a report in writing to the office of the Chief Inspector stating—

(*a*) the name and full postal address of the patient,

(*b*) the disease from which he believes the patient to be suffering, and

(*c*) the name and address of the factory in which the patient is, or was last, employed.

(*3*) Where the report under sub-section (*2*) is confirmed to the satisfaction of the Chief Inspector, by the certificate of a certifying surgeon or otherwise, that the person is suffering from a disease specified in [4][the Third Schedule], he shall pay to the medical practitioner such fee as may be prescribed, and the fee so paid shall be recoverable as an arrear of land-revenue from the occupier of the factory in which the person contracted the disease.

(*4*) If any medical practitioner fails to comply with the provisions of sub-section (*2*), he shall be punishable with fine which may extend to [5][one thousand rupees].

[6][(*5*) The Central Government may, by notification in the Official Gazette, add to or alter the Third Schedule and any such addition or alteration shall have effect as if it had been made by this Act.]

90. Power to direct enquiry into cases of accident or disease.—(*1*) The State Government may, if it considers it expedient so to do, appoint a competent person to inquire into the causes of any accident occurring in a factory or into any case where a disease specified in [7][the Third Schedule] has been, or is suspected to have been contracted in a factory, and may also appoint one or more persons possessing legal or special knowledge to act as assessors in such inquiry.

1. Section 88 re-numbered as sub-section (*1*) thereof by Act 94 of 1976, s. 37 (w.e.f. 26-10-1976).
2. Ins. by s. 37, *ibid.* (w.e.f. 26-10-1976).
3. Ins. by s. 38, *ibid.* (w.e.f. 26-10-1976).
4. Subs. by Act 20 of 1987, s. 27, for "the Schedule" (w.e.f. 1-12-1987).
5. Subs. by s. 27, *ibid.*, for "fifty rupees" (w.e.f. 1-12-1987).
6. Added by s. 27, *ibid.* (w.e.f. 1-12-1987).
7. Subs. by s. 28, *ibid.*, for "the Schedule" (w.e.f. 1-12-1987).

(*2*) The person appointed to hold an inquiry under this section shall have all the powers of a Civil Court under the Code of Civil Procedure, 1908 (5 of 1908), for the purposes of enforcing the attendance of witnesses and compelling the production of documents and material objects, and may also, so far as may be necessary for the purposes of the inquiry, exercise any of the powers of an Inspector under this Act; and every person required by the person making the inquiry to furnish any information shall be deemed to be legally bound so to do within the meaning of section 176 of the Indian Penal Code (45 of 1860).

(*3*) The person holding an inquiry under this section shall make a report to the State Government stating the causes of the accident, or as the case may be, disease, and any attendant circumstances, and addition any observations which he or any of the assessors may think fit to make.

(*4*) The State Government may, if it thinks fit, cause to be published any report made under this section or any extracts therefrom.

(*5*) The State Government may make rules for regulating the procedure at inquiries under this section.

91. Power to take samples.—(*1*) An Inspector may at any time during the normal working hours of a factory, after informing the occupier or manager of the factory or other person for the time being purporting to be in charge of the factory, take in the manner hereinafter provided a sufficient sample of any substances used or intended to be used in the factory, such use being—

(*a*) in the belief of the Inspector in contravention of any of the provisions of this Act or the rules made thereunder, or

(*b*) in the opinion of the Inspector likely to cause bodily injury to, or injury to the health of, workers in the factory.

(*2*) Where the Inspector takes a sample under sub-section (*1*), he shall, in the presence of the person informed under that sub-section unless such person wilfully absents himself, divide the sample into three portions and effectively seal and suitably mark them, and shall permit such person to add his own seal and mark thereto.

(*3*) The person informed as aforesaid shall, if the Inspector so requires, provide the appliances for dividing, sealing and marking the sample taken under this section.

(*4*) The Inspector shall—

(*a*) forthwith give one portion of the sample to the person informed under sub-section (*1*);

(*b*) forthwith send the second portion to a Government Analyst for analysis and report thereon;

(*c*) retain the third portion for production to the Court before which proceedings, if any, are instituted in respect of the substance.

(*5*) Any document purporting to be a report under the hand of any Government Analyst upon any substance submitted to him for analysis and report under this section, may be used as evidence in any proceedings instituted in respect of the substance.

[1][**91A. Safety and occupational health surveys.—**(*1*) The Chief Inspector, or the Director General of Factory Advice Service and Labour Institutes, or the Director General of Health Services, to the Government of India, or such other officer as may be authorised in this behalf by the State Government or the Chief Inspector or the Director General of Factory Advice Service and Labour Institutes or the Director General of Health Services may, at any time during the normal working hours of a factory, or at any other time as is found by him to be necessary, after giving notice in writing to the occupier or manager of the factory or any other person who for the time being purports to be in charge of the factory, undertake safety and occupational health surveys, and such occupier or manager or other person shall afford all facilities for such survey, including facilities for the examination and testing of plant and machinery and collection of samples and other data relevant to the survey.

1. Ins. by Act 94 of 1976, s. 39 (w.e.f. 26-10-1976).

(*2*) For the purpose of facilitating surveys under sub-section (*1*) every worker shall, if so required by the person conducting the survey, present himself to undergo such medical examination as may be considered necessary by such person and furnish all information in his possession and relevant to the survey.

(*3*) Any time spent by a worker for undergoing medical examination or furnishing information under sub-section (*2*) shall, for the purpose of calculating wages and extra wages for overtime work, be deemed to be time during which such worker worked in the factory.]

[1][*Explanation.*—For the purposes of this section, the report, if any, submitted to the State Government by the person conducting the survey under sub-section (*1*) shall be deemed to be a report submitted by an Inspector under this Act.]

CHAPTER X

PENALTIES AND PROCEDURE

92. General penalty for offences.—Save as is otherwise expressly provided in this Act and subject to the provisions of section 93 , if in, or in respect of, any factory there is any contravention of any of the provisions of this Act or of any rules made thereunder or of any order in writing given thereunder, the occupier and manager of the factory shall each be guilty of an offence and punishable with imprisonment for a term which may extend to [2][two years] or with fine which may extend to [3][one lakh rupees] or with both, and if the contravention is continued after conviction, with a further fine which may extend to [4][one thousand rupees] for each day on which the contravention is so continued:

[5][Provided that where contravention of any of the provisions of Chapter IV or any rule made thereunder or under section 87 has resulted in an accident causing death or serious bodily injury, the fine shall not be less than [6][twenty-five thousand rupees] in the case of an accident causing death, and [7][five thousand rupees] in the case of an accident causing serious bodily injury.

Explanation.—In this section and in section 94 "serious bodily injury" means an injury which involves, or in all probability will involve, the permanent loss of the use of, or permanent injury to, any limb or the permanent loss of, or injury to, sight or hearing, or the fracture of any bone, but shall not include, the fracture of bone or joint (not being fracture of more than one bone or joint) of any phalanges of the hand or foot.]

[8][**93. Liability of owner of premises in certain circumstances.—**(*1*) Where in any premises separate buildings are leased to different occupiers for use as separate factories, the owner of the premises shall be responsible for the provision and maintenance of common facilities and services, such as approach roads, drainage, water supply, lighting and sanitation.

(*2*) The Chief Inspector shall have, subject to the control of the State Government, power to issue orders to the owner of the premises in respect of the carrying out of the provisions of sub-section (*1*).

(*3*) Where is any premises, independent or self-containted, floors or flats are leased to different occupiers for use as separate factories, the owner of the premises shall be liable as if he were the occupier or manager of a factory, for any contravention of the provisions of this Act in respect of—

(*i*) latrines, urinals and washing facilities in so far as the maintenance of the common supply of water for these purposes is concerned;

(*ii*) fencing of machinery and plant belonging to the owner and not specifically entrusted to the custody or use of an occupier;

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1. Ins. by Act 20 of 1987, s. 29 (w.e.f. 1-12-1987).
2. Subs. by s. 30, *ibid.*, for "three months" (w.e.f. 1-12-1987).
3. Subs. by s. 30, *ibid.*, for "two thousand rupees" (w.e.f. 1-12-1987).
4. Subs. by s. 30, *ibid.*, for "seventy-five rupees" (w.e.f. 1-12-1987).
5. Ins. by Act 94 of 1976, s. 40 (w.e.f. 26-10-1976).
6. Subs. by Act 20 of 1987, s. 30, for "one thousand rupees" (w.e.f. 1-12-1987).
7. Subs. by s. 30, *ibid.*, for "five hundred rupees" (w.e.f. 1-12-1987).
8. Subs. by Act 25 of 1954, s. 21, for section 93 (w.e.f. 7-5-1954).

(*iii*) safe means of access to the floors or flats and maintenance and cleanliness of staircases and common passages;

(*iv*) precautions in case of fire;

(*v*) maintenance of hoists and lifts; and

(*vi*) maintenance of any other common facilities provided in the premises.

(*4*) The Chief Inspector shall have, subject to the control of the State Government, power to issue orders to the owner of the premises in respect of the carrying out the provisions of sub-section (*3*).

(*5*) The provisions of sub-section (*3*) relating to the liability of the owner shall apply where in any premises independent rooms with common latrines, urinals and washing facilities are leased to different occupiers for use as separate factories:

Provided that the owner shall be responsible also for complying with the requirements relating to the provision and maintenance of latrines, urinals and washing facilities.

(*6*) The Chief Inspector shall have, subject to the control of the State Government, the power to issue orders to the owner of the premises referred to in sub-section (*5*) in respect of the carrying out of the provisions of section 46 or section 48.

(*7*) Where in any premises portions of a room or a shed are leased to different occupiers for use as separate factories, the owner of the premises shall be liable for any contravention of the provisions of—

(*i*) Chapter III, except sections 14 and 15;

(*ii*) Chapter IV, except sections 22, 23, 27, 34, 35 and 36:

Provided that in respect of the provisions of sections 21, 24 and 32 the owner's liability shall be only in so far as such provisions relate to things under his control:

Provided further that the occupier shall be responsible for complying with the provisions of Chapter IV in respect of plant and machinery belonging to or supplied by him;

(*iii*) section 42.

(*8*) The Chief Inspector shall have, subject to the control of the State Government, power to issue orders to the owner of the premises in respect of the carrying out the provisions of sub-section (*7*).

(*9*) In respect of sub-sections (*5*) and (*7*), while computing for the purposes of any of the provisions of this Act the total number of workers employed, the whole of the premises shall be deemed to be a single factory.]

94. Enhanced penalty after previous conviction.—[1][(*1*)] If any person who has been convicted of any offence punishable under section 92 is again guilty of an offence involving a contravention of the same provision, he shall be punishable on a subsequent conviction with imprisonment for a term which may extend to [2][three years] or with fine [3][which shall not be less than [4][ten thousand rupees] but which may extend to [5][two lakh rupees]] or with both:

[6][Provided that the court may, for any adequate and special reasons to be mentioned in the judgment, impose a fine of less than [4][ten thousand rupees]:

1. Section 94 renumbered as sub-section (*1*) thereof by Act 94 of 1976, s. 41 (w.e.f. 26-10-1976).
2. Subs. by Act 20 of 1987, s. 31, for "six months" (w.e.f. 1-12-1987).
3. Subs. by Act 94 of 1976, s. 41, for "which may extend to one thousand rupees" (w.e.f. 26-10-1976).
4. Subs. by Act 20 of 1987, s. 31, for "two hundred rupees" (w.e.f. 1-12-1987).
5. Subs. by s. 31, *ibid.*, for "five thousand rupees" (w.e.f. 1-12-1987).
6. Subs. by Act 94 of 1976, s. 41, for the proviso (w.e.f. 26-10-1976).

Provided further that where contravention of any of the provisions of Chapter IV or any rule made thereunder or under section 87 has resulted in an accident causing death or serious bodily injury, the fine shall not be less than [1][thirty-five thousand rupees] in the case of an accident causing death and [2][ten thousand rupees] in the case of an accident causing serious bodily injury.]

[3][(*2*) For the purposes of sub-section (*1*), no cognizance shall be taken of any conviction made more than two years before the commission or the offence for which the person is subsequently being convicted.]

95. Penalty for obstructing Inspector.—Whoever wilfully obstructs an Inspector in the exercise of any power conferred on him by or under this Act, or fails to produce on demand by an Inspector any registers or other documents in his custody kept in pursuance of this Act or of any rules made thereunder, or conceals or prevents any worker in a factory from appearing before, or being examined by, an Inspector, shall be punishable with imprisonment for a term which may extend to [4][six months] or with fine which may extend to [5][ten thousand rupees] or with both.

96. Penalty for wrongfully disclosing results of analysis under section 91.—Whoever, except in so far as it may be necessary for the purposes of a prosecution for any offence punishable under this Act, publishes or discloses to any person the results of an analysis made under section 91, shall be punishable with imprisonment for a term which may extend to [6][six months] or with fine which may extend to [7][ten thousand rupees] or with both.

[8][**96A. Penalty for contravention of the provisions of sections 41B, 41 C and 41 H.—**(*1*) Whoever Whoever fails to comply with or contravenes any of the provisions of section 41B , 41 C or 41 H or the rules made thereunder, shall, in respect of such failure or contravention, be punishable with imprisonment for a term which may extend to seven years and with fine which may extend to two lakh rupees, and in case the failure or contravention continues, with additional fine which may extend to five thousand rupees for every day during which such failure or contravention continues after the conviction for the first such failure or contravention.

(*2*) If the failure or contravention referred to in sub-section (*1*) continues beyond a period of one year after the date of conviction, the offender shall be punishable with imprisonment for a term which may extend to ten years.]

97. Offences by workers.—(*1*) Subject to the provisions of section 111, if any worker employed in a factory contravenes any provision of this Act or any rules or orders made thereunder, imposing any duty or liability on workers, he shall be punishable with fine which may extend to [9][five hundred rupees].

(*2*) Where a worker is convicted of an offence punishable under sub-section (*1*) the occupier or manager of the factory shall not be deemed to be guilty of an offence in respect of that contravention, unless it is proved that he failed to take all reasonable measures for its prevention.

98. Penalty for using false certificate of fitness.—Whoever knowingly uses or attempts to use, as a certificate of fitness granted to himself under section 70 , a certificate granted to another person under that section, or who, having procured such a certificate, knowingly allows it to be used, or an attempt to use it to be made, by another person, shall be punishable with imprisonment for a term which may extend to [10][two months] or with fine which may extend to [11][one thousand rupees] or with both.

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1. Subs. by Act 20 of 1987, s. 31, for "two thousand rupess" (w.e.f. 1-12-1987).
2. Subs. by s. 31, *ibid.*, for "one thousand rupees" (w.e.f. 1-12-1987).
3. Ins. by Act 94 of 1976, s. 41 (w.e.f. 26-10-1976).
4. Subs. by Act 20 of 1987, s. 32, for "three months" (w.e.f. 1-12-1987).
5. Subs. by s. 32, *ibid.*, for "five hundred rupees" (w.e.f. 1-12-1987).
6. Subs. by s. 33, *ibid.*, for "three months" (w.e.f. 1-12-1987).
7. Subs. by s. 33, *ibid.*, for "five hundred rupees" (w.e.f. 1-12-1987).
8. Ins. by s. 34, *ibid.* (w.e.f. 1-12-1987).
9. Subs. by s. 35, *ibid.*, for "twenty rupees" (w.e.f. 1-12-1987).
10. Subs. by s. 36, *ibid.*, for "one month" (w.e.f. 1-12-1987).
11. Subs. by s. 36, *ibid.*, for "fifty rupees" (w.e.f. 1-12-1987).

99. Penalty for permitting double employment of child.—If a child works in a factory on any day on which he has already been working in another factory, the parent or guardian of the child or the person having custody of or control over him or obtaining any direct benefit from his wages, shall be punishable with fine which may extend to [1][one thousand rupees], unless it appears to the Court that the child so worked without the consent or connivance of such parent, guardian or person.

100. [*Determination of occupier in certain cases.*] *Rep. by the Factories (Amendment) Act,* 1987 (20 *of* 1987), s. 38 (*w.e.f.* 1-12-1987).

101. Exemption of occupier or manager from liability in certain cases.—Where the occupier or manager of a factory is charged with an offence punishable under this Act, he shall be entitled, upon complaint duly made by him and on giving to the prosecutor not less than three clear days' notice in writing of his intention so to do, to have any other person whom he charges as the actual offender brought before the Court at time appointed for hearing the charge; and if, after the commission of the offence has been proved, the occupier or manager of the factory, as the case may be, proves to the satisfaction of the Court—

(*a*) that he has used due diligence to enforce the execution of this Act, and

(*b*) that the said other person committed the offence in question without his knowledge, consent or connivance,

that other person shall be convicted of the offence and shall be liable to the like punishment as if he were the occupier or manager of the factory, and the occupier or manager, as the case may be, shall be discharged from any liability under this Act in respect of such offence:

Provided that in seeking to prove as aforesaid, the occupier or manager of the factory, as the case may be, may be examined on oath, and his evidence and that of any witness whom he calls in his support shall be subject to cross-examination on behalf of the person he charges as the actual offender and by the prosecutor:

Provided further that, if the person charged as the actual offender by the occupier or manager cannot be brought before the Court at the time appointed for hearing the charge, the Court shall adjourn the hearing from time to time for a period not exceeding three months and if by the end of the said period the person charged as the actual offenders cannot still be brought before the Court, the Court shall proceed to hear the charge against the occupier or manager and shall, if the offence be proved, convict the occupier or manager.

102. Power of Court to make orders.—(*1*) Where the occupier or manager of a factory is convicted of an offence punishable under this Act the Court may, in addition to awarding any punishment, by order in writing require him, within a period specified in the order (which the court may, if it thinks fit and on application in such behalf, from time to time extend) to take such measures as may be so specified for remedying the matters in respect of which the offence was committed.

(*2*) Where an order is made under sub-section (*1*) the occupier or manager of the factory, as the case may be, shall not be liable under this Act in respect of the continuation of the offence during the period, or extended period, if any, allowed by the Court, but if, on the expiry of such period or extended period, as the case may be, the order or the Court has not been fully complied with, the occupier or manager, as the case may be, shall be deemed to have committed a further offence, and may be sentenced therefore by the Court to undergo imprisonment for a term which may extend to six months or to pay a fine which may extend to one hundred rupees for every day after such expiry on which the order has not been complied with, or both to undergo such imprisonment and to pay such fine, as aforesaid.

103. Presumption as to employment.—If a person is found in a factory at any time, except during intervals for meals or rest, when work is going on or the machinery is in motion, he shall until the contrary is proved, be deemed for the purposes of this Act and the rules made thereunder to have been at that time employed in the factory.

1. Subs. by Act 20 of 1987, s. 37, for "fifty rupees" (w.e.f. 1-12-1987).

104. Onus as to age.—(*1*) When any act or omission would, if a person were under a certain age, be an offence punishable under this Act, and such person is in the opinion of the Court *prima facie* under such age, the burden shall be on the accused to prove that such person is no under such age.

(*2*) A declaration in writing by a certifying surgeon relating to a worker that he has personally examined him and believes him to be under the age stated is such declaration shall, for the purposes of this Act and the rules made thereunder, be admissible as evidence of the age of that worker.

[1][**104A. Onus of proving limits of what is practicable, etc.—**In any proceeding for an offence for the contravention of any provision of this Act or rules made thereunder consisting of a failure to comply with a duty or requirement to do something, it shall be for the person who is alleged to have failed to comply with such duty or requirement, to prove that it was not reasonably practicable or, as the case may be, all practicable measures were taken to satisfy the duty or requirement.]

105. Cognizance of offences.—(*1*) No Court shall take cognizance of any offence under this Act except on complaint by, or with the previous sanction in writing of, an Inspector.

(*2*) No Court below that of a Presidency Magistrate or of a Magistrate of the first class shall try any offence punishable under this Act.

106. Limitation of prosecutions.—No Court shall take cognizance of any offence punishable under this Act unless complaint thereof is made within three months of the date on which the alleged commission of the offence came to the knowledge of an Inspector:

Provided that where the offence consists of disobeying a written order made by an Inspector, complaint thereof may be made within six months of the date on which the offence is alleged to have been committed.

[2][*Explanation.*—For the purposes of this section,—

(*a*) in the case of a continuing offence, the period of limitation shall be computed with reference to every point of time during which the offence continues;

(*b*) where for the performance of any act time is granted or extended on an application made by the occupier or manager of a factory, the period of limitation shall be computed from the date on which the time so granted or extended expired.]

[3][**106A. Jurisdiction of a court for entertaining proceedings, etc., for offence.—**For the purposes of conferring jurisdiction on any court in relation to an offence under this Act or the rules made thereunder in connection with the operation of any plant, the place where the plant is for the time being situate shall be deemed to be the place where such offence has been committed.]

CHAPTER XI

SUPPLEMENTAL

107. Appeals.—(*1*) The manager of a factory on whom an order in writing by an Inspector has been served under the provisions of this Act or the occupier of the factory may, within thirty days of the service of the order, appeal against it to the prescribed authority, and such authority may, subject to rules made in this behalf by the State Government, confirm, modify or reverse the order.

(*2*) Subject to rules made in this behalf by the State Government (which may prescribe classes of appeals which shall not be heard with the aid of assessors), the appellate authority may, or if so required in the petition of appeal shall, hear the appeal with the aid of assessors, one of whom shall be appointed by the appellate authority and the other by such body representing the industry concerned as may be prescribed:

Provided that if no assessor is appointed by such body before the time fixed for hearing the appeal, or if the assessor so appointed fails to attend the hearing at such time, the appellate authority may, unless satisfied that the failure to attend is due to sufficient cause, proceed to hear the appeal without the aid of such assessor or, if it thinks fit, without the aid of any assessor.

1. Ins. by Act 20 of 1987, s. 39 (w.e.f. 1-12-1987).
2. Ins. by Act 94 of 1976, s. 43 (w.e.f. 26-10-1976).
3. Ins. by Act 20 of 1987, s. 40 (w.e.f. 1-12-1987).

(*3*) Subject to such rules as the Stale Government may make in this behalf and subject to such conditions as to partial compliance or the adoption of temporary measures as the appellate authority may in any case think fit to impose, the appellate authority may, if it thinks fit, suspend the order appealed against pending the decision of the appeal.

108. Display of notices.—(*1*) In addition to the notices required to be displayed in any factory by or under this Act, there shall be displayed in every factory a notice containing such abstracts of this Act and of the rules made thereunder as may be prescribed and also the name and address of the Inspector and the certifying surgeon.

(*2*) All notices required by or under this Act to be displayed in a factory shall be in English and in a language understood by the majority of the workers in the factory, and shall be displayed at some conspicuous and convenient place at or near the main entrance to the factory, and shall be maintained in a clean and legible condition.

(*3*) The Chief Inspector may, by order in writing served on the manager of any factory, require that there shall be displayed in the factory any other notice or poster relating to the health, safety or welfare of the workers in the factory.

109. Service of notices.—The State Government may make rules prescribing the manner of the service of orders under this Act on owners, occupiers or managers of factories.

110. Returns.—The State Government may make rules requiring owners, occupiers or managers of factories to submit such returns, occasional or periodical, as may in its opinion be required for the purposes of this Act.

111. Obligations of workers.—(*1*) No worker in a factory—

(*a*) shall wilfully interfere with or misuse any appliance, convenience or other thing provided in a factory for the purposes of securing the health, safety or welfare of the workers therein;

(*b*) shall wilfully and without reasonable cause do anything likely to endanger himself or others; and

(*c*) shall wilfully neglect to make use of any appliance or other thing provided in the factory for the purposes of securing the health or safety of the workers therein.

(*2*) If any worker employed in a factory contravenes any of the provisions of this section or of any rule or order made thereunder, he shall be punishable with imprisonment for a term which may extend to three months, or with fine which may extend to one hundred rupees, or with both.

[1][**111A. Right of workers, etc.—**Every worker shall have the right to—

(*i*) obtain from the occupier, information relating to workers' health and safety at work,

(*ii*) get trained within the factory wherever possible, or, to get himself sponsored by the occupier for getting trained at a training center or institute, duly approved by the Chief Inspector, where training is imparted for workers' health and safety at work,

(*iii*) represent to the Inspector directly or through his representative in the matter of inadequate provision for protection of his health or safety in the factory.]

112. General power to make rules.—The State Government may make rules providing for any matter which, under any of the provisions of this Act, is to be or may be prescribed or which may be considered expedient in order to give effect to the purposes of this Act.

113. Powers of Centre to give directions.—The Central Government may give directions to a State Government to the carrying into execution of the provisions of this Act.

114. No charge for facilities and conveniences.—Subject to the provisions of section 46 no fee or charge shall be realised from any worker in respect of any arrangements or facilities to be provided, or any equipments or appliances to be supplied by the occupier under the provisions of this Act.

1. Ins. by Act 20 of 1987, s. 41 (w.e.f. 1-12-1987).

115. Publication of rules.—[1][(*1*)] All rules made under this Act shall be published in the Official Gazette, and shall be subject to the condition of previous publication; and the date to be specified under clause (*3*) of section 23 of the General Clauses Act, 1897 (10 of 1897), shall be not less than [2][forty-five days] from the date on which the draft of the proposed rules was published.

[3][(*2*) Every rule made by the State Government under this Act shall be laid, as soon as may be after it is made, before the State Legislature.]

116. Application of Act to Government factories.—Unless otherwise provided this Act shall apply to factories belonging to the Central or any State Government.

117. Protection to persons acting under this Act.—No suit, prosecution or other legal proceeding shall lie against any person for anything which is in good faith done or intended to be done under this Act.

118. Restrictions on disclosure of information.—(*1*) No Inspector shall, while in service or after leaving the service, disclose otherwise than in connection with the execution, or for the purposes, of this Act any information relating to any manufacturing or commercial business or any working process which may come to his knowledge in the course of his official duties.

(*2*) Nothing in sub-section (*1*) shall apply to any disclosure of information made with the previous consent in writing of the owner of such business or process or for the purposes of any legal proceeding (including arbitration) pursuant to this Act or of any criminal proceeding which may be taken, whether pursuant to this Act or otherwise, or for the purposes of any report of such proceedings as aforesaid.

(*3*) If any Inspector contravenes the provisions of sub-section (*1*) he shall be punishable with imprisonment for a term which may extend to six months, or with fine which may extend to one thousand rupees, or with both.

[4][**118A. Restriction on disclosure of information.—**(*1*) Every Inspector shall treat as confidential the source of any complaint brought to his notice on the breach of any provision of this Act.

(*2*) No inspector shall, while making an inspection under this Act, disclose to the occupier, manager or his representative that the inspection is made in pursuance of the receipt of a complaint:

Provided that nothing in this sub-section shall apply to any case in which the person who has made the complaint has consented to disclose his name.]

[5][**119. Act to have effect notwithstanding anything contained in Act 37 of 1970.—**The provisions of this Act shall have effect notwithstanding anything inconsistent therewith contained in the Contract Labour (Regulation and Abolition) Act, 1970 [6][or any other law for the time being in force.]]

120. Repeal and savings.—The enactments set out in the Table appended to this section are hereby repealed:

Provided that anything done under the said enactments which could have been done under this Act if it had then been in force shall be deemed to have been done under this Act.

*TABLE.***—[***Enactments repealed.*] *Rep. by the Repealing and Amending Act,* 1950 (35 *of* 1950), s. 2 and the First Schedule (*w.e.f.* 10-4-1950.)

1. Section 115 renumbered as sub-section (*1*) thereof by Act 20 of 1987, s. 42 (w.e.f. 1-12-1987).
2. Subs. by s. 42, *ibid.*, for "three months" (w.e.f. 1-12-1987).
3. Ins. by s. 42, *ibid.* (w.e.f. 1-12-1987).
4. Ins. by s. 43, *ibid.* (w.e.f. 1-12-1987).
5. Ins. by Act 94 of 1976, s. 44 (w.e.f. 26-10-1976).
6. Ins. by Act 20 of 1987, s. 44 (w.e.f. 1-12-1987).

[1][THE FIRST SCHEDULE]

[*See* section 2 (*cb*)]

LIST OF INDUSTRIES INVOLVING HAZARDOUS PROCESSES

1. Ferrous Metallurgical industries

—Integrated Iron and Steel

—Ferrow-alloys

—Special Steels

2. Non-ferrous Metallurgical Industries

—Primary Metallurgical Industries, namely, size, lead, copper, manganese and aluminium

3. Foundries (ferrous and non-ferrous)

—Castings and forgings including cleaning or smoothening/roughening by sand and shot blasting

4. Coal (including coke) industries

—Coal Lignite, coke, etc.

—Fuel Gases (including Coal Gas, Producer Gas, Water Gas)

5. Power Generating Industries

6. Pulp and paper (including paper products) industries

7. Fertiliser Industries

—Nitrogenous

—Phosphatic

—Mixed

8. Cement Industries

—Portland Cement (including slag cement, puzzolona cement and their products)

9. Petroleum industries

—Oil Refining

—Lubricating Oils and Greases

10. Petro-chemical Industries

11. Drugs and Pharmaceutical Industries

—Narcotics, Drugs and Pharmaceutical

12. Fermentation Industries (Distilleries and Breweries)

13. Rubber (Synthetic Industries)

14. Paints and Pigment Industries

15. Leather Tanning Industries

16. Electroplating Industries

1. Ins. by Act 20 of 1987, s. 45 (w.e.f. 1-12-1987).

17. Chemical Industries

—Coke Oven By-products and Coal tar Distillation products

—Industrial Gases (nitrogen, oxygen, acetylene, argon, carbon dioxide, hydrogen, sulphur dioxide, nitrous oxide halogenated hydrocarbon, ozone, etc.)

—Industrial Carbon

—Alkalies and Acids

—Chromates and dichromates

—Leads and its compounds

—Electro chemicals (metallic sodium, potassium and magnesium, chlorates, perchlorates and peroxides)

—Electro thermal produces (artificial abrasive, calcium carbide)

—Nitrogenous compounds (cyanides, cyanamides, and other nitrogenous compounds)

—Phosphorous and its compounds

—Halogens and Halogenated compounds (Chlorine, Fluorine, Bromine and Iodine)

—Explosives (including industrial explosives and detonators and fuses)

18. Insecticides, Fungicides, Herbicides and other Pesticides Industries

19. Synthetic Resin and Plastics

20. Man-made Fiber (Cellulosic and non-cellulosic) industry

21. Manufacture and repair of electrical accumulators

22. Glass and Ceramics

23. Grinding or glazing of metals

24. Manufacture, handling and processing of asbestos and its products

25. Extraction of oils and fats from vegetable and animal sources

26. Manufacture, handling and use of benzene and substances containing benzene

27. Manufacturing processes and operations involving carbon disulphide

28. Dyes and Dyestuff including their intermediates

29. Highly flammable liquids and gases.

*THE SECOND SCHEDULE

(*See* section 41 F)

PERMISSIBLE LEVELS OF CERTAIN CHEMICAL SUBSTANCES IN WORK ENVIRONMENT

Substance	Permissible limits of exposure			
	Time-weighted average concentration (8 hrs)		Short-term exposure limit (15 min)	
	ppm	Mg/m^3	ppm	Mg/m^3
Acetaldehyde	100	180	150	270
Acetic acid.	10	25	15	37
Acetone.	750	1780	1000	2375
Acrelein.	0.1	0.25	0.3	0.8
Acrylonitrile—skin	2	4.5	. .	. .
Aldrin-skin.	. .	0.25	. .	0.75
Allychloride.	1	3	2	6
Ammonia.	0.25	18	35	27
Aniline-Skin.	2	10	5	20
Anisidine (o., Pisoners)—skin.	0.1	0.5	. .	. .
Arsenic and compounds (as As)	. .	0.2	. .	. .
Benzene.	10	20	25	75
Beryllium	. .	0.20	. .	. .
Boron trifluoride.	0.1	0.3	. .	. .
Bromine.	0.1	0.7	0.3	2
Butane.	800	1900	. .	. .
2-Butanone (Methyl-ethyl Ketone-MEK)	200	590	300	885
n-Butyl acetate.	150	710	200	950
n-Butyle alcohol-Skin.	C50	C150	. .	. .
sec/tert. Butyl acetate.	200	950	250	1190
Butyl Mercaptan.	0.5	1.5	. .	. .
Cadmium-Dusts and salts (as Cd)	. .	0.05	. .	0.2
Calcium oxide.	. .	2	. .	. .
Carbaryl (Sevin)	. .	5	. .	10
Carbofuran (Furadan)	. .	0.1	. .	. .
Carbon disulphide—Skin.	10	30	. .	. .

* Ins. by Act 20 of 1987, s. 45 (w.e.f. 1-6-1988).

	ppm	Mg/m^3	ppm	Mg/m^3
Carbon monoxide)	50	40	400	440
Carbon to trachloride—skin	m5	30	20	125
Carbonyl Chloride (Phosgene).	0.1	0.4	..	..
Chlorobenzene (Monochloro-benzene).	75	350	. .	. .
Chlordane-skin.	. .	0.5	. .	. .
Chlorine	1	3	3	9
Chloroform	10	50	50	225
Bis-Chloromethyl ether	0.001	0.005	. .	. .
Chromic acid and chromates (as Cr)	. .	0.05	. .	. .
Chromous Salts (as Cr).	. .	0.05	. .	. .
Copper fume.	. .	0.2	. .	. .
Cotton dust, raw	. .	0.2	. .	0.6
Crosol, all isomers—skin	5	22	. .	. .
Cyanides (as CN)—skin	. .	5	. .	. .
Cyanogen	10	20	. .	. .
DDT (Dichlorodiphenyl Trichloroethane)	. .	1	. .	3
demeton-skin	0.01	0.1	0.03	0.3
Diazinon-skin	. .	0.1	. .	0.3
Dibutyl Phythalate	. .	5	. .	10
Dichlorvos (DDVP)—skin	0.1	1	0.3	3
Dieldrin—skin	. .	0.25	. .	0.75
Dinitrobenzene (all isomers)—skin	0.15	1	0.5	3
Dinitrotolune-skin	. .	1.5	. .	5
Diphenyl	0.2	1.5	0.6	4
Endosulfan (Thiodan)—skin	. .	0.1	. .	0.4
Endrin—skin	. .	0.1	. .	0.3
Ethyl acetate	400	1400	. .	. .
Ethyl alcohol	1000	1900	. .	. .
Ethylamine	10	18	. .	. .
Fluorides (as F)	. .	2.5	. .	. .
Fluorine	1	2	2	4
Formic Acid	5	9	. .	. .
Hydrazine—skin	0.1	0.1	. .	. .
Hydrogen Chloride	C5	C7	. .	. .

	ppm	Mg/m^3	ppm	Mg/m^3
Hydrogen Cyanide—skin.	C10	C10	. .	. .
Hydrogen fluoride (as F)	3	2.5	6	5
Hydrogen Peroxide.	1	1.5	2	3
Hydrogen Sulphide.	10	14	15	21
Iodine.	C0.1	C1	. .	. .
Iron-Oxide Fume (Fe_z O_3) (as Fe)	. .	5	. .	10
Isoamyl acetate.	100	525	125	665
Isoamyl alcohol.	100	360	125	450
Isobutyl alcohal.	50	150	75	225
Lead, inorg, dusts and fumes (as Pb)	. .	0.15	. .	0.45
Lindane-skin.	. .	0.5	. .	1.5
Malathion-skin.	. .	10	. .	. .
Manganese (as Mn) dust and compounds.	. .	C05	. .	. .
Fume	. .	1	. .	0.3
Mercury (as Hg)—skin Alkyl compounds.	. .	0.01	. .	0.03
All forms except alkyl vapour.	. .	0.05	. .	. .
Aryl and inorganic compounds.	. .	0.1	. .	. .
Methyl alcohol (methanol)—skin.	200	260	250	310
Methyl cellosolve—skin (2 methoxy ethanol)	5	16	. .	. .
Methyl isobutyl ketone—skin.	50	205	75	300
Methyl Isocyanate.	0.02	0.05	. .	. .
Napthalene.	10	50	15	75
Nickel carbonyl (as Ni)	0.05	0.35	. .	. .
Nitric acid.	2	5	4	10
Nitric oxide.	25	30	35	45
Nitrobenzene—skin.	1	5	2	10
Nitrogen dioxide.	3	6	5	10
Oil mist, minerals.	. .	5	. .	10
Oxone.	0.1	0.2	0.3	0.6
Parathion—skin.	. .	0.1	. .	0.3
Phenol—skin.	5	19	10	38
Phorate (Thimet)—skin.	. .	0.05	. .	0.2
Phosgene (Carbonyl Chloride)	0.1	0.4	. .	. .
Phosphine.	0.3	0.4	1	1

	ppm	Mg/m^3	ppm	Mg/m^3
Phosphorus (yellow)	. .	0.1	. .	0.3
Phosphorus pentachloride.	0.1	1	. .	. .
Phosphorus trichloride.	0.2	1.5	0.5	3
Picric acid—skin.	. .	0.1	. .	0.3
Pyridine.	5	15	10	30
Silane (silicon tetrahydride)	5	7	. .	. .
Sodium hydroxide.	. .	C2	. .	. .
Styrene, monomer (phanylethylene)	50	215	100	425
Sulphur dioxide.	2	5	5	10
Sulphur hexafluoride.	1000	6000	1250	7500
Sulphuric acid.	. .	1	. .	. .
Toluene (Toluol)	100	375	150	560
0-Toluidinz—skin.	2	9	. .	. .
Tributyl phosphate.	0.2	2.5	0.4	5
Trichloroethylene.	50	270	200	1080
Uranium, natural (as U)	. .	0.2	. .	0.5
Vinyl chloride	5	10	. .	. .
Welding fumes.	. .	5	. .	. .
Xylene (o-, m-, P-isomers)	100	435	150	655
Zirconium compounds (as Zr)	. .	5	. .	10

C denotes ceiling limit

*Not more than 4 times a day with at least 60 min. interval between successive exposures.

Substance	Permissible time-weighted average concentration (8 hours)
(i) Silica	
(a) Crystalline	
(b) Quartz	
(1) In term of dusts count	$\frac{10600}{\% \text{ Quartz}+10}$ mppcm

Substance	Permissible time-weighted average concentration (8 hours)
(2) In terms of respirable dust	$\frac{10}{\text{\% respirable quartz}+2}$ mg/m^3
(3) In terms of total dust	$\frac{10}{\text{\% Quartz}+3}$ mg/m^3
(ii) Cristobalite	Half the limits given against quartz.
(iii) Tridymite	Half the limits given against quartz.
(iv) Silca, fused	Same limits as for quartz.
(v) (a) Tripoli	Same limit as in formula in item 2 given against quartz.
(b) Amorphous	705 mppcm.]

[1][THE THIRD SCHEDULE]

(*See* sections 89 and 90)

LIST OF NOTIFIABLE DISEASES

1. Lead poisoning, including poisoning by any preparation or compound of lead or their sequelae.
2. Lead tetra-ethyle poisoning.
3. Phosphorus poisoning or its sequelae.
4. Mercury poisoning or its sequelae.
5. Manganese poisoning or its sequelae.
6. Arsenic poisoning or its sequelae.
7. Poisoning by nitrous fumes.
8. Carbon bisulphide poisoning.
9. Benzene poisoning, including poisoning by any of its homologues, their nitro or amido derivatives or its sequelae.
10. Chrome ulceration or its sequelae.
11. Anthrax.
12. Silicosis.
13. Poisoning by halogens or halogen derivatives of the hydrocarbons of the aliphatic series.
14. Pathological manifestations due to—

    (*a*) radium or other radio-active substances;

    (*b*) X-rays.
15. Primary epitheliomatous cancer of the skin.

1. The existing Schedule renumbered as the Third Schedule by Act 20 of 1987, s. 46 (w.e.f. 1-12-1987).

16. Toxic anaemia.

17. Toxic jaundice due to poisonous substances.

[1][18. Oil acne or dermatitis due to mineral oils and compounds containing mineral oil base.

19. Byssionosis.

20. Asbestosis.

21. Occupational or contact dermatitis caused by direct contract with chemicals and paints. These are of two types, that is, primary irritants and allergie sensitizers.

22. Noise induced hearing loss (exposure to high noise levels).]

[2][23. Beriyllium poisoning.

24. Carbon monoxide.

25. Coal miners' pnoumoconiosis.

26. Phosgene poisoning.

27. Occupational cancer.

28. Isocyanates poisoning.

29. Taxic nephritis.]

1. Ins. by Act 94 of 1976, s. 45 (w.e.f. 26-10-1976).
2. Ins. by Act 20 of 1987, s. 46 (w.e.f. 1-12-1987).

Dinesh Laha

From: Sarkar, Suvankar (GE Vernova) <suvankar.sarkar@ge.com>
Sent: 31 August 2023 12:31
To: Sanjay Garhwal
Cc: Prabhat Chandra; Bhaskar Sen Choudhury; Pai, Sanath (GE Vernova); Acharya, Arvind (GE Vernova); Rao, Jagdish (GE Vernova)
Subject: Rotor roll in and roll out plan for the 2 X 9FA.03 Gas Turbine units at OTPC-Palatana site.
Attachments: Rotor-roll-in-roll-out.pdf; Rotor inspection.png

To,
Mr. Sanjay Garhwal,
Chief Operating Officer
ONGC Tripura Power Company Ltd, Palatana
Tripura.

Subject: Rotor roll in and roll out plan for the 2 X 9FA.03 Gas Turbine units at OTPC-Palatana site.

Dear Sir,

This has reference to the subject above.

We would like to bring to your kind notice about the fact that the two 9FA.03 Gas Turbine units, operating at OTPC Palatana site has completed, GT#1 74,750 FFH and GT#2 65,080 FFH (As on 31st August 2023). The stipulated defined design life of the rotor is 144,000 FFH and will be expired beyond that.

Considering the same, GE is recommending to plan an action against each rotor which would help in extending the life of the rotor before the expiration of the same and also to have an standby rotor at site for future exigencies.

Bearing in mind the 9FA.03 rotor manufacturing schedule and expected demand, the delivery lead time of a new rotor has moved beyond ~36 Months from the placement of PO and hence we would like you to start planning proactively.

GE team has worked out an optimized recommendation of buying a new rotor, pulling out the old rotor and performing a repair at GE shop to extend life of removed rotor by another 100,000 FFH.

We are happy to enclose the rotor-roll-in-roll-out plan for your kind consideration along with Financials, necessary guidelines as per GER 3620.

Looking forward for your kind appointment for detail discussion on the above submission at the earliest.
Thanks & Regards
Suvankar Sarkar

GE Power

Sales Manager

Phone: +91 74394 22634
suvankar.sarkar@ge.com

April 21st, 2023

INDICATIVE PROPOSAL NO: 1643645 Rev. 00

ONGC Tripura Power Company Limited Site: OTPC
USN: 298967

Subject: Fr 9FA Spare New Unit Rotor

Regarding the above subject, we are pleased to submit the following Indicative Proposal of 9FA Spare New Unit Rotor for USN 298967

Scope of Supply

GE Energy Parts Inc. (hereinafter called "Seller" or "GEEPI") is pleased to present this Indicative proposal to OTPC for 1x 9FA Spare New Unit Rotor. Tech write up and scope of supply attached as Appendix A in this Quote

Cycle

Expected Cycle: The standard delivery schedule for the Engineering and Manufacturing of the items from the date of order acceptance by Seller shall be ~ 27 Months. The delivery timeline is tentative and needs to be reconfirmed based on date of actual order placement. Shipping cycle is excluded in this delivery timeline.

Installation Activity

Not included in this Indicative Proposal

Budgetary Price:

The Indicative Proposal price for 1x 9FA Spare New Unit Rotor is: $24,831,600 USD (US Dollars Twenty-Four Million Eight Hundred Thirty-One Thousand Six Hundred only)

Notes:

1. This Indicative Proposal is not a quotation nor an offer for the sale of parts and/or services described herein. The information contained herein is subject to change and/or revision without prior notice. For a formal proposal, please contact your GE Sales Representative, and reference this Indicative Proposal.
2. This Indicative Proposal assumes execution during 2023. For execution beyond this range, an adjustment in price and cycle will take place. A new Indicative Proposal will be provided upon request.
3. ***COVID-19 VIRUS:*** The COVID-19 epidemic and government actions in response to it have affected and will continue to affect GE's ability to deliver goods and services around the world and the impacts of this should also be considered with regard to price and cycle time estimate.
4. The prices are on FCA basis, Port of export (Incoterms 2010).
5. The prices are exclusive of all applicable taxes, Custom duty, Insurance & Customs clearance charges. These charges shall be borne and paid directly by OTPC to the tax authorities.

We appreciate having the opportunity to provide the budgetary quote for the above scope of work and look forward to handling your valued order. Should questions arise, please feel free to contact me.

Sincerely, Suvankar Sarkar

Appendix A – Tech Write up & Scope of Supply

Section 1 - Technical Summary

1.1 Customer Value

The compressor rotor section of the unit rotor asset that is offered in this technical proposal is a flared fully enhanced compressor rotor, which incorporate the following features:

- Dovetail slots of forward stub shaft (CW0) incorporate shot peening and undercut
- Dovetail slots of wheel 1 (CW1) incorporate shot peening
- Enhanced R0 blades. Blades with completely new airfoil design that were improved with:
  - Airfoil shot peening. The full airfoil surface is mechanically peened to achieve improved tolerance to erosion, corrosion, and foreign object damage.
  - Laser shock peening. The leading edge root is treated with laser shock peening to provide high resistance to erosion, corrosion, and foreign object damage.
  - Dovetail undercut. Performed on both sides of the dovetail, this feature is intended to minimize the fretting wear by mitigating stress at the edge of contact and moving the fretting area away from high stresses.
  - Graphite coating on dovetail. Coating is applied on both sides of the dovetail to reduce the fretting wear.
  - Squealer tip. Feature intended to increase the rub tolerance.
- Enhanced R1 thru R3 blades. These blades have the same airfoil design as original design; however, they were improved with:
  - Full airfoil shot peening
  - Dovetail undercut
  - Graphite coating on dovetail
- Enhanced R4 and R5 blades. These blades have the same airfoil design as original design; however, they were improved with:
  - Full airfoil shot peening
  - Dovetail undercut
- Enhanced R6 thru R8 blades. These blades have the same airfoil design as original design; however, they were improved with:
  - Full airfoil shot peening
- Round slot bottom (RSB) design on the dovetail slots of stage 12 thru 17 wheels, which greatly reduce the stress on the slot and hence exclude the rotor from TIL 1972.
- Optimized clocking on stages 14 thru 16 blade & wheel assemblies. Clocking feature on the compressor rotor refers to the blade pattern that results for stages R14 thru R16 once the compressor rotor has been stacked/assembled. The current-production rotors are built with an optimum clocking to improve the stator reliability by eliminating the S14 thru S16 vane rocking phenomena.

Furthermore, the turbine rotor section of the asset offered herein is a Gen-IV turbine rotor without turbine blades that incorporates the following features:

- Optimized air-cooling slot design on the stage 1 and 2 wheels, which greatly reduces the chances of stress cracking in the corners of the cooling slots

- Redesigned lock-wire tabs on stage 1, 2 and 3 wheels
- New balance groove design on stage 1, 2 and 3 wheels, as well as on the stage 1-2 and 2-3 spacers. The redesigned groove does not require wheel staking for positioning the balance weights

1.2 Control System

The modification treated in this technical proposal has no impact on the existing gas turbine control system.

1.3 Performance Effect

The proposed modification has no effect on gas turbine performance.

1.4 Emissions Effect

The modification treated in this technical proposal has no impact on the existing gas turbine control system.

1.5 Generator Evaluation

For detailed scope and price information on work to be performed in customer site or in a GE Power service center by GE Power personnel, a separate quote must be obtained from FieldCore and Parts and Repair Services.

1.6 Site Information

None.

1.7 Maintenance Effect

The rotor solutions treated herein have no impact by themselves on the maintenance practices; therefore, the information outlined in GE publication GER-35620N applies. However, since both rotor solutions offered herein are comprised of fully-enhanced compressor sections (enhanced blades for stages R0 thru R8 and optimized aft clocking), the following table lists the maintenance effects enhanced compressor hardware on compressor-related Technical Information Letters (TILs).

TIL number	TIL title	Affected parts	Requirements for pre-enhanced parts	Requirements for enhanced parts
1638-R3	F-CLASS R0/R1 PLATFORM ULTRASONIC TESTING	R0 and R1 blades	R0 and R1 ultrasonic (UT) inspections	UT Inspections are not required for enhanced R0s or enhanced R1s
1509-R4	F-CLASS FRONT-END (R0, S0, AND R1) COMPRESSOR INSPECTIONS	R0 and R1 blades, S0 vanes	R0 and R1 tip inspections, S0 trailing edge inspections, R0 root inspections	Only annual borescope inspections are required for compressors with enhanced R0, S0, and R1 airfoils.

Since the compressor section of the proposed rotor incorporates round-slot-bottom design on stage 12 thru 17 compressor wheels, the rotor is not affected by TIL 1972.

Furthermore, note that the recommended inspections for turbine wheels on the proposed rotor are reduced with regards to the wheels in the existing rotor, as outlined in TILs 1945 and 1937.

Information concerning maintenance, including hours based and starts-based inspection intervals, may be found in GE publication GER-3620N:

https://www.gepower.com/content/dam/gepower-pgdp/global/en_US/documents/technical/ger/ger-3620n-heavy-duty-gas-turbine-operationg-maintenance-considerations.pdf

1.8 GE Publications

Use the following relevant GE documents located online for your use at:
http://www.ge-energy.com/prod_serv/products/tech_docs/en/all_gers.htm

Section 2: Scope of Supply
2.1 Scope of Supply

Group 1: Installation of a brand-new unit rotor spool into GT serial number 298872/298967

- New flared-enhanced unit rotor spool
- Bushing modification for the compressor forward flange (load coupling)
- Compressor bolting nuts and locknuts
- Replacement thrust bearing shims
- Engineering effort
- Wooden crate for unit rotor assembly

2.2 Non-GE / Excluded Scope
For detailed scope and price information on work to be performed in a GE Power service center by GE Power personnel, a separate quote must be obtained from Parts and Repair Services and/or from Inspection and Life Extension Services (I&LES).

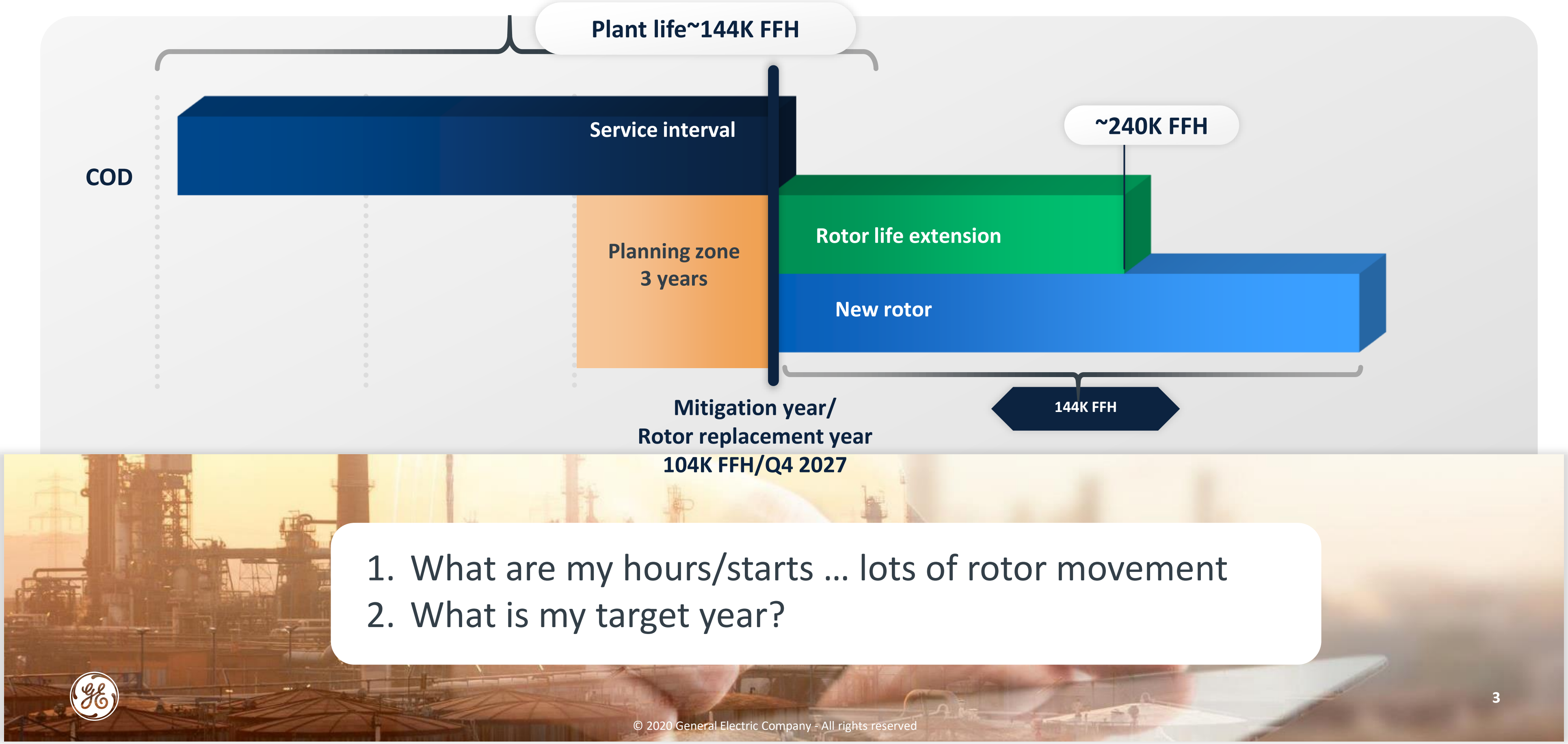
Similarly, for detailed scope and price information on work to be at the customer site by GE Power personnel, a separate quote must be obtained from FieldCore.

ONGC Tripura Power Company

Rotor Planning Strategy

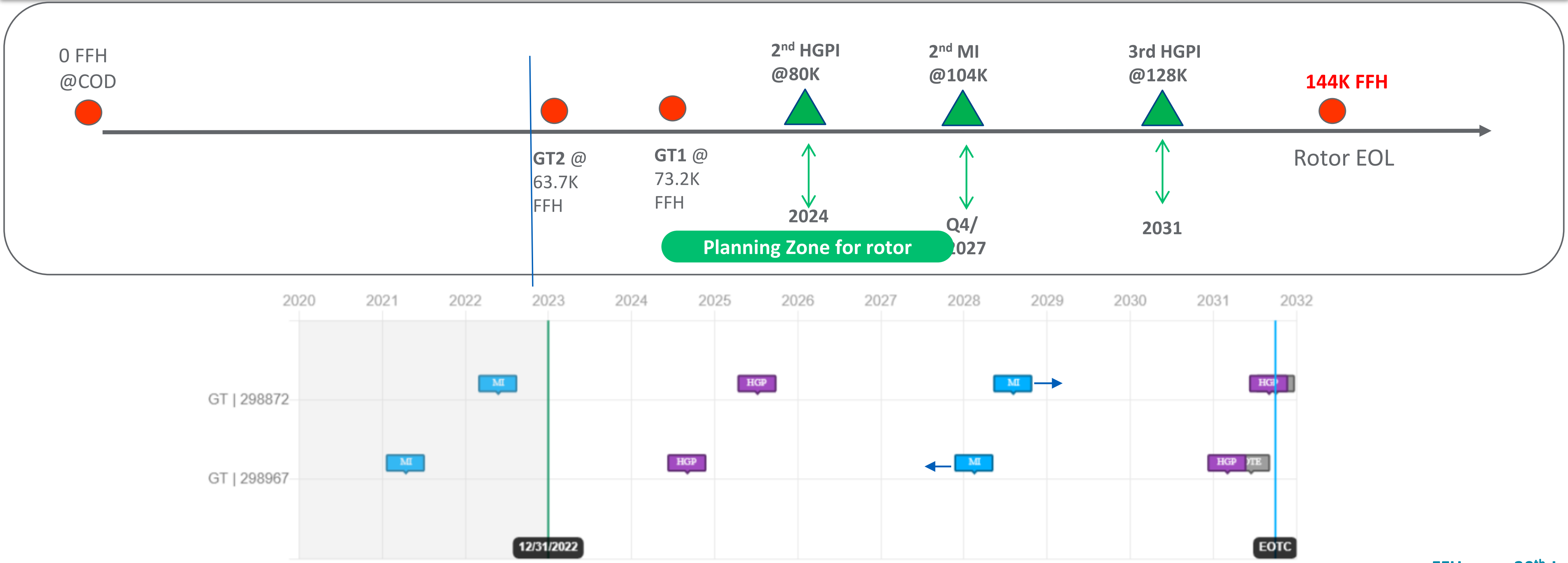
August 31, 2023

Things to consider when planning rotor maintenance



Proactively planning a rotor helps in timely outage and avoiding downtime.

Outage and Rotor delivery timeline



FFH as on 30th June 2023

Typical strategy for 2-unit site

New unit rotor	Delivery timeline of ~36 months	**Plan the outage better and ready in case of exigency**
Removed rotor	Remove GT1 rotor for refurbishment	Refurbishment timeline of 10+ months+ delivery
GT2 Removed rotor	Refurbishment	Maintain a spare rotor at site

Value Story

Installed Capacity - 2 Blocks	MW	**726.6**
Aux. Consumption	%	**3.50%**
Net Capacity	MW	701.17
PAF	%	**85%**
PLF	%	**85%**
Gross Gen.	MMkWh	5410
Net Generation	MMkWh	5221
Rotor Replacement Period	Months	**36**
AFC recovery - 2 Blocks	Rs Crores/Month	**65.00**
AFC recovery - 1 Block	Rs Crores/Month	**32.50**
Apprx. Loss with shortfall in AFC recovery due to unavailability of the Block	**Rs Crores**	**845**
	$ MM	**107**

(Note- above calculations are based on TGBPP Petition 2019-2024)

Appendix

Why plan a spare ?

Outcomes

1. Lower the risk of unavailability of unit due to any forced outage
2. Lower wait period incase of forced outage
3. Lower life cycle cost
4. Maintain or increase revenue
5. Considering the location of site, its important to have a in house spare rotor
6. New rotor will provide turbine wheels with new lockwire tab design that will mitigate the risk of crack initiation at a tab location.

Considerations

- How much longer will I run?
  Do I need 1 rotor per GT or do I need a back up

- Will my operating profile shift from hours to starts?
  Does this change my rotor life needs?

- What is the time-horizon for action?
  Must I make a large one-time investment or do I have time for a step-wise improvement at multiple outages to get to the end-state?

Longer cycle time - It takes 36 months to deliver a rotor

- Value Story

A plant would not be operational for 36 months in case of as rotor failure and a spare rotor is not available

There would be an estimated loss of Rs 261 crores (~$33MM) due to shortfall in projected Annual Fixed Charge recovery over this period.*

(Estimated based on TGBPP Petition 2019-24)*

Heavy-Duty Gas Turbine Operating and Maintenance Considerations

GER-3620P (01/21)

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Mardy Merine

GE Power
Atlanta, GA

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Heavy-Duty Gas Turbine Operating and Maintenance Considerations

Introduction

Maintenance costs and machine availability are two of the most important concerns to a heavy-duty gas turbine equipment owner. Therefore, a well thought out maintenance program that reduces the owner's costs while increasing equipment availability should be instituted. For this maintenance program to be effective, owners should develop a general understanding of the relationship between the operating plans and priorities for the plant, the skill level of operating and maintenance personnel, and all equipment manufacturer's recommendations regarding the number and types of inspections, spare parts planning, and other major factors affecting component life and proper operation of the equipment.

In this document, operating and maintenance practices for heavy-duty gas turbines will be reviewed, with emphasis placed on types of inspections plus operating factors that influence maintenance schedules.

Note:

- The operation and maintenance practices outlined in this document are based on full utilization of GE-approved parts, repairs, and services. Contact GE for support and solutions when operational practices are not aligned with GER-3620 recommendations.
- The operating and maintenance discussions presented are generally applicable to all GE heavy-duty gas turbines; i.e., Frames 3, 5, 6, 7, and 9. *Appendix G* provides a list of common B/E-, F-, and H-class heavy-duty gas turbines with current and former naming conventions. For purposes of illustration, the GE GT-7E.03 was chosen for most components except exhaust systems, which are illustrated using different gas turbine models as indicated. Also, the operating and maintenance discussions presented for all B/E-class units are generally applicable to Frame 3 and Frame 5 units unless otherwise indicated. Consult the GE Operation and Maintenance (O&M) Manual for specific questions on a given machine, or contact the local GE service representative.
- GE merged with Alstom in 2015. This revision of GER-3620 includes operating and maintenance considerations applicable to Alstom technology type heavy duty gas turbines (later named GE Annular/Silo Fleet) where explicitly stated. The naming for the GE Annular/Silo Fleet is related to the type of combustion system installed and further described in chapter "Combustion Parts"/Appendix G. Unit specific inspection guidelines (IGLs) should be consulted for detailed operating and maintenance considerations, including maintenance intervals and recommended outage scope.

Maintenance Planning

Advanced planning for maintenance is necessary for utility, industrial, independent power, and cogeneration plant operators in order to maintain reliability and availability. The correct implementation of planned maintenance and inspection provides direct benefits in the avoidance of forced outages, unscheduled repairs, and downtime. The primary factors that affect the maintenance planning process are shown in *Figure 1*. The owners' operating mode and practices will determine how each factor is weighted. Gas turbine parts requiring the most careful attention are those associated with the combustion process, together with those exposed to the hot gases discharged from the combustion system. These are called the combustion section and hot gas path parts, and they include combustion liners, end caps, fuel nozzle assemblies, crossfire tubes, transition pieces, turbine nozzles, turbine stationary shrouds, and turbine buckets.

Additional, longer-term areas for consideration and planning are the lives of the compressor rotor, turbine rotor, casings, and exhaust diffuser. The basic configuration and recommended maintenance of GE heavy-duty gas turbines are oriented toward:

- Maximum periods of operation between inspections and overhauls
- In-place, on-site inspection and maintenance
- Use of local trade skills to disassemble, inspect, and re-assemble gas turbine components

In addition to maintenance of the basic gas turbine, other station auxiliaries require periodic servicing including the control devices, fuel-metering equipment, gas turbine auxiliaries, and load package. The primary maintenance effort involves five basic systems: controls and accessories, combustion, turbine, generator, and balance-of-plant. Controls and accessories are typically serviced in outages of short duration, whereas the other four systems are maintained through less frequent outages of longer duration. This document is focused on

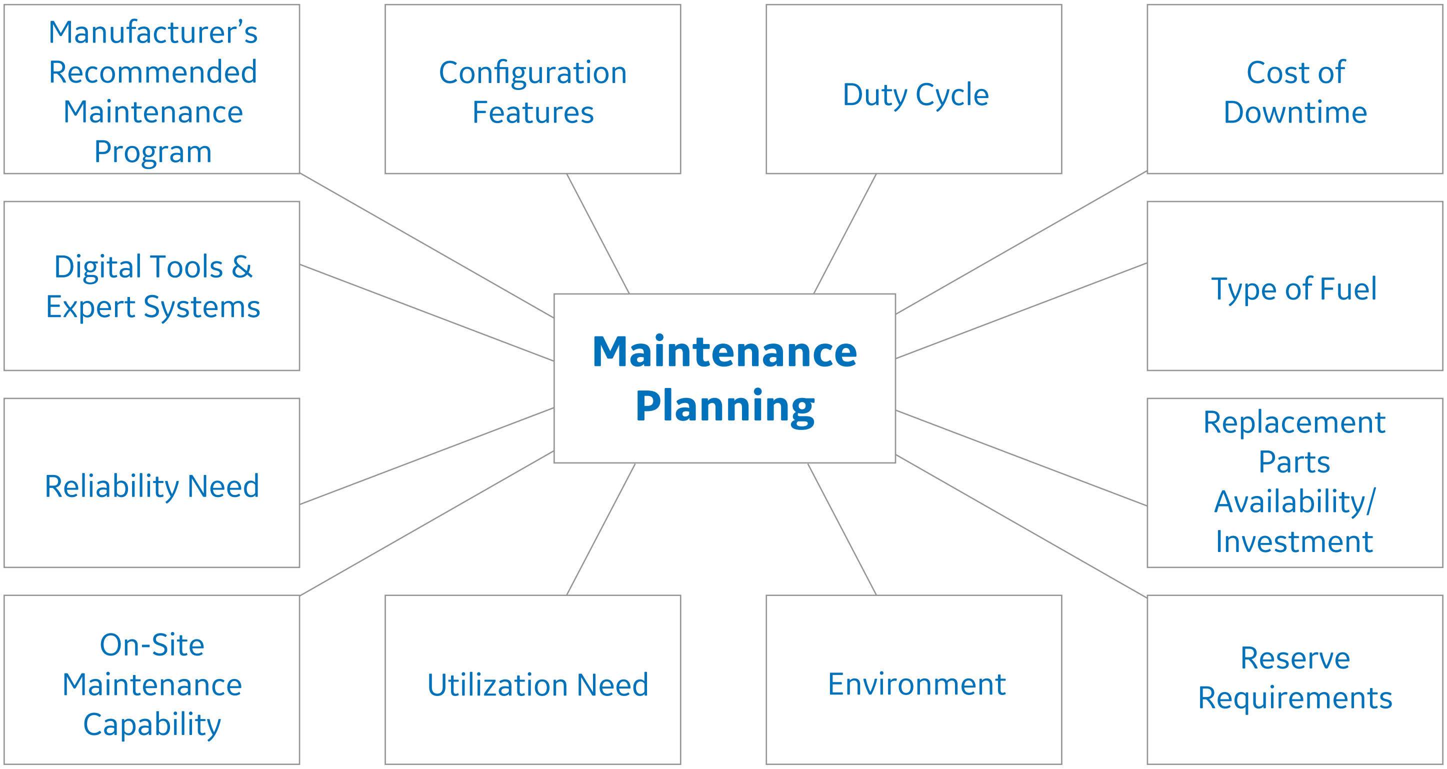

Figure 1. Key factors affecting maintenance planning

maintenance planning for the basic gas turbine, which includes the combustion and turbine systems. The other systems, while outside the scope of this document, also need to be considered for successful plant maintenance.

The inspection and repair requirements, outlined in the O&M Manual provided to each owner, lend themselves to establishing a pattern of inspections. These inspection patterns will vary from site to site, because factors such as air and fuel quality are used to develop an inspection and maintenance program. In addition, supplementary information is provided through a system of Technical Information Letters (TILs) associated with specific gas turbines after shipment. This updated information, in addition to the O&M manual, aims to assure optimum installation, operation, and maintenance of the turbine. (See *Figure 2*.) Many of the TILs contain advisory technical recommendations to help resolve issues and improve the operation, maintenance, safety, reliability, or availability of the turbine. The recommendations contained in TILs should be reviewed and factored into the overall maintenance planning program.

- **O&M Manual**
  - Turbine-specific manual provided to customer
  - Includes outline of recommended Inspection and Repair requirements
  - Helps customers to establish a pattern of systematic inspections for their site
- **Technical Information Letters (TILs)***
  - Issued after shipment of turbine
  - Provides O&M updates related to turbine installation, maintenance, and operation
  - Provides advisory technical recommendations to help resolve potential issues

* Specific smaller frame turbines are issued service letters known as Customer Information Notices (NICs) instead of TILs

Figure 2. Key technical reference documents to include in maintenance planning

Digital Solutions for Asset Management

Operational and business conditions are continually evolving as the power industry is undergoing a rapid transformation. Dynamic conditions require power generation and utility companies to refine how they monitor and maintain operating assets. Businesses that embrace digital solutions have best managed these dynamic shifts in the industry. GE provides a suite of digital tools that is built on years of power production domain expertise. These tools enable strategic plant operation by providing insights related to equipment operation, improved outage planning, and more continuous operation in line with industry demand. GE Power's Asset Performance Management (APM), M&D Center coverage, and Asset Life Odometers, can improve reliability, availability and improve maintenance across not only the gas turbine, but the entire plant.

- **Asset Performance Management (APM)**
  GE Power's Asset Performance Management solution is a dynamic suite of tools, created to provide customers with real time access to data and predictive analytics in a collaborative environment focused on enhancing operation and maintenance decisions. APM not only gives insight into asset operation but also provides the capability to shift to a predictive maintenance operating model. Utilizing GE's expertise as one of the leading OEMs in the industry, physics based and fleet reliability models can more accurately predict the effect of operation and events, on parts and assets across the plant. Our advanced models, linked to failure modes, enable customers to extend useful life of parts, improve outage workloads and enhance outage planning cycles. With one of the widest failure mode coverages in the industry, APM helps asset-centric organizations drive safer and more reliable operations while facilitating improved performance at a lower, more sustainable, cost.
- **Remote Monitoring and Diagnostic (M&D) Center**
  The GE Remote M&D Center provides customers direct access to GE engineers and power production experts for real-time collaboration on operation and maintenance decisions. Utilizing the latest Digital tools, subject matter experts in the M&D center continuously monitor connected assets, evaluate alarm indications, and take action to help ensure accurate diagnoses and rapid remediation. First established over 20 years ago, GE's M&D center is connected to more than 5000 power production assets, giving GE one of the richest data sets of experience from across the world, which combines with our unique domain knowledge to provide excellent analytics, and proven results reducing unplanned downtime.
- **Outage Workscope**
  GE Power's Outage Excellence process, a milestone-driven outage planning cycle, improves asset specific outage workscope through digital predictions and inspections. This methodology enables GE and customers, to plan and execute real-time condition based maintenance and provision emergent work, on time and to budget. Digital inspections are utilized to analyze asset conditions and evaluate technical risks, thereby identifying the correct outage scope to reduce unplanned downtime with no impact to performance.

Gas Turbine Configuration Maintenance Features

The GE heavy-duty gas turbine is constructed to withstand severe duty and to be maintained on-site, with off-site repair required only on certain combustion components, hot gas path parts, and rotor assemblies needing specialized shop service. The following features are configured into GE heavy-duty gas turbines to facilitate on-site maintenance:

- All casings, shells and frames are split on machine horizontal centerline. Upper halves may be lifted individually for access to internal parts.
- With upper-half compressor casings removed, all stationary vanes can be slid circumferentially out of the casings for inspection or replacement without rotor removal. HA gas turbines also require the removal of inner casings for hot gas path maintenance.
- With the upper-half of the turbine shell lifted, each half of the first stage nozzle assembly can be removed for inspection, repair, or replacement without rotor removal. On some units, upper-half, later-stage nozzle assemblies are lifted with the turbine shell, also allowing inspection and/or removal of the turbine buckets. HA gas turbines require removal of the inner turbine shell for access to and maintenance of the hot gas path hardware. Special tooling is required to remove

the inner turbine shell. The GE Annular/Silo Fleet requires removal of the upper-half and inner shell as well as the rotor to access all nozzles for maintenance.

- All turbine buckets are moment-weighed and computer charted in sets for rotor spool assembly so that they may be replaced without the need to remove or rebalance the rotor assembly.
- All bearing housings and liners are split on the horizontal centerline so that they may be inspected and replaced when necessary. The lower half of the bearing liner can be removed without removing the rotor.
- All seals and shaft packings are separate from the main bearing housings and casing structures and may be readily removed and replaced.
- On most configurations, combustion components can be removed for inspection, maintenance, or replacement without lifting any casings. All major accessories, including filters and coolers, are separate assemblies that are readily accessible for inspection or maintenance. They may also be individually replaced as necessary.
- Casings can be inspected during any outage or any shutdown when the unit enclosure is cool enough for safe entry. The exterior of the inlet, compressor case, compressor discharge case, turbine case, and exhaust frame can be inspected during any outage or period when the enclosure is accessible. The interior surfaces of these cases can be inspected to various degrees depending on the type of outage performed. All interior surfaces can be inspected during a major outage.
- Exhaust diffusers can be inspected during any outage by entering the diffuser through the stack or Heat Recovery Steam Generator (HRSG) access doors. The flow path surfaces, flex seals, and other flow path hardware can be visually inspected with or without the use of a borescope. Diffusers can be weld-repaired without the need to remove the exhaust frame upper half.
- Inlets can be inspected during any outage or shutdown.

As an alternative to on-site maintenance, in some cases plant availability can be improved by applying gas turbine modular replacements. This is accomplished by exchanging engine modules or even the complete gas turbine with new or refurbished units. The removed modules/engines can then be sent to an alternate location for maintenance.

Provisions have been built into GE heavy-duty gas turbines to facilitate several special inspection procedures. These special procedures provide for the visual inspection and clearance measurement of some of the critical internal components without removal of the casings. These procedures include gas path borescope inspection (BI), radial clearance measurements, and turbine nozzle axial clearance measurements.

A GE gas turbine is a fully integrated configuration consisting of stationary and rotating mechanical, fluid, thermal, and electrical systems. The turbine's performance, as well as the performance of each component within the turbine, is dependent upon the operating interrelationship between internal components and the total operating systems. GE's engineering process evaluates how new configurations, configuration changes, and repairs affect components and systems. This configuration, evaluation, testing, and approval helps assure the proper balance and interaction between all components and systems for safe, reliable, and economical operation.

The introduction of new, repaired, or modified parts must be evaluated in order to avoid negative effects on the operation and reliability of the entire system. The use of non-GE approved parts, repairs, and maintenance practices may represent a significant risk. Pursuant to the governing terms and conditions, warranties and performance guarantees are predicated upon proper storage, installation, operation, and maintenance, conforming to GE approved operating instruction manuals and repair/modification procedures.

Borescope Inspections

An effective borescope inspection program monitors the condition of internal components without casing removal. Borescope inspections should be scheduled with consideration given to the operation and environment of the gas turbine and information from the O&M Manual and TILs.

GE heavy-duty gas turbine designs incorporate provisions in both compressor and turbine casings for borescope inspection of intermediate compressor rotor stages, first, second and third-stage turbine buckets, and turbine nozzle partitions. These provisions are radially aligned holes through the compressor casings, turbine shell, and internal stationary turbine shrouds that allow the penetration of an optical borescope into the compressor or turbine flow path area. Borescope inspection access locations for the various frame sizes can be found in *Appendix E*.

Figure 3 provides a recommended interval for a planned borescope inspection program following initial baseline inspections. It should be recognized that these borescope inspection intervals are based on average unit operating modes. Adjustment of these borescope intervals may be made based on operating experience, mode of operation, fuels used, employment of online M&D analytics, and the results of previous borescope inspections. GE should be consulted before any change to the borescope frequency is made.

In general, an annual or semiannual borescope inspection uses all the available access points to verify the condition of the internal hardware. This should include, but is not limited to, signs of excessive gas path fouling, symptoms of surface degradation (such as erosion, corrosion, or spalling), displaced components, deformation or object damage, material loss, nicks, dents, cracking, indications of contact or rubbing, or other anomalous conditions.

Borescope	Gas and Distillate Fuel Oil	At combustion inspection or annually, whichever occurs first
	Heavy Fuel Oil	At combustion inspection or semiannually, whichever occurs first

Figure 3. Borescope inspection planning

During BIs and similar inspections, the condition of the upstream components should be verified, including all systems from the filter house to the compressor inlet.

The application of a borescope monitoring program will assist with the scheduling of outages and preplanning of parts requirements, resulting in outage preparedness, lower maintenance costs, and higher availability and reliability of the gas turbine.

Major Factors Influencing Maintenance and Equipment Life

There are many factors that can influence equipment life, and these must be understood and accounted for in the owner's maintenance planning. Starting cycle (hours per start), power setting, fuel, level of steam or water injection, and site environmental conditions are some of the key factors in determining maintenance interval requirements, as these factors directly influence the life of replaceable gas turbine parts.

Non-consumable components and systems, such as the compressor airfoils, may be affected by site environmental conditions as well as plant and accessory system effects. Other factors affecting maintenance planning are shown in *Figure 1*. Operators should consider these external factors to prevent the degradation and shortened life of non-consumable components. GE provides supplementary documentation to assist in this regard.

In the GE approach to maintenance planning, a natural gas fuel unit that operates at base load with no water or steam injection is established as the baseline condition, which sets the maximum recommended maintenance intervals. For operation that differs from the baseline, maintenance factors (MF) are established to quantify the effect on component lives and provide the increased frequency of maintenance required. For example, a maintenance factor of two would indicate a maintenance interval that is half of the baseline interval.

Starts and Hours Criteria

Gas turbines wear differently in continuous duty application and cyclic duty application, as shown in *Figure 5*. Thermal mechanical fatigue is the dominant life limiter for peaking machines, while creep, oxidation, and corrosion are the dominant life limiters for continuous duty machines. GE bases most gas turbine maintenance requirements on independent counts of starts and hours. Whichever criteria limit is first reached determines the maintenance interval. A graphical display of the GE approach is shown in *Figure 8*. In this figure, the inspection interval recommendation is defined by the rectangle established by the starts and hours criteria. These recommendations for inspection fall within the parts' life expectations and are selected such that components acceptable for continued use at the inspection point will have low risk of failure during the subsequent operating interval.

- **Continuous Duty Application**
  - Rupture
  - Creep Deflection
  - Corrosion
  - Oxidation
  - Erosion
  - High-Cycle Fatigue
  - Rubs/Wear
  - Foreign Object Damage
- **Cyclic Duty Application**
  - Thermal Mechanical Fatigue
  - High-Cycle Fatigue
  - Rubs/Wear
  - Foreign Object Damage

Figure 4. Causes of wear – hot gas path components

The interactions of continuous duty and cyclic duty applications can have a second order effect on the lifetime of components. As a result, an alternative to the aforementioned approach, converts each start cycle and operating hour to an equivalent number of operating hours (EOH) with inspection intervals based on the equivalent hours count. The EOH counting may be done through either a linear or elliptical formula. A third variant for determining maintenance intervals is a combination of the starts, operating hours and EOH concept.

These various EOH methods are illustrated in *Figure 6*.

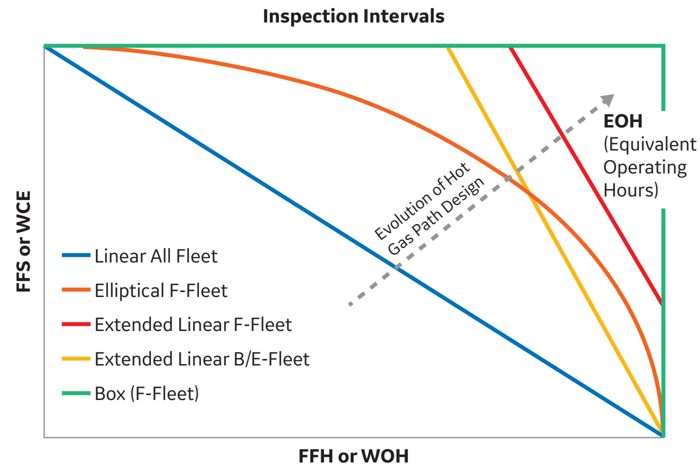

Figure 6. Hot gas path maintenance interval comparisons. GE method vs. EOH method. FFS = Factored Fired Starts, FFH = Factored Fired Hours, WCE = Weighted Cyclic Events, WOH = Weighted Operating Hours.

Service Factors

The effect of fired starts and fired hours on component lifetime are not the only wear mechanisms which must be considered. As

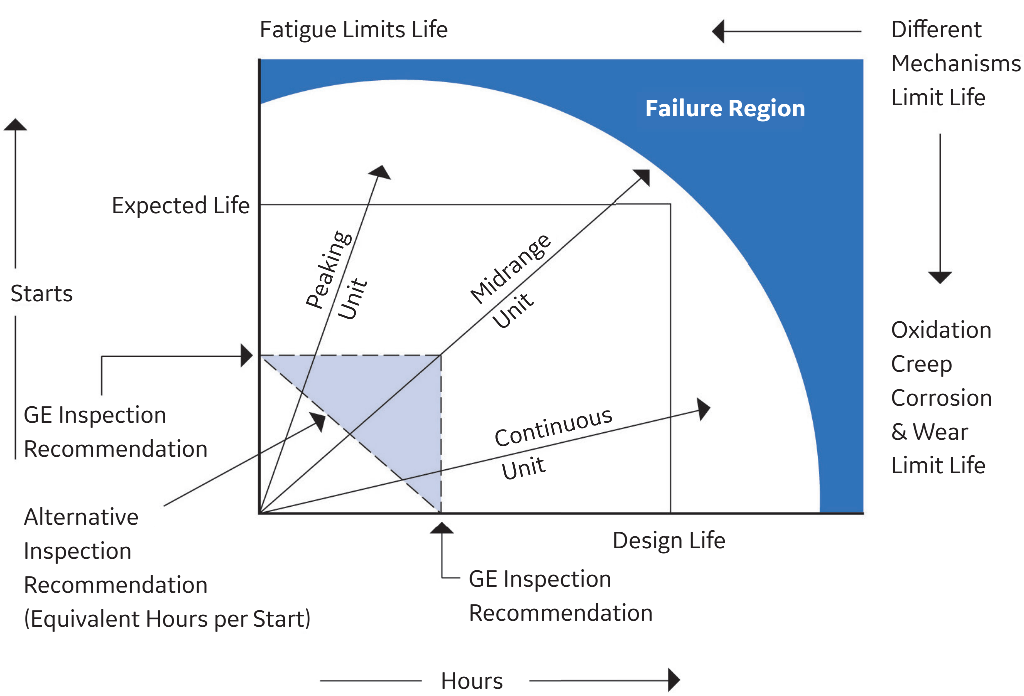

Figure 5. GE bases gas turbine maintenance requirements on independent counts of starts and hours

shown in *Figure 7*, influences such as fuel type and quality, firing temperature setting, and the amount of steam or water injection are considered with regard to the hours-based criteria. Startup rate and the number of trips are considered with regard to the starts-based criteria. In both cases, these influences may reduce the maintenance intervals.

Typical baseline inspection intervals (6B.03/7E.03):

Hot gas path inspection	24,000 hrs or 1200 starts
Major inspection	48,000 hrs or 2400 starts

Criterion is hours or starts (whichever occurs first)

Factors affecting maintenance:

Hours-Based Factors

- Fuel type
- Peak load
- Diluent (water or steam injection)

Starts-Based Factors

- Start type (conventional or peaking-fast)
- Start load (max. load achieved during start cycle, e.g. part, base, or peak load)
- Shutdown type (normal cooldown, rapid cooldown, or trip)

Figure 7. Maintenance factors

When these service or maintenance factors are involved in a unit's operating profile, the hot gas path maintenance "rectangle" that describes the specific maintenance criteria for this operation is reduced from the ideal case, as illustrated in *Figure 8*. The following discussion will take a closer look at the key operating factors and how they can affect maintenance intervals as well as parts refurbishment/replacement intervals.

Maintenance Factors Reduce Maintenance Interval

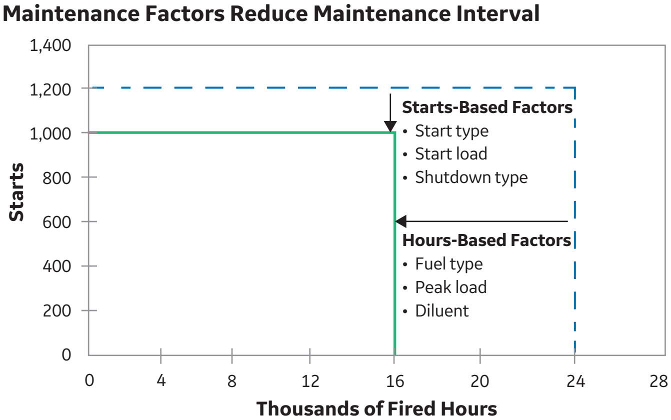

Figure 8. GE maintenance intervals

Fuel

Fuels burned in gas turbines range from clean natural gas to residual oils and affect maintenance, as illustrated in *Figure 9*. Although *Figure 9* provides the basic relationship between fuel severity factor and hydrogen content of the fuel, there are other fuel constituents that should be considered. Selection of fuel severity factor typically requires a comprehensive understanding of fuel constituents and how they affect system maintenance. The selected fuel severity factor should also be adjusted based on inspection results and operating experience.

Heavier hydrocarbon fuels have a maintenance factor ranging from three to four for residual fuels and two to three for crude oil fuels. This maintenance factor is adjusted based on the water-to-fuel ratio in cases when water injection for NO_x abatement is used. These fuels generally release a higher amount of radiant thermal energy, which results in a subsequent reduction in combustion hardware life, and frequently contain corrosive elements such as sodium, potassium, vanadium, and lead that can cause accelerated hot corrosion of turbine nozzles and buckets. In addition, some elements in these fuels can cause deposits either directly or through compounds formed with inhibitors that are used to prevent corrosion. These deposits affect performance and can require more frequent maintenance.

Distillates, as refined, do not generally contain high levels of these corrosive elements, but harmful contaminants can be present in these fuels when delivered to the site. Two common ways of contaminating number two distillate fuel oil are: salt-water ballast mixing with the cargo during sea transport, and contamination of the distillate fuel when transported to site in tankers, tank trucks, or pipelines that were previously used to transport contaminated fuel, chemicals, or leaded gasoline. GE's experience with distillate fuels indicates that the hot gas path maintenance factor can range from as low as one (equivalent to natural gas) to as high as three. Unless operating experience suggests otherwise, it is recommended that a hot gas path maintenance factor of 1.5 be used for operation on distillate oil. Note also that contaminants in liquid fuels can affect the life of gas turbine auxiliary components such as fuel pumps and flow dividers.

Not shown in *Figure 9* are alternative fuels such as industrial process gas, syngas, and bio-fuel. A wide variety of alternative fuels exist, each with their own considerations for combustion in

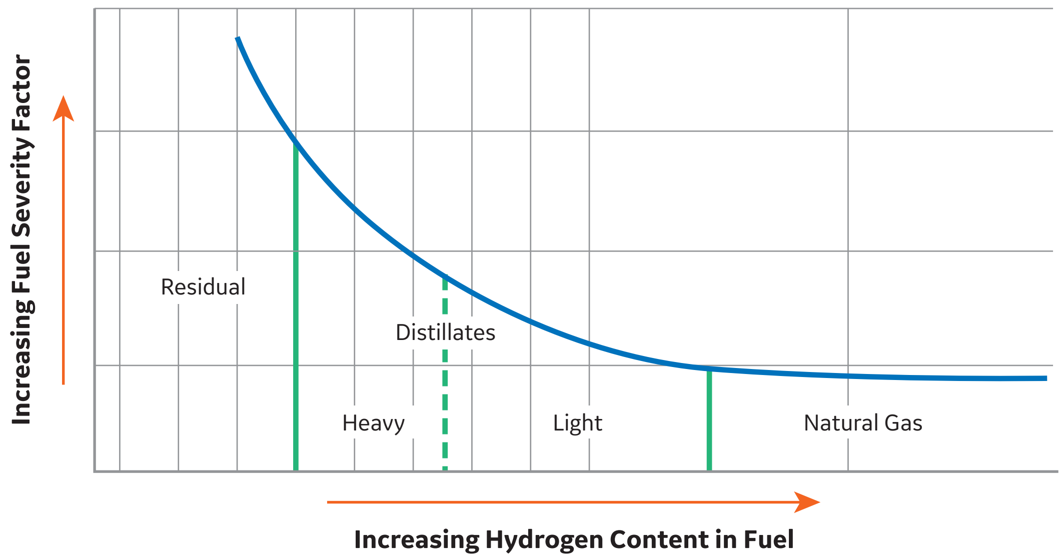

Figure 9. Estimated effect of fuel type on maintenance

a gas turbine. Although some alternative fuels can have a neutral effect on gas turbine maintenance, many alternative fuels require unit-specific intervals and fuel severity factors to account for their fuel constituents or water/steam injection requirements.

As shown in *Figure 9*, natural gas fuel that meets GE specification is considered the baseline, optimum fuel with regard to turbine maintenance. Proper adherence to GE fuel specifications in GEI-41040 and GEI-41047 is required to allow proper combustion system operation and to maintain applicable warranties. Liquid hydrocarbon carryover can expose the hot gas path hardware to severe overtemperature conditions that can result in significant reductions in hot gas path parts lives or repair intervals. Liquid hydrocarbon carryover is also responsible for upstream displacement of flame in combustion chambers, which can lead to severe combustion hardware damage. Owners can control this potential issue by using effective gas scrubber systems and by superheating the gaseous fuel prior to use to approximately 50°F (28°C) above the hydrocarbon dew point temperature at the turbine gas control valve connection. For exact superheat requirement calculations, please review GEI 41040. Integral to the system, coalescing filters installed upstream of the performance gas heaters is a best practice and ensures the most efficient removal of liquids and vapor phase constituents.

Undetected and untreated, a single shipment of contaminated fuel can cause substantial damage to the gas turbine hot gas path components. Potentially high maintenance costs and loss of availability can be reduced or eliminated by:

- Placing a proper fuel specification on the fuel supplier. For liquid fuels, each shipment should include a report that identifies specific gravity, flash point, viscosity, sulfur content, pour point and ash content of the fuel.
- Providing a regular fuel quality sampling and analysis program. As part of this program, continuous monitoring of water content in fuel oil is recommended, as is fuel analysis that, at a minimum, monitors vanadium, lead, sodium, potassium, calcium, and magnesium.
- Providing proper maintenance of the fuel treatment system when burning heavier fuel oils.
- Providing cleanup equipment for distillate fuels when there is a potential for contamination.

In addition to their presence in the fuel, contaminants can also enter the turbine via inlet air, steam/water injection, and carryover from evaporative coolers. In some cases, these sources of contaminants have been found to cause hot gas path degradation equal to that seen with fuel-related contaminants. GE specifications define limits for maximum concentrations of contaminants for fuel, air, and steam/water.

In addition to fuel quality, fuel system operation is also a factor in equipment maintenance. Liquid fuel should not remain unpurged or in contact with hot combustion components after shutdown and should not be allowed to stagnate in the fuel system when strictly gas fuel is run for an extended time. To reduce varnish and coke accumulation, dual fuel units (gas and liquid capable) should be shutdown running gas fuel whenever possible. Likewise, during extended operation on gas, regular transfers from gas to liquid are recommended to exercise the system components and reduce coking.

Contamination and build-up may prevent the system from removing fuel oil and other liquids from the combustion, compressor discharge, turbine, and exhaust sections when the unit is shut down or during startup. Liquid fuel oil trapped in the system piping also creates a safety risk. Correct functioning of the false start drain system (FSDS) should be ensured through proper maintenance and inspection per GE procedures.

Firing Temperatures

Peak load is defined as operation above base load and is achieved by increasing turbine operating temperatures. Significant operation at peak load will require more frequent maintenance and replacement of hot gas path and combustion components. *Figure 10* defines the parts life effect corresponding to increases in firing temperature. It should be noted that this is not a linear relationship, and this equation should not be used for decreases in firing temperature.

B/E-class: $$A_p = e^{(0.018*\Delta T_f)}$$

F-class: $$A_p = e^{(0.023*\Delta T_f)}$$

A_p = Peak fire severity factor
ΔT_f = Peak firing temperature adder (in °F)

Figure 10. Peak fire severity factors - natural gas and light distillates

It is important to recognize that a reduction in load does not always mean a reduction in firing temperature. For example, in heat recovery applications, where steam generation drives overall plant efficiency, load is first reduced by closing variable inlet guide vanes to reduce inlet airflow while maintaining maximum exhaust temperature. For these combined cycle applications, firing temperature does not decrease until load is reduced below approximately 80% of rated output. Conversely, a non-DLN turbine running in simple cycle mode maintains fully open inlet guide vanes during a load reduction to 80% and will experience over a 200°F/111°C reduction in firing temperature at this output level. The hot gas path and combustion part lives change for different modes of operation. This turbine control effect is illustrated in *Figure 11*. Turbines with DLN combustion systems use inlet guide vane turndown as well as inlet bleed heat to extend operation of low NO_x premix operation to part load conditions.

Firing temperature effects on hot gas path and combustion maintenance as described above, relate to clean burning fuels such as natural gas and light distillates. Higher operating temperatures affect the creep capability of hot gas path components which is the primary life limiting mechanism. The life capability of combustion components can also be affected.

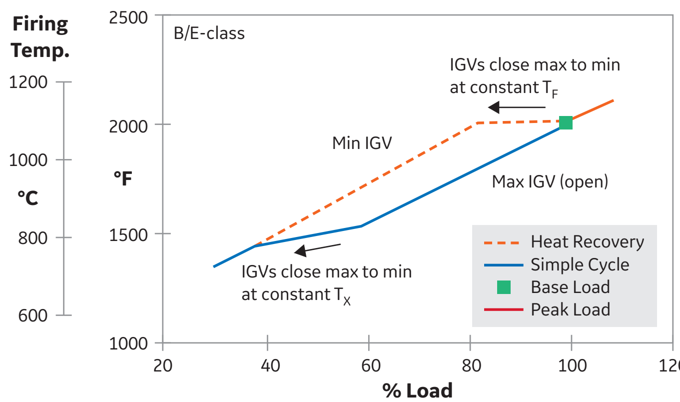

Figure 11. Firing temperature and load relationship – heat recovery vs. simple cycle operation

Steam/Water Injection

Water or steam injection for emissions control or power augmentation can affect part life and maintenance intervals even when the water or steam meets GE specifications. This relates to the effect of the added water on the hot gas transport properties. Higher gas conductivity, in particular, increases the heat transfer to the buckets and nozzles and can lead to higher metal temperature and reduced part life.

Part life reduction from steam or water injection is directly affected by the way the turbine is controlled. The control system on most base load applications reduces firing temperature as water or steam is injected. This is known as dry control curve operation, which counters the effect of the higher heat transfer on the gas side and results in no net effect on bucket life. This is the standard configuration for all gas turbines, both with and without water or steam injection. On some installations, however, the control system is configured to keep firing temperature constant with water or steam injection. This is known as wet control curve operation, which results in additional unit output but decreases parts life as previously described. Units controlled in this way are generally in peaking applications where annual operating hours are low or where operators have determined that reduced parts lives are justified by the power advantage. *Figure 12* illustrates the wet and dry control curve and the performance differences that result from these two different modes of control.

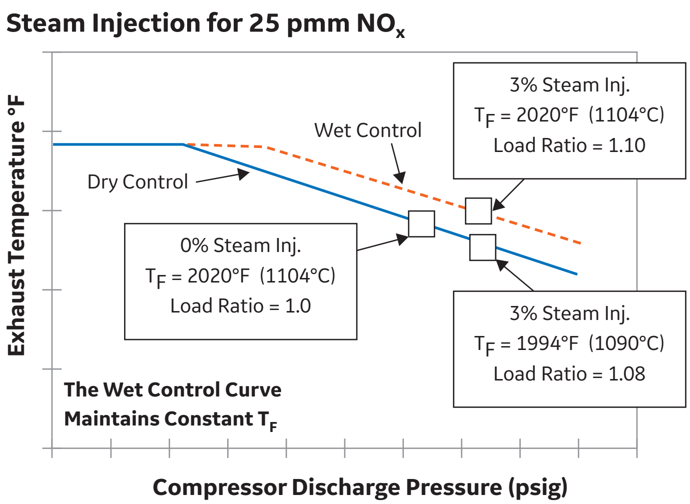

Figure 12. Exhaust temperature control curve – dry vs. wet control 7E.03

An additional factor associated with water or steam injection relates to the higher aerodynamic loading on the turbine components that results from the injected flow increasing the cycle pressure ratio. This additional loading can increase the downstream deflection rate of the second- and third-stage nozzles, which would reduce the repair interval for these components. However, the introduction of high creep strength stage two and three nozzle (S2N/S3N) alloys, such as GTD-222™* and GTD-241™*, has reduced this factor in comparison to previously applied materials such as FSX-414* and N-155*.

Water injection for NO_x abatement should be performed according to the control schedule implemented in the controls system. Forcing operation of the water injection system at high loads can lead to combustion and HGP hardware damage due to thermal shock.

Cyclic Effects and Fast Starts

In the previous discussion, operating factors that affect the hours-based maintenance criteria were described. For the starts-based maintenance criteria, operating factors associated with the cyclic effects induced during startup, operation, and shutdown of the turbine must be considered. Operating conditions other than the standard startup and shutdown sequence can potentially reduce the cyclic life of the gas turbine components and may require more frequent maintenance including part refurbishment and/or replacement.

Fast starts are common deviations from the standard startup sequence. GE has introduced a number of different fast start systems, each applicable to particular gas turbine models. Fast starts may include any combination of Anticipated Start Purge, fast acceleration (light-off to FSNL), and fast loading. Some fast start methods do not affect inspection interval maintenance factors. Fast starts that do affect maintenance factors are referred to as peaking-fast starts or simply peaking starts.

The effect of peaking-fast starts on the maintenance interval depends on the gas turbine model, the unit configuration, and the particular start characteristics. For example, simple cycle 7F.03 units with fast start capability can perform a peaking start in which the unit is brought from ignition to full load in less than 15 minutes. Conversely, simple cycle 6B and other smaller frame units can perform conventional starts that are less than 15 minutes without affecting any maintenance factors. For units that have peaking-fast start capability, *Figure 13* shows conservative peaking-start factors that may apply.

Because the peaking-fast start factors can vary by unit and by system, the baseline factors may not apply to all units. For example, the latest 7F.03 peaking-fast start system has the start factors shown in *Figure 14*. For comparison, the 7F.03 nominal fast start that does not affect maintenance is also listed. Consult applicable unit-specific documentation or your GE service representative to verify the hours/starts factors that apply.

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Starts-Based Combustion Inspection

A_s = 4.0 for B/E-class

A_s = 2.0 for F-class

Starts-Based Hot Gas Path Inspection

P_s = 3.5 for B/E-class

P_s = 1.2 for F-class

Starts-Based Rotor Inspection

F_s = 2.0 for F-class*

* See *Figure 21* for details

Refer to unit specific documentation for HA-class

Figure 13. Peaking-fast start factors

7F.03 Starts-Based Combustion Inspection

A_s = 1.0 for 7F nominal fast start

A_s = 1.0 for 7F peaking-fast start

7F.03 Starts-Based Hot Gas Path Inspection

P_s = Not applicable for 7F nominal fast start (counted as normal starts)

P_s = 0.5 for 7F peaking-fast start

7F.03 Starts-Based Rotor Inspection

F_s = 1.0 for 7F nominal fast start

F_s = 2.0 for 7F peaking-fast start*

* See *Figure 21* for details

Figure 14. 7F.03 fast start factors

Hot Gas Path Parts

Figure 15 illustrates the firing temperature changes occurring over a normal startup and shutdown cycle. Light-off, acceleration, loading, unloading, and shutdown all produce gas and metal temperature changes. For rapid changes in gas temperature, the edges of the bucket or nozzle respond more quickly than the thicker bulk section, as pictured in *Figure 16*. These gradients, in turn, produce thermal stresses that, when cycled, can eventually lead to cracking.

Figure 17 describes the temperature/strain history of a representative bucket stage 1 bucket during a normal startup and shutdown cycle. Light-off and acceleration produce transient compressive strains in the bucket as the fast responding leading edge heats up more quickly than the thicker bulk section of the airfoil. At full load conditions, the bucket reaches its maximum metal temperature and a compressive strain is produced from the normal steady state temperature gradients that exist in the cooled part. At shutdown, the conditions reverse and the faster responding edges cool more quickly than the bulk section, which results in a tensile strain at the leading edge.

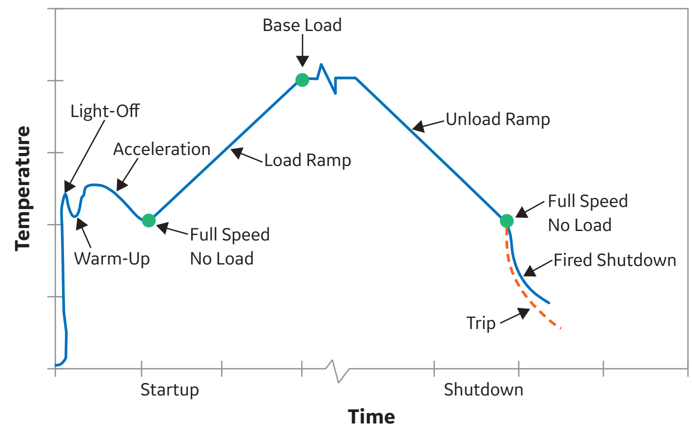

Figure 15. Turbine start/stop cycle – firing temperature changes

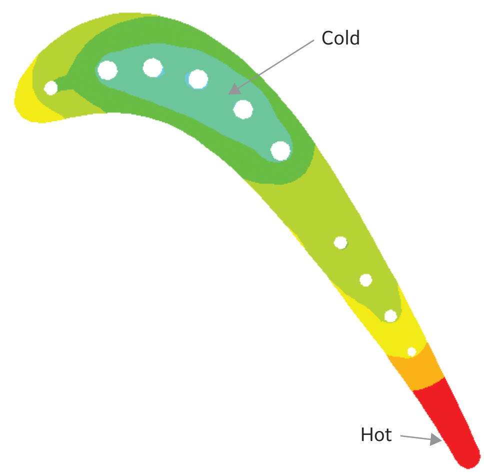

Figure 16. Second stage bucket transient temperature distribution

Thermal mechanical fatigue testing has found that the number of cycles that a part can withstand before cracking occurs is strongly influenced by the total strain range and the maximum metal temperature. Any operating condition that significantly increases the strain range and/or the maximum metal temperature over the normal cycle conditions will reduce the fatigue life and increase the starts-based maintenance factor. For example,

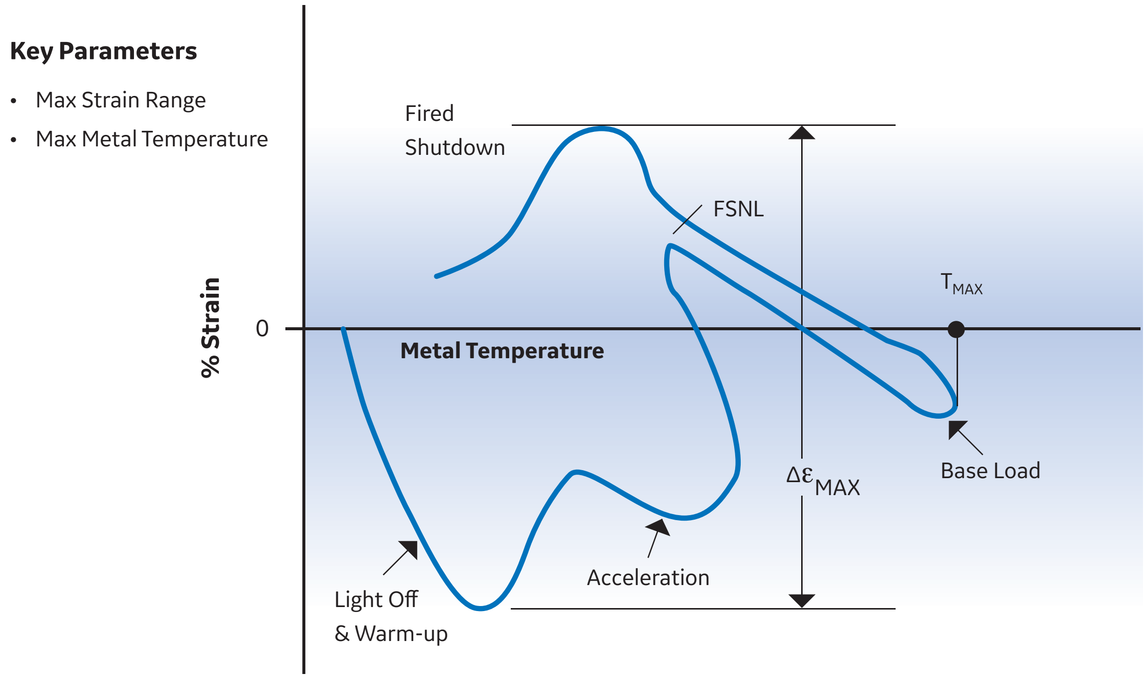

Figure 17. Representative Bucket low cycle fatigue (LCF)"

Figure 18 compares a normal operating cycle with one that includes a trip from full load. The significant increase in the strain range for a trip cycle results in a life effect that equates to eight normal start/stop cycles, as shown. Trips from part load will have a reduced effect because of the lower metal temperatures at the initiation of the trip event. *Figure 19* illustrates that while a trip from between 80% and 100% load has an 8:1 trip severity factor, a trip from full speed no load (FSNL) has a trip severity factor of 2:1. Similarly, overfiring of the unit during peak load operation leads to increased component metal temperatures. As a result, a trip from peak load has a trip severity factor of 10:1.

Trips are to be assessed in addition to the regular startup/shutdown cycles as starts adders. As such, in the factored starts equation of *Figure 42*, one is subtracted from the severity factor so that the net result of the formula (*Figure 42*) is the same as that dictated by the increased strain range. For example, a startup and trip

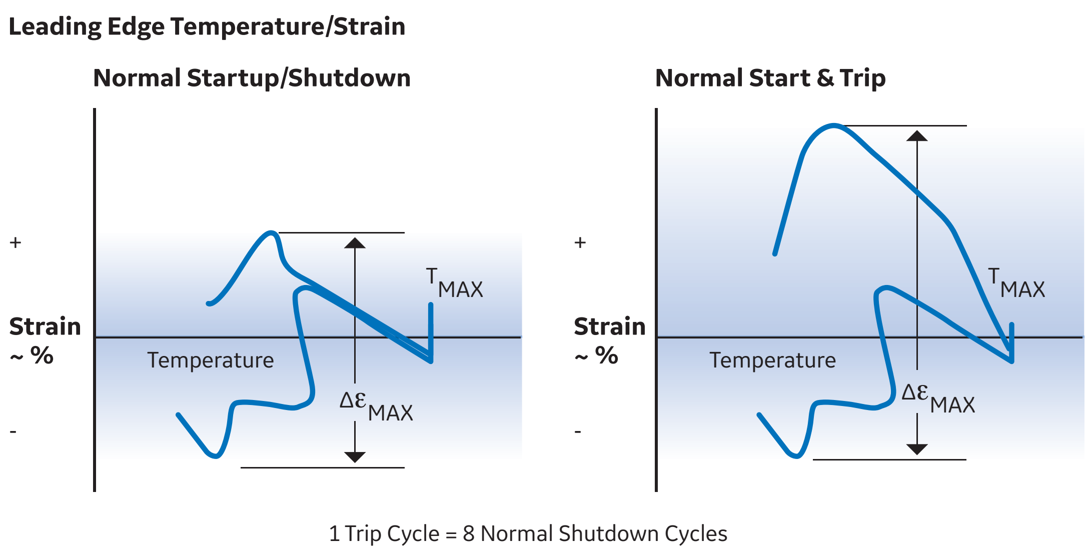

Figure 18. Representative Bucket low cycle fatigue (LCF)

from base load would count as eight total cycles (one cycle for startup to base load plus 8-1=7 cycles for trip from base load), just as indicated by the 8:1 maintenance factor.

Similarly to trips from load, peaking-fast starts will affect the starts-based maintenance interval. Like trips, the effects of a peaking-fast start on the machine are considered separate from a normal cycle and their effects must be tabulated in addition to the normal start/stop cycle. However, there is no -1 applied to these factors, so a 7F.03 peaking-fast start during a base load cycle would have a total effect of 1.5 cycles. Refer to *Appendix A* for factored starts examples, and consult unit-specific documentation to determine if an alternative hot gas path peaking-fast start factor applies.

While the factors described above will decrease the starts-based maintenance interval, part load operating cycles allow for an extension of the maintenance interval. *Figure 20* can be used in considering this type of operation. For example, two operating cycles to maximum load levels of less than 60% would equate to one start to a load greater than 60% or, stated another way, would have a maintenance factor of 0.5.

Factored starts calculations are based upon the maximum load achieved during operation. Therefore, if a unit is operated at part load for three weeks, and then ramped up to base load for the last ten minutes, then the unit's total operation would be described as a base load start/stop cycle.

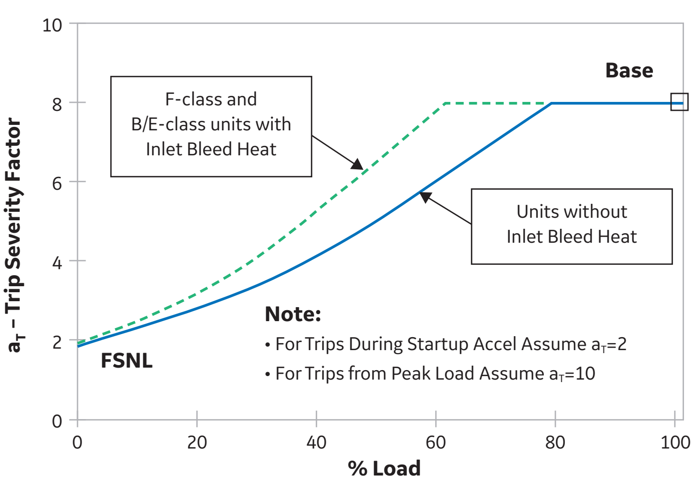

Figure 19. Maintenance factor – trips from load

Rotor Parts

The maintenance and refurbishment requirements of the rotor structure, like the hot gas path components, are affected by the cyclic effects of startup, operation, and shutdown, as well as loading and off-load characteristics. Maintenance factors specific to the operating profile and rotor configuration must be incorporated into the operator's maintenance planning. A GE Rotor life extension is required when the accumulated rotor factored fired starts or hours reach the inspection limit. (See *Figure 43* and *Figure 44* in the Inspection Intervals section.)

The thermal condition when the startup sequence is initiated is a major factor in determining the rotor maintenance interval and individual rotor component life. Rotors that are cold when the startup commences experience transient thermal stresses as the turbine is brought on line. Large rotors with their longer thermal time constants develop higher thermal stresses than smaller rotors undergoing the same startup time sequence. High thermal stresses reduce thermal mechanical fatigue life and the inspection interval.

In addition to the startup thermal condition, the rotor shutdown thermal condition can influence the rotor maintenance factor as well. A normal rotor cool down following a normal fired shutdown or trip relies heavily on natural convection for cool down of the rotor structure at turning gear/ratchet speed as discussed in *Figure F-1*. However, an operator may elect to perform a rapid/forced/crank cool down (see Rapid Cool-Down, *page 23*) which is defined as when an operator creates a forced convection cooling flow thru the unit by operating the rotor at an

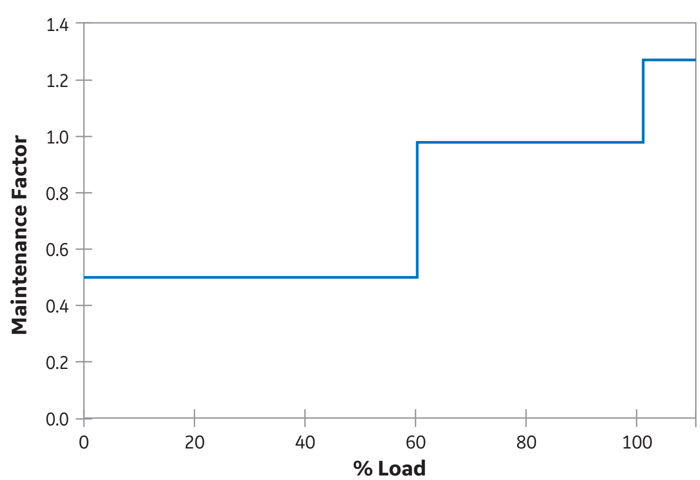

Figure 20. Maintenance factor – effect of start cycle maximum load level

increased mechanical speed (typically purge speed) after a normal shutdown or trip to achieve a faster than normal cool down of the rotor structure. This accelerated cooling down of the rotor has transient thermal effects which increase the thermal mechanical fatigue damage to the rotor structure.

Initial rotor thermal condition is not the only operating factor that influences rotor maintenance intervals and component life. Peaking-fast starts, where the turbine is ramped quickly to load, also increase thermal gradients on the rotor.

Though the concept of rotor maintenance factors is applicable to all gas turbine rotors, only F-class rotors will be discussed in detail. For all other rotors, reference unit-specific documentation to determine additional maintenance factors that may apply. The rotor maintenance factor for a startup is a function of the downtime following a previous period of operation. As downtime increases, the rotor metal temperature approaches ambient conditions, and thermal fatigue during a subsequent startup increases. As such, cold starts are assigned a rotor maintenance factor of two and hot starts a rotor maintenance factor of less than one due to the lower thermal stress under hot conditions. This effect varies from one location in the rotor structure to another. The most limiting location determines the overall rotor maintenance factor.

Figure 21 lists recommended operating factors that should be used to determine the rotor's overall maintenance factor for certain F-class rotors. The physics governing the thermal stresses and mechanical fatigue are similar for FA.05 and 6F.01 class rotors; however, F-class factors may not be appropriate for inspection intervals see unit specific documentation. Refer to technical information letters for HA rotor maintenance factors.

The significance of each of these factors is dependent on the unit operation. There are three categories of operation that are typical of most gas turbine applications. These are peaking, cyclic, and continuous duty as described below:

- Peaking units have a relatively high starting frequency and a low number of hours per start. Operation follows a seasonal demand. Peaking units will generally see a high percentage of warm and cold starts.
- Cyclic units start daily with weekend shutdowns. Twelve to sixteen hours per start is typical, which results in a warm rotor condition for a large percentage of the starts. Cold starts are generally seen only after a maintenance outage or following a two-day weekend outage.
- Continuous duty applications see a high number of hours per start. Most starts are cold because outages are generally maintenance driven. While the percentage of cold starts is high, the total number of starts is low. The rotor maintenance interval on continuous duty units will be determined by operating hours rather than starts.

Figure 22 lists reference operating profiles of these three general categories of gas turbine applications. These duty cycles have different combinations of hot, warm, and cold starts with each starting condition having a different effect on rotor maintenance

F, FA, and FB*-class Rotors

	Rotor Maintenance Factors	
	Peaking-Fast Start**	**Normal Start**
Hot 1 Start Factor (0 < downtime ≤ 1 hour) ****	4.0	2.0
Hot 2 Start Factor (1 hour < downtime ≤ 4 hours) ****	1.0	0.5
Warm 1 Start Factor (4 hours < downtime ≤ 20 hours) ****	1.8	0.9
Warm 2 Start Factor (20 hours < downtime ≤ 40 hours) ****	2.8	1.4
Cold Start Factor (Downtime > 40 hours)****	4.0	2.0
Rapid/Forced/Crank Cooling Shutdown ***	4.0	4.0

* Other factors may apply to early 9F.03 units.

** An F-class peaking-fast start is typically a start in which the unit is brought from ignition to full load in less than 15 minutes.

*** If a unit is on turning gear/ratchet after normal shutdown or trip for more than 8 hours prior to Rapid/Forced/Crank cooling being initiated, this factor is equal to 0.0 as outlined in *Figure 44*

**** Downtime hours counted from time unit reaches turning gear/ratchet until initiation of next start.

Figure 21. Operation-related maintenance factors

	Peaking	Cyclic	Continuous
Hot 2 Start Factor (1 hour < downtime ≤ 4 hours)	3%	1%	10%
Warm 1 Start Factor (4 hours < downtime ≤ 20 hours)	10%	82%	5%
Warm 2 Start Factor (20 hours < downtime ≤ 40 hours)	37%	13%	5%
Cold Start Factor (Downtime > 40 hours)	50%	4%	80%
Hours/Start	4	16	400
Hours/Year	600	4800	8200
Starts/Year	150	300	21
Percent Rapid/Forced/ Crank Cools	3%	1%	10%
Rapid/Forced/Crank Cooling Shutdown/Year	5	3	2
Typical Maintenance Factor (Starts-Based)	1.7	1.0	NA
• Operational Profile is Application Specific • Inspection Interval is Application Specific			

Figure 22. 7F/7FA gas turbine reference operational profile

interval as previously discussed. As a result, the starts-based rotor maintenance interval will depend on an application's specific duty cycle. In the Rotor Inspection Interval section, a method will be described to determine a maintenance factor that is specific to the operation's duty cycle. The application's integrated maintenance factor uses the rotor maintenance factors described above in combination with the actual duty cycle of a specific application and can be used to determine rotor inspection intervals. In this calculation, the reference duty cycle that yields a starts-based maintenance factor equal to one is defined in *Figure 23*. Duty cycles different from the *Figure 23* definition, in particular duty cycles with more cold starts or a high number of rapid/forced/crank cool operations, will have a maintenance factor greater than one.

Turning gear or ratchet operation after shutdown and before starting/restarting is a crucial part of normal operating procedure. After a shutdown, turning of the warm rotor is essential to avoid bow, or bend, in the rotor. Initiating a start with the rotor in a bowed condition could lead to high vibrations and excessive rubs. *Figure F-1* describes turning gear/ratchet scenarios and operation guidelines (See *Appendix*). Relevant operating instructions and TILs should be adhered to where applicable. As a best practice, units should remain on turning gear or ratchet following a planned shutdown until wheelspace temperatures have stabilized at or near ambient temperature. If the unit is to see no further activity for 48 hours after cool-down is completed, then it may be taken off of turning gear.

Figure F-1 also provides guidelines for hot restarts. When an immediate restart is required, it is recommended that the rotor be placed on turning gear for one hour following a trip from load, trip from full speed no load, or normal shutdown. This will allow transient thermal stresses to subside before superimposing a startup transient. If the machine must be restarted in less than one hour, a start factor of 2 will apply.

Longer periods of turning gear operation may be necessary prior to a cold start or hot restart if bow is detected. Vibration data taken while at crank speed can be used to confirm that rotor bow is at acceptable levels and the start sequence can be initiated. Users should reference the O&M Manual and appropriate TILs for specific instructions and information for their units.

Baseline Unit

Cyclic Duty			
6	Starts/Week		
16	Hours/Start		
4	Outage/Year Maintenance		
50	Weeks/Year		
4800	Hours/Year		
300	Starts/Year		
	12	Cold Starts/Year	4%
	39	Warm 2 Starts/Year	13%
	246	Warm 1 Starts/Year	82%
	3	Hot 2 Starts/Year	1%
	0	Rapid/Forced/Crank Cools/Year	
	1	Maintenance Factor	
Baseline Unit Achieves Maintenance Factor = 1			

Figure 23. Baseline for starts-based maintenance factor definition

Combustion Parts

From hardware configuration standpoint, GE combustion hardware configuration include transition pieces, combustion liners, combustion unibodies, combustor cones, flow sleeves, head-end assemblies containing fuel nozzles and cartridges, end caps and end covers, and assorted other hardware parts including cross-fire tubes, spark plugs and flame detectors. In addition, there are various fuel and air delivery components such as purge or check valves and flexible hoses.

GE offers several types of combustion systems configurations: Standard combustors, Multi-Nozzle Quiet Combustors (MNQC), Integrated Gasification Combined Cycle (IGCC) combustors, and Dry Low NO_x (DLN) combustors. The GE Annular/Silo Fleet offers further combustion systems: Silo combustors with single burners (SB) for Natural or LBTu gases or multiple EnVironmental burners (EV), furthermore Annular combustors with EnVironmental Burners (EV), Advanced EnVironmental Burners (AEV) and Sequential EnVironmental Burners (SEV). Each of the combustion configurations mentioned above, has specific gas or liquid fuel operating characteristics that affect differently combustion hardware factored maintenance intervals and refurbishment requirements.

Gas turbines fitted with DLN combustion systems operate in incremental combustion modes to reach to base load operation. A combustion mode constitutes a range of turbine load where fuel delivery in combustion cans is performed via certain combination of fuel nozzles or fuel circuits within the fuel nozzles. For example, for DLN 2.6 combustion systems, mode 3 refers to the load range when fuel is being delivered to PM 1 (Premix 1) and PM 2 (Premix 2) fuel nozzles through gas control valves PM 1 and PM 2.

Combustion modes change when turbine load, and consequently combustion reference temperature value (TTRF1 or CRT) crosses threshold values defining the initiation of next combustion mode.

- **Continuous mode operation** mentioned in this section refers to intentional turbine operation in a certain combustion mode for longer than what typically takes during normal startup/shutdown.
- **Extended mode operation** mentioned in this sections is possible in DLN1 or 1+ and DLN2 or 2+ combustion configuration only, where the controls logics can be forced to extend a Lean-Lean Mode or Piloted Premixed Mode beyond the turbine load corresponding to a normal combustion mode transfer (as defined via TTRF1 or CRT values).

From operational standpoint, earlier DLN combustion configurations such as DLN1/1+, DLN2/2+ use diffusion combustion (non-Premix) at part load before reaching the low emissions combustion mode (Premix). These combustion modes nomenclatures are referred to as Lean-Lean, extended Lean-Lean, sub-Piloted Premix and Piloted Premix Modes. General recommendation for continuous mode operation is in the combustion mode that provides guaranteed emissions, which is the premixed combustion mode (PM). This combustion mode is also the most beneficial operation mode for ensuring expected hardware life.

Continuous and extended mode operation in non-PM combustion modes is not recommended due to reduction in combustion hardware life as shown in *Figure 24*.

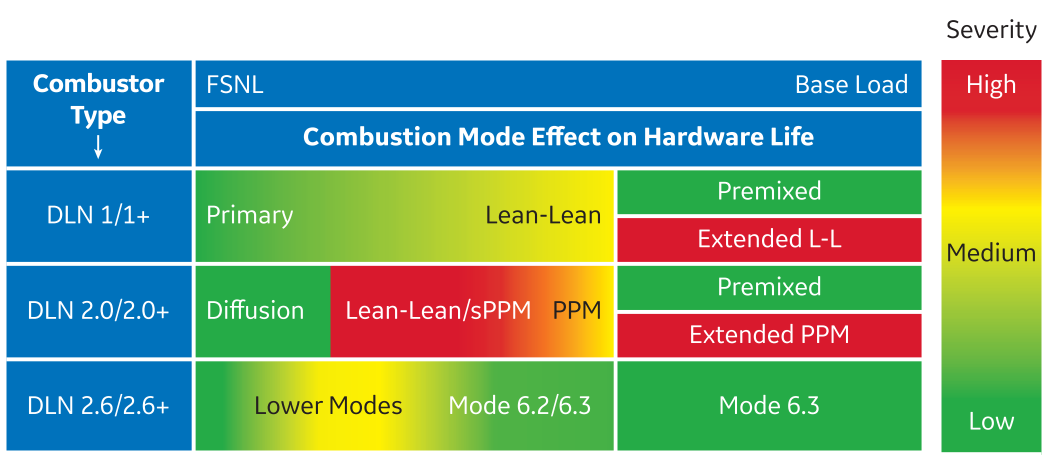

Figure 24: DLN combustion mode effect on combustion hardware

The use of non-emissions compliant combustion modes can affect the factored maintenance intervals of combustion hardware as shown below:

- DLN-1/DLN-1+ extended lean-lean operation results in a maintenance factor of 10. Nimonic 263 will have a maintenance factor of 4.
- DLN 2.0/DLN 2+ extended piloted premixed operation results in a maintenance factor of 10.
- Continuous mode operation in Lean-Lean (L-L), sub-Piloted Premixed (sPPM), or Piloted Premixed (PPM) modes is not recommended as it will accelerate combustion hardware degradation.
- In addition, cyclic operation between piloted premixed and premixed modes leads to thermal loads on the combustion liner and transition piece similar to the loads encountered during the startup/shutdown cycle.

Another factor that can affect combustion system maintenance is acoustic dynamics. Acoustic dynamics are pressure oscillations generated by the combustion process within the combustion chambers, which when are present at high levels can lead to significant wear of combustion or hot gas path components. Common GE practice is to tune the combustion system to levels of acoustic dynamics deemed low enough not to affect life of gas turbine hardware. In addition, GE encourages monitoring of combustion dynamics during turbine operation throughout the full range of ambient temperatures and loads.

Combustion disassembly is performed, during scheduled combustion inspections (CI). Inspection interval guidelines are included in *Figure 36*. It is expected, and recommended, that intervals be modified based on specific experience. Replacement intervals are usually defined by a recommended number of combustion (or repair) intervals and are usually combustion component specific. In general, the replacement interval as a function of the number of combustion inspection intervals is reduced if the combustion inspection interval is extended. For example, a component having an 8,000-hour CI interval, and a six CI replacement interval, would have a replacement interval of four CI intervals if the inspection intervals were increased to 12,000 hours (to maintain a 48,000-hour replacement interval).

For combustion parts, the baseline operating conditions that result in a maintenance factor of one are fired startup and shutdown to base load on natural gas fuel without steam or water injection. Factors that increase the hours-based maintenance factor include peak load operation, distillate or heavy fuels, and steam or water injection. Factors that increase starts-based maintenance factor include peak load start/stop cycles, distillate or heavy fuels, steam or water injection, trips, and peaking-fast starts.

Casing Parts

Most GE gas turbines have inlet, compressor, compressor discharge, and turbine cases in addition to exhaust frames. Inner barrels are typically attached to the compressor discharge case. These cases provide the primary support for the bearings, rotor, and gas path hardware.

The exterior of all casings should be visually inspected for cracking, loose hardware, and casing slippage at each combustion, hot gas path, and major outage. The interior of all casings should be inspected whenever possible. The level of the outage determines which casing interiors are accessible for visual inspection. Borescope inspections are recommended for the inlet cases, compressor cases, and compressor discharge cases during gas path borescope inspections. All interior case surfaces should be inspected visually, digitally, or by borescope during a major outage.

Key inspection areas for casings are listed below.

- Bolt holes
- Shroud pin and borescope holes in the turbine shell (case)
- Compressor stator hooks
- Turbine shell shroud hooks
- Compressor discharge case struts
- Inner barrel and inner barrel bolts
- Inlet case bearing surfaces and hooks
- Inlet case and exhaust frame gibs and trunions
- Extraction manifolds (for foreign objects)

Exhaust Diffuser Parts

GE exhaust diffusers come in either axial or radial configurations as shown in *Figures 25 and 26* below. Both types of diffusers are composed of a forward and aft section. Forward diffusers are normally axial diffusers, while aft diffusers can be either axial or radial. Axial diffusers are used in the F and HA-class gas turbines, while radial diffusers are used in B/E-class gas turbines.

Exhaust diffusers are subject to high gas path temperatures and vibration due to normal gas turbine operation. Because of the extreme operating environment and cyclic operating nature of gas turbines, exhaust diffusers may develop cracks in the sheet metal surfaces and weld joints used for diffuser construction. Additionally, erosion may occur due to extended operation at high temperatures. Exhaust diffusers should be inspected as follows at every combustion, hot gas path and major outage. The inspections shall only be performed when the unit is shut down; and following site health and safety procedures.

- Internal inspection for:
  - Cracking, erosion, and distortion
  - Missing or visually damaged hardware.
- External inspection for:
  - Evidence of gas leaks
  - Visual damage on aft support legs (plus spring support, if available)
  - Visual damage or distortion of the diffuser outer surface.

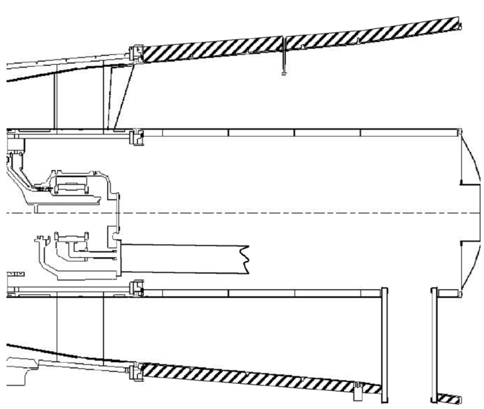

Figure 25. F-class axial diffuser

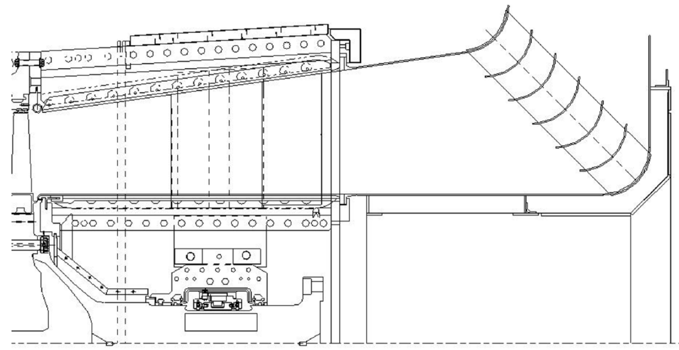

Figure 26. E-class radial diffuser

In addition, flex seals, L-seals, and horizontal joint gaskets should be visually/borescope inspected for signs of wear or damage at every combustion, hot gas path, and major outage. GE recommends that seals with signs of wear or damage be replaced.

To summarize, key areas that should be inspected are listed below. Any damage should be reported to GE for recommended repairs.

- Forward diffuser carrier flange (6F)
- Diffuser strut airfoil leading and trailing edges
- Turning vanes in radial diffusers (B/E-class)
- Insulation packs on interior or exterior surfaces
- Clamp ring attachment points to exhaust frame (major outage only)
- Flex seals and L-seals
- Horizontal joint gaskets

Off-Frequency Operation

GE heavy-duty single shaft gas turbines are engineered to operate at 100% speed with the capability to operate over approximately a 94% to 105% speed range. Operation at other than rated speed has the potential to affect maintenance requirements. Depending on the industry code requirements, the specifics of the turbine configuration, and the turbine control philosophy employed, operating conditions can result that will accelerate life consumption of gas turbine components, particularly rotating flowpath hardware. Where this is true, the maintenance factor associated with this operation must be understood. These off-frequency events must be analyzed and recorded in order to include them in the maintenance plan for the gas turbine.

Some turbines are required to meet operational requirements that are aimed at maintaining grid stability under sudden load or capacity changes. Most codes require turbines to remain on line in the event of a frequency disturbance. For under-frequency operation, the turbine output may decrease with a speed decrease, and the net effect on the turbine is minimal.

In some cases of under-frequency operation, turbine output lapse must be compensated in order to meet the specification-defined output requirement. If the normal output fall-off with speed results in loads less than the defined minimum, the turbine must compensate. Turbine overfiring is the most obvious compensation option, but other means, such as inlet guide vane opening, water-wash, inlet fogging, or evaporative cooling also provide potential means for compensation. A maintenance factor may need to be applied for some of these methods. In addition, off-frequency operation, including rapid Rate of Change of Frequency, may expose the compressor, combustion, and turbine components to high stress and reduce fatigue life. When frequency deviation withstand requirements are combined with active power response requirement (also known as governor response), a start-based penalty may be incurred to consider the accelerated life consumption of the flowpath hardware.

It is important to understand that operation at over-frequency conditions will not trade one-for-one for periods at under-frequency conditions. As was discussed in the firing temperature section above, operation at peak firing conditions has a nonlinear, logarithmic relationship with maintenance factor.

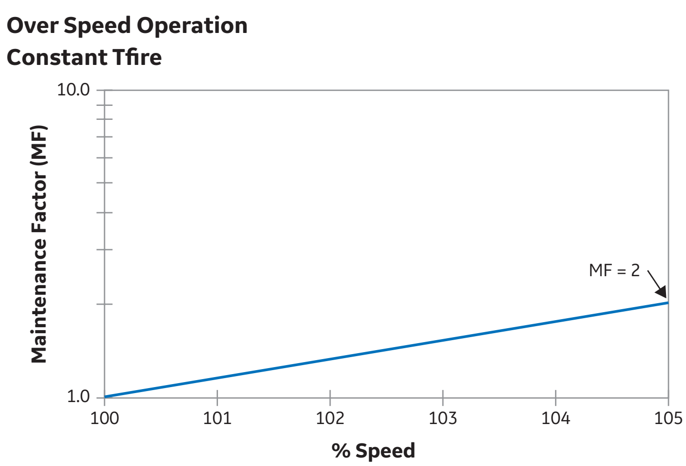

Figure 27. Maintenance factor for overspeed operation ~constant T_F

Over-frequency or high speed operation can also introduce conditions that affect turbine maintenance and part replacement intervals. If speed is increased above the nominal rated speed, the rotating components see an increase in mechanical stress proportional to the square of the speed increase. If firing temperature is held constant at the overspeed condition, the life consumption rate of hot gas path rotating components will increase as illustrated in *Figure 27* where one hour of operation at 105% speed is equivalent to two hours at rated speed.

If overspeed operation represents a small fraction of a turbine's operating profile, this effect on parts life can sometimes be ignored. However, if significant operation at overspeed is expected and rated firing temperature is maintained, the accumulated hours must be recorded and included in the calculation of the turbine's overall maintenance factor and the maintenance schedule adjusted to reflect the overspeed operation.

Compressor Condition and Performance

Maintenance and operating costs are also influenced by the quality of the air that the turbine consumes. In addition to the negative effects of airborne contaminants on hot gas path components, contaminants such as dust, salt, and oil can cause compressor blade erosion, corrosion, and fouling.

Fouling can be caused by submicron dirt particles entering the compressor as well as from ingestion of oil vapor, smoke, sea salt, and industrial vapors. Corrosion of compressor blading causes pitting of the blade surface, which, in addition to increasing the surface roughness, also serves as potential sites for fatigue crack initiation. These surface roughness and blade contour changes will decrease compressor airflow and efficiency, which in turn reduces the gas turbine output and overall thermal efficiency. Generally, axial flow compressor deterioration is the major cause of loss in gas turbine output and efficiency. Recoverable losses, attributable to compressor blade fouling, typically account for 70-85% percent of the performance losses seen. As *Figure 28* illustrates, compressor fouling to the extent that airflow is reduced by 5%, will reduce output by up to 8% and increase heat rate by up to 3%. Fortunately, much can be done through proper operation and maintenance procedures both to reduce fouling type losses and to limit the deposit of corrosive elements. On-line compressor wash systems are available to maintain compressor efficiency by washing the compressor while at load, before significant fouling has occurred. Off-line compressor wash systems are used to clean heavily fouled compressors. Other procedures include maintaining the inlet filtration system, inlet evaporative coolers, and other inlet systems as well as periodic inspection and prompt repair of compressor blading. Refer to system-specific maintenance manuals.

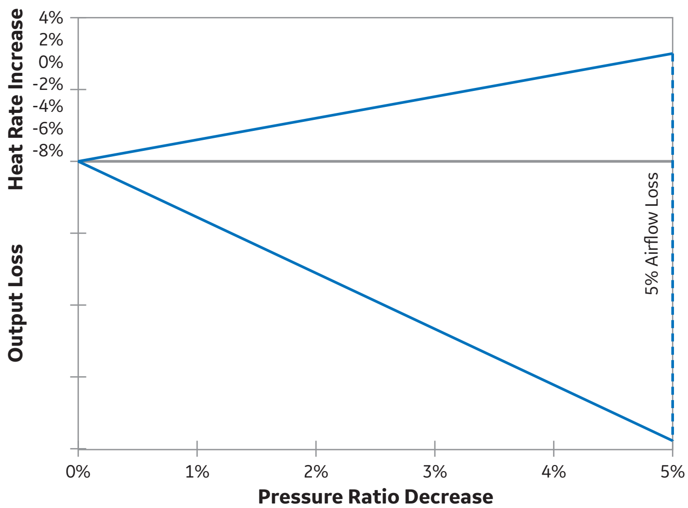

Figure 28. Deterioration of gas turbine performance due to compressor blade fouling

There are also non-recoverable losses. In the compressor, these are typically caused by nondeposit-related blade surface roughness, erosion, and blade tip rubs. In the turbine, nozzle throat area changes, bucket tip clearance increases and leakages are potential causes. Some degree of unrecoverable performance degradation should be expected, even on a well-maintained gas turbine. The owner, by regularly monitoring and recording unit performance parameters, has a very valuable tool for diagnosing possible compressor deterioration.

Lube Oil Cleanliness

Contaminated or deteriorated lube oil can cause wear and damage to bearing liners. This can lead to extended outages and costly repairs. Routine sampling of the turbine lube oil for proper viscosity, chemical composition, and contamination is an essential part of a complete maintenance plan.

Lube oil should be sampled and tested per GEK-32568, "Lubricating Oil Recommendations for Gas Turbines with Bearing Ambients Above 500°F (260°C)." Additionally, lube oil should be checked periodically for particulate and water contamination as outlined in GEK-110483, "Cleanliness Requirements for Power Plant Installation, Commissioning and Maintenance." At a minimum, the lube oil should be sampled on a quarterly basis; however, monthly sampling is recommended.

Moisture Intake

One of the ways some users increase turbine output is through the use of inlet foggers. Foggers inject a large amount of moisture in the inlet ducting, exposing the forward stages of the compressor to potential water carry-over. Operation of a compressor in such an environment may lead to long-term degradation of the compressor due to corrosion, erosion, fouling, and material property degradation. Experience has shown that depending on the quality of water used, the inlet silencer and ducting material, and the condition of the inlet silencer, fouling of the compressor can be severe with inlet foggers. Similarly, carryover from evaporative coolers and water washing more than recommended can degrade the compressor. The water quality standard that should be adhered to is found in GEK-101944, "Requirements for Water/Steam Purity in Gas Turbines." Water carry-over may subject blades and vanes to corrosion and associated pitting. Such corrosion may be accelerated by a saline environment (see GER-3419). Reductions in fatigue strength may result if the environment is acidic and if pitting is present on the blade. This condition is exacerbated by downtime in humid environments, which promotes wet corrosion.

Water droplets may cause leading edge erosion up to and through the middle stages of the compressor. This erosion, if sufficiently developed, may lead to an increased risk of blade failure. Online water washing may also cause some leading edge erosion on the forward stage compressor blades and vanes. To mitigate this erosion risk, safeguards are in-place that control the amount of water used, frequency of usage, and radial location of water wash nozzles.

Maintenance Inspections

Maintenance inspection types may be broadly classified as standby, running, and disassembly inspections. The standby inspection is performed during off-peak periods when the unit is not operating and includes routine servicing of accessory systems and device calibration. The running inspection is performed by observing key operating parameters while the turbine is running. The disassembly inspection requires opening the turbine for inspection of internal components. Disassembly inspections progress from the combustion inspection to the hot gas path inspection to the major inspection as shown in *Figure 29*. Details of each of these inspections are described below. The section ABC Inspections describes the maintenance inspections for the GE Annular/Silo Fleet.

Standby Inspections

Standby inspections are performed on all gas turbines but pertain particularly to gas turbines used in peaking and intermittent-duty service where starting reliability is of primary concern. This inspection includes routinely servicing the battery system, changing filters, checking oil and water levels, cleaning relays, and checking device calibrations. Servicing can be performed in off-peak periods without interrupting the availability of the turbine. A periodic startup test run is an essential part of the standby inspection.

The O&M Manual, as well as the Service Manual Instruction Books, contains information and drawings necessary to perform these periodic checks. Among the most useful drawings in the Service Manual Instruction Books for standby maintenance are the control specifications, piping schematics, and electrical elementaries. These drawings provide the calibrations, operating limits, operating characteristics, and sequencing of all control devices. This information should be used regularly by operating and maintenance personnel. Careful adherence to minor standby inspection maintenance can have a significant effect on reducing overall maintenance costs and maintaining high turbine reliability. It is essential that a good record be kept of all inspections and maintenance work in order to ensure a sound maintenance program.

Running Inspections

Running inspections consist of the general and continued observations made while a unit is operating. This starts by establishing baseline operating data during startup of a new unit and after any major disassembly work. This baseline then serves as a reference from which subsequent unit deterioration can be measured.

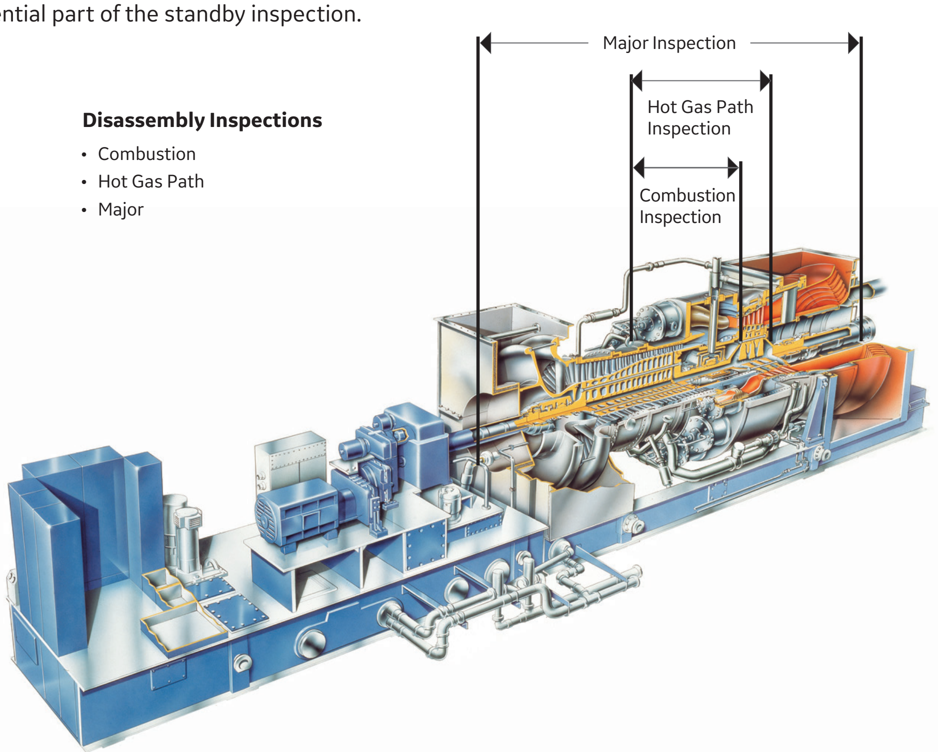

Figure 29. 7E.03 heavy-duty gas turbine – disassembly inspections

Data should be taken to establish normal equipment startup parameters as well as key steady state operating parameters. Steady state is defined as conditions at which no more than a 5°F/3°C change in wheelspace temperature occurs over a 15-minute time period. Data must be taken at regular intervals and should be recorded to permit an evaluation of the turbine performance and maintenance requirements as a function of operating time. This operating inspection data, summarized in *Figure 30*, includes: load versus exhaust temperature, vibration level, fuel flow and pressure, bearing metal temperature, lube oil pressure, exhaust gas temperatures, exhaust temperature spread variation, startup time, and coast-down time. This list is only a minimum and other parameters should be used as necessary. A graph of these parameters will help provide a basis for judging the conditions of the system. Deviations from the norm help pinpoint impending issues, changes in calibration, or damaged components.

• **Speed**	
• **Load**	
• **Fired Starts**	
• **Fired Hours**	
• **Temperatures** – Inlet Ambient – Compressor Discharge – Turbine Exhaust – Turbine Wheelspace – Lube Oil Header	– Lube Oil Tank – Bearing Metal – Bearing Drains – Exhaust Spread
• **Pressures** – Compressor Discharge – Lube Pump(s) – Bearing Header – Barometric	– Cooling Water – Fuel – Filters (Fuel, Lube, Inlet Air)
• **Vibration**	
• **Generator** – Output Voltage – Phase Current – VARS – Load	– Field Voltage – Field Current – Stator Temp. – Vibration
• **Startup Time**	
• **Coast-Down Time**	

Figure 30. Operating inspection data parameters

A sudden abnormal change in running conditions or a severe trip event could indicate damage to internal components. Conditions that may indicate turbine damage include high vibration, high exhaust temperature spreads, compressor surge, abnormal changes in health monitoring systems, and abnormal changes in other monitoring systems. It is recommended to conduct a borescope inspection after such events whenever component damage is suspected.

Load vs. Exhaust Temperature

The general relationship between load and exhaust temperature should be observed and compared to previous data. Ambient temperature and barometric pressure will have some effect upon the exhaust temperature. High exhaust temperature can be an indicator of deterioration of internal parts, excessive leaks or a fouled air compressor. For mechanical drive applications, it may also be an indication of increased power required by the driven equipment.

Vibration Level

The vibration signature of the unit should be observed and recorded. Minor changes will occur with changes in operating conditions. However, large changes or a continuously increasing trend give indications of the need to apply corrective action.

Fuel Flow and Pressure

The fuel system should be observed for the general fuel flow versus load relationship. Fuel pressures through the system should be observed. Changes in fuel pressure can indicate that the fuel nozzle passages are plugged or that fuel-metering elements are damaged or out of calibration.

Exhaust Temperature and Spread Variation

The most important control function to be monitored is the exhaust temperature fuel override system and the back-up over temperature trip system. Routine verification of the operation and calibration of these functions will minimize wear on the hot gas path parts.

Startup Time

Startup time is a reference against which subsequent operating parameters can be compared and evaluated. A curve of the starting parameters of speed, fuel signal, exhaust temperature, and critical sequence bench marks versus time will provide a good indication of the condition of the control system. Deviations from normal conditions may indicate impending issues, changes in calibration, or damaged components.

Coast-Down Time

Coast-down time is an indicator of bearing alignment and bearing condition. The time period from when the fuel is shut off during a normal shutdown until the rotor comes to turning gear speed can be compared and evaluated.

Close observation and monitoring of these operating parameters will serve as the basis for effectively planning maintenance work and material requirements needed for subsequent shutdown periods.

Rapid Cool-Down

Prior to an inspection, a common practice is to force cool the unit to speed the cool-down process and shorten outage time. Force cooling involves turning the unit at crank speed for an extended period of time to continue flowing ambient air through the machine. This is permitted, although a natural cool-down cycle on turning gear or ratchet is preferred for normal shutdowns when no outage is pending. Forced cooling should be limited since it imposes additional thermal stresses on the unit that may result in a reduction of parts life. Opening the compartment doors during any cool-down operation is prohibited unless an emergency situation requires immediate compartment inspection. Cool-down times should not be accelerated by opening the compartment doors or lagging panels, since uneven cooling of the outer casings may result in excessive case distortion and heavy blade rubs. Cool-down is considered complete when all wheelspace temperatures are below 150°F when measured at turning gear/ratchet speed.

Combustion Inspection

The combustion inspection is a relatively short disassembly inspection of fuel nozzles, liners, transition pieces, crossfire tubes and retainers, spark plug assemblies, flame detectors, and combustor flow sleeves. This inspection concentrates on the combustion liners, transition pieces, fuel nozzles, and end caps, which are recognized as being the first to require replacement and repair in a good maintenance program. Proper inspection, maintenance, and repair (*Figure 31*) of these items will contribute to a longer life of the downstream parts, such as turbine nozzles and buckets.

Figure 29 illustrates the section of a 7E.03 unit that is disassembled for a combustion inspection. The combustion liners, transition pieces, and fuel nozzle assemblies should be removed and replaced with new or repaired components to reduce downtime. The removed liners, transition pieces, and fuel nozzles can then be cleaned and repaired after the unit is returned to operation and be available for the next combustion inspection interval. Typical combustion inspection requirements are:

- Inspect combustion chamber components.
- Inspect each crossfire tube, retainer and combustion liner.
- Inspect combustion liner for TBC spalling, wear, and cracks.
- Inspect combustion system and discharge casing for debris and foreign objects.
- Inspect flow sleeve welds for cracking.
- Inspect transition piece for wear and cracks.
- Inspect fuel nozzles for plugging at tips, erosion of tip holes, and safety lock of tips.
- Inspect impingement sleeves for cracks (where applicable).
- Inspect all fluid, air, and gas passages in nozzle assembly for plugging, erosion, burning, etc.
- Inspect spark plug assembly for freedom from binding; check condition of electrodes and insulators.
- Replace all consumables and normal wear-and-tear items such as seals, lockplates, nuts, bolts, gaskets, etc.
- Perform visual inspection of first-stage turbine nozzle partitions and borescope inspect (*Figure 3*) turbine buckets to mark the progress of wear and deterioration of these parts. This inspection will help establish the schedule for the hot gas path inspection.
- Perform borescope inspection of compressor.
- Visually inspect the compressor inlet, checking the condition of the inlet guide vanes (IGVs) and VSVs, where applicable, IGV bushings and VSV bushings, where applicable, and first stage rotating blades.
- Check the condition of IGV actuators and VSV actuators, where applicable, and rack-and-pinion gearing.
- Verify the calibration of the IGVs and VSVs, where applicable.

- Visually inspect compressor discharge case struts for signs of cracking.
- Visually inspect compressor discharge case inner barrel if accessible.
- Visually inspect the last-stage buckets and shrouds.
- Visually inspect the exhaust diffuser for any cracks in flow path surfaces. Inspect insulated surfaces for loose or missing insulation and/or attachment hardware in internal and external locations. In B/E-class machines, inspect the insulation on the radial diffuser and inside the exhaust plenum as well.
- Inspect exhaust frame flex seals, L-seals, and horizontal joint gaskets for any signs of wear or damage.
- Verify proper operation of purge and check valves. Confirm proper setting and calibration of the combustion controls.
- Inspect turbine inlet systems including filters, evaporative coolers, silencers, etc. for corrosion, cracks, and loose parts.

After the combustion inspection is complete and the unit is returned to service, the removed combustion hardware can be inspected by a qualified GE field service representative and, if necessary, sent to a qualified GE Service Center for repairs. It is recommended that repairs and fuel nozzle flow testing be performed at qualified GE service centers.

See the O&M Manual for additional recommendations and unit specific guidance.

Combustion Inspection

Key Hardware	Inspect For	Potential Action
Combustion liners Combustion end covers Fuel nozzles End caps Transition pieces Cross fire tubes Flow sleeves Purge valves Check valves Spark plugs Flame detectors Flex hoses IGV and VSV and bushings Compressor and turbine (borescope)	Foreign object damage (FOD) Abnormal wear Cracking Liner cooling hole plugging TBC coating condition Oxidation/corrosion/erosion Hot spots/burning Missing hardware Clearance limits	Repair/refurbish/replace • Transition Pieces – Strip and recoat – Weld repair – Creep repair • Fuel nozzles – Weld repair – Flow test – Leak test • Liners – Strip and recoat – Weld repair – Hula seal replacement – Repair out-of-roundness
Exhaust diffuser	Cracks	Weld repair
Exhaust diffuser Insulation	Loose/missing parts	Replace/tighten parts
Forward diffuser flex seal	Wear/cracked parts	Replace seals
Compressor discharge case	Cracks	Repair or monitor
Cases – exterior	Cracks	Repair or monitor

Criteria	Inspection Methods
• O&M Manual • TILs • GE Field Engineer	• Visual • Liquid Penetrant • Borescope

Availability of On-Site Spares is Key to Minimizing Downtime

Figure 31. Combustion inspection – key elements

Hot Gas Path Inspection

The purpose of a hot gas path inspection is to examine those parts exposed to high temperatures from the hot gases discharged from the combustion process. The hot gas path inspection outlined in *Figure 32* includes the full scope of the combustion inspection and, in addition, a detailed inspection of the turbine nozzles, stator shrouds, and turbine buckets. To perform this inspection, the top half of the turbine shell must be removed. Prior to shell removal, proper machine centerline support using mechanical jacks is necessary to assure proper alignment of rotor to stator, obtain accurate half-shell clearances, and prevent twisting of the stator casings. Reference the O&M Manual for unit-specific jacking procedures.

Special inspection procedures apply to specific components in order to ensure that parts meet their intended life. These inspections may include, but are not limited to, dimensional inspections, Fluorescent Penetrant Inspection (FPI), Eddy Current Inspection (ECI), and other forms of non-destructive testing (NDT). The type of inspection required for specific hardware is determined on a part number and operational history basis, and can be obtained from a GE service representative.

Similarly, repair action is taken on the basis of part number, unit operational history, and part condition. Repairs including (but not limited to) strip, chemical clean, HIP (Hot Isostatic Processing), heat treat, and recoat may also be necessary to ensure full parts life. Weld repair will be recommended when necessary, typically as determined by visual inspection and NDT. Failure to perform the required repairs may lead to retirement of the part before its life potential is fulfilled. In contrast, unnecessary repairs are an unneeded expenditure of time and resources. To verify the types of inspection and repair required, contact your GE service representative prior to an outage.

For inspection of the hot gas path (*Figure 31*), all combustion transition pieces and the first-stage turbine nozzle assemblies must be removed. Removal of the second- and third-stage turbine nozzle segment assemblies is optional, depending upon the results of visual observations, clearance measurements, and other required inspections. The buckets can usually be inspected in place. FPI of the bucket vane sections may be required to detect any cracks. In addition, a complete set of internal turbine radial and axial clearances (opening and closing) must be taken during any hot

Hot Gas Path Inspection

Combustion Inspection Scope—Plus:

Key Hardware	Inspect For	Potential Action
Nozzles (1, 2, 3, 4) Buckets (1, 2, 3, 4) Stator shrouds Compressor blading (borescope)	Foreign object damage Oxidation/corrosion/erosion Cracking Cooling hole plugging Remaining coating life Nozzle deflection/distortion Abnormal deflection/distortion Abnormal wear Missing hardware Clearance limits Evidence of creep	Repair/refurbish/replace • Nozzles – Weld repair – Reposition – Recoat • Buckets – Strip & recoat – Weld repair – Blend • Stator shrouds – Weld repair – Blend – Recoat
Turbine shell	Cracks	Repair or monitor

Criteria
- O&M Manual
- TILs
- GE Field Engineer

Inspection Methods
- Visual
- Liquid Penetrant
- Borescope

Availability of On-Site Spares is Key to Minimizing Downtime

Figure 32. Hot gas path inspection – key elements

gas path inspection. Re-assembly must meet clearance diagram requirements to prevent rubs and to maintain unit performance. In addition to combustion inspection requirements, typical hot gas path inspection requirements are:

- Inspect and record condition of first-, second-, and third-stage buckets (and fourth-stage for HA). If it is determined that the turbine buckets should be removed, follow bucket removal and condition recording instructions. Buckets with protective coating should be evaluated for remaining coating life.
- Inspect and record condition of first-, second-, and third-stage nozzles (and fourth-stage for HA).
- Inspect seals and hook fits of turbine nozzles and diaphragms for rubs, erosion, fretting, or thermal deterioration.
- Inspect and record condition of later-stage nozzle diaphragm packings.
- Inspect lab seals and brush seals for any signs of damage.
- Inspect double walled casings mounting surfaces (ledges and wedges) for signs of coating degradation or loss.
- Inspect double walled casing alignment screws and pins for signs of wear of damage.
- Inspect double walled casing seals (dog bone seals) for signs of wear or damage.
- Inspect the exhaust frame mini-case and forward diffuser mini-panel.
- Check discourager seals for rubs, and deterioration of clearance.
- Record the bucket tip clearances.
- Inspect bucket shank seals for clearance, rubs, and deterioration.
- Perform inspections on cutter teeth of tip-shrouded buckets. Consider refurbishment of buckets with worn cutter teeth, particularly if concurrently refurbishing the honeycomb of the corresponding stationary shrouds. Consult your GE service representative to confirm that the bucket under consideration is repairable.
- Check the turbine stationary shrouds for clearance, cracking, erosion, oxidation, rubbing, and build-up of debris.
- Inspect turbine rotor for cracks, object damage, or rubs.
- Check and replace any faulty wheelspace thermocouples.
- Perform borescope inspection of the compressor.
- Visually inspect the turbine shell shroud hooks for signs of cracking.

The first-stage turbine nozzle assembly is exposed to the direct hot gas discharge from the combustion process and is subjected to the highest gas temperatures in the turbine section. Such conditions frequently cause nozzle cracking and oxidation, and in fact, this is expected. The second- and third-stage nozzles are exposed to high gas bending loads, which in combination with the operating temperatures can lead to downstream deflection and closure of critical axial clearances. To a degree, nozzle distress can be tolerated, and criteria have been established for determining when repair is required. More common criteria are described in the O&M Manuals. However, as a general rule, first-stage nozzles will require repair at the hot gas path inspection. The second- and third-stage nozzles may require refurbishment to re-establish the proper axial clearances. Normally, turbine nozzles can be repaired several times, and it is generally repair cost versus replacement cost that dictates the replacement decision.

Coatings play a critical role in protecting the buckets operating at high metal temperatures. They ensure that the full capability of the high strength superalloy is maintained and that the bucket rupture life meets construction expectations. This is particularly true of cooled bucket configurations that operate above 1985°F (1085°C) firing temperature. Significant exposure of the base metal to the environment will accelerate the creep rate and can lead to premature replacement through a combination of increased temperature and stress and a reduction in material strength, as described in *Figure 33*. This degradation process is driven by oxidation of the unprotected base alloy. On early generation uncooled designs, surface degradation due to corrosion or oxidation was considered to be a performance issue and not a factor in bucket life. This is no longer the case at the higher firing temperatures of current generation designs.

Given the importance of coatings, it must be recognized that even the best coatings available will have a finite life, and the condition of the coating will play a major role in determining bucket life. Refurbishment through stripping and recoating is an option for achieving bucket's expected life, but if recoating is selected, it should be done before the coating is breached to expose base metal. Normally, for 7E.03 turbines, this means that recoating

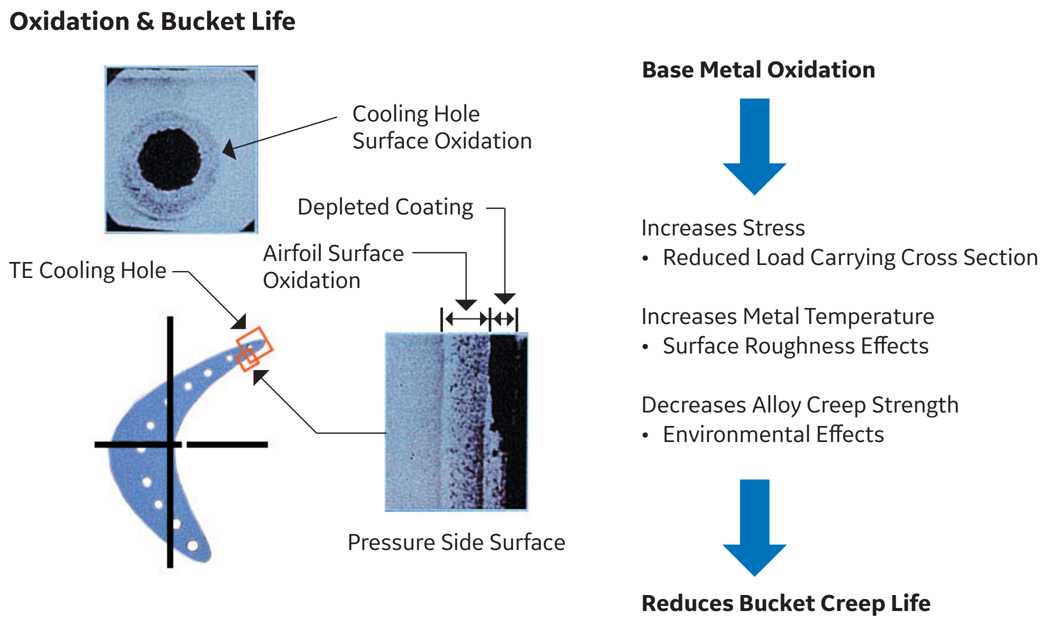

Figure 33. Stage 1 bucket oxidation and bucket life

will be required at the hot gas path inspection. If recoating is not performed at the hot gas path inspection, the life of the buckets would generally be one additional hot gas path inspection interval, at which point the buckets would be replaced. For F-class gas turbines, recoating of the first stage buckets is recommended at each hot gas path inspection. Visual and borescope examination of the hot gas path parts during the combustion inspections as well as nozzle-deflection measurements will allow the operator to monitor distress patterns and progression. This makes part-life predictions more accurate and allows adequate time to plan for replacement or refurbishment at the time of the hot gas path inspection. It is important to recognize that to avoid extending the hot gas path inspection, the necessary spare parts should be on site prior to taking the unit out of service.

See the O&M Manual for additional recommendations and unit specific guidance.

Major Inspection

The purpose of the major inspection is to examine all of the internal rotating and stationary components from the inlet of the machine through the exhaust. A major inspection should be scheduled in accordance with the recommendations in the owner's O&M Manual or as modified by the results of previous borescope and hot gas path inspections. The work scope shown in *Figure 34* involves inspection of all of the major flange-to-flange components of the gas turbine, which are subject to deterioration during normal turbine operation. This inspection includes previous elements of the combustion and hot gas path inspections, and requires laying open the complete flange-to-flange gas turbine to the horizontal joints, as shown in *Figure 29*.

Removal of all of the upper casings allows access to the compressor rotor and stationary compressor blading, as well as to the bearing assemblies. Prior to removing casings, shells, and frames, the unit must be properly supported. Proper centerline support using mechanical jacks and jacking sequence procedures are necessary to assure proper alignment of rotor to stator, obtain accurate half shell clearances, and to prevent twisting of the casings while on the half shell. Reference the O&M Manual for unit-specific jacking procedures. In addition to combustion and hot gas path inspection requirements, typical major inspection requirements are:

- Check all radial and axial clearances against their original values (opening and closing).
- Inspect all casings, shells, and frames/diffusers for cracks and erosion.
- Inspect compressor inlet and compressor flow-path for fouling, erosion, corrosion, and leakage.
- Check rotor and stator compressor blades for tip clearance, rubs, object damage, corrosion pitting, and cracking.

- Remove turbine buckets and perform a nondestructive check of buckets and wheel dovetails. Wheel dovetail fillets, pressure faces, edges, and intersecting features must be closely examined for conditions of wear, galling, cracking, or fretting.
- Inspect unit rotor for heavy corrosion, cracks, object damage, or rubs.
- Inspect bearing liners and seals for clearance and wear.
- Visually inspect compressor and compressor discharge case hooks for signs of wear.
- Visually inspect compressor discharge case inner barrel.
- Inspect exhaust frame flex seals, L-seals, and horizontal joint gaskets for any signs of wear or damage. Inspect steam gland seals for wear and oxidation.
- Inspect lab seals and brush seals for any signs of damage.
- Inspect double walled casings mounting surfaces (ledges and wedges) for signs of coating degradation or loss.
- Inspect double walled casing alignment screws and pins for signs of wear of damage.
- Inspect double walled casing seals (dog bone seals) for signs of wear or damage.
- Inspect the exhaust frame mini-case and forward diffuser mini-panel.
- Check torque values for steam gland bolts and re-torque to full values.
- Check alignment – gas turbine to generator/gas turbine to accessory gear.
- Inspect casings for signs of casing flange slippage.

Comprehensive inspection and maintenance guidelines have been developed by GE and are provided in the O&M Manual to assist users in performing each of the inspections previously described.

Major Inspection

Hot Gas Path Inspection Scope—Plus:

Key Hardware	Inspect For	Potential Action
Compressor blading	Foreign object damage	Repair/refurbishment/replace
Unit rotor	Oxidation/corrosion/erosion	• Bearings/seals
Journals and seal surfaces	Cracking	– Clean
Bearing seals	Leaks	– Assess oil condition
Exhaust system	Abnormal wear	– Re-babbitt
	Missing hardware	• Compressor blades
	Clearance limits	– Clean
	Coating wear	– Blend
	Fretting	• Exhaust system
		– Weld repair
		– Replace flex seals/L-seals
Compressor and compressor discharge case hooks	Wear	Repair
All cases – exterior and interior	Cracks	Repair or monitor
Cases – Exterior	Slippage	Casing alignment

Criteria		Inspection Methods	
• O&M Manual	• TILs	• Visual	• Liquid Penetrant
• GE Field Engineer		• Borescope	• Ultrasonics

Figure 34. Gas turbine major inspection – key elements

Parts Planning

Prior to a scheduled disassembly inspection, adequate spares should be on-site. Lack of adequate on-site spares can have a major effect on plant availability. For example, a planned outage such as a combustion inspection, which should only take two to five days, could take weeks if adequate spares are not on-site. GE will provide recommendations regarding the types and quantities of spare parts needed; however, it is up to the owner to purchase these spare parts on a planned basis allowing adequate lead times.

Early identification of spare parts requirements ensures their availability at the time the planned inspections are performed. Refer to the Reference Drawing Manual provided as part of the comprehensive set of O&M Manuals to aid in identification and ordering of gas turbine parts.

Additional benefits available from the renewal parts catalog data system are the capability to prepare recommended spare parts lists for the combustion, hot gas path and major inspections as well as capital and operational spares.

Estimated repair and replacement intervals for some of the major components are shown in *Appendix D.* These tables assume that operation, inspections, and repairs of the unit have been done in accordance with all of the manufacturer's specifications and instructions.

The actual repair and replacement intervals for any particular gas turbine should be based on the user's operating procedures, experience, maintenance practices, and repair practices. The maintenance factors previously described can have a major effect on both the component repair interval and service life. For this reason, the intervals given in *Appendix D* should only be used as guidelines and not certainties for long range parts planning. Owners may want to include contingencies in their parts planning.

The estimated repair and replacement interval values reflect current production hardware (the typical case) with design improvements such as advanced coatings and cooling technology. With earlier production hardware, some of these lives may not be achievable. Operating factors and experience gained during the course of recommended inspection and maintenance procedures will be a more accurate predictor of the actual intervals.

The estimated repair and replacement intervals are based on the recommended inspection intervals shown in *Figure 36.* For certain models, technology upgrades are available that extend the maintenance inspection intervals. The application of inspection (or repair) intervals other than those shown in *Figure 36* can result in different replacement intervals than those shown in *Appendix D.* See your GE service representative for details on a specific system.

It should be recognized that, in some cases, the service life of a component is reached when it is no longer economical to repair any deterioration as opposed to replacing at a fixed interval. This is illustrated in *Figure 35* for a first stage nozzle, where repairs continue until either the nozzle cannot be restored to minimum acceptance standards or the repair cost exceeds or approaches the replacement cost. In other cases, such as first-stage buckets, repair options are limited by factors such as irreversible material damage. In both cases, users should follow GE recommendations regarding replacement or repair of these components.

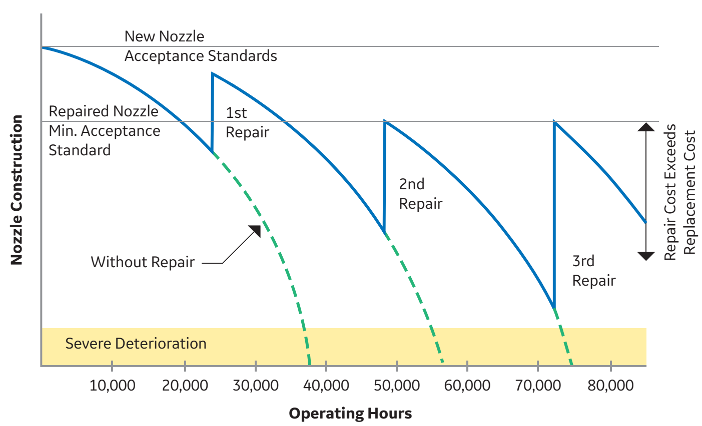

Figure 35. First-stage nozzle repair program: natural gas fired – continuous dry – base load

It should also be recognized that the life consumption of any one individual part within a parts set can have variations. This may lead to a certain percentage of "fallout," or scrap, of parts being repaired. Those parts that fallout during the repair process will need to be replaced by new parts. Parts fallout will vary based on the unit operating environment history, the specific part design, and the current repair technology.

Inspection Intervals

In the absence of operating experience and resulting part conditions, *Figure 36* lists the recommended visual, combustion, hot gas path and major inspection intervals for current production GE turbines operating under typical conditions of natural gas fuel, base load, and no water/steam injection. These recommended intervals represent factored hours or starts calculated using maintenance factors to account for application specific operating conditions. Initially, recommended intervals are based on the expected operation of a turbine at installation, but this should be reviewed and adjusted as operating and maintenance data are accumulated. While reductions in the recommended intervals will result from the factors described previously or unfavorable operating experience, increases in the recommended intervals may also be considered where operating experience has been favorable.

The condition of the combustion and hot gas path parts provides a basis for customizing a program for inspection and maintenance. The condition of the compressor and bearing assemblies is the key driver in planning a major inspection. Historical operation and machine conditions can be used to tailor maintenance programs such as site specific repair and inspection criteria to specific sites/machines. GE leverages these principles and accumulated site and fleet experience in a "Condition Based Maintenance" program as the basis for maintenance of units under Contractual Service Agreements. This experience was accumulated on units that operate with GE approved repairs, field services, monitoring, and full compliance to GE's technical recommendations.

GE can assist operators in determining the appropriate maintenance intervals for their particular application. Equations have been developed that account for the factors described earlier and can be used to determine application-specific combustion, hot gas path, and major inspection intervals.

Borescope Inspection Interval

In addition to the planned maintenance intervals, which undertake scheduled inspections or component repairs or replacements, borescope inspections should be conducted to identify any additional actions, as discussed in the sections "Gas Turbine Configuration Maintenance Features." Such inspections may identify additional areas to be addressed at a future scheduled maintenance outage, assist with parts or resource planning, or indicate the need to change the timing of a future outage. The BI should use all the available access points to verify the condition of the internal hardware. As much of the Major Inspection workscope as possible should be done using this visual inspection without disassembly. Refer to *Figure 3* for standard recommended BI frequency. Specific concerns may warrant subsequent BIs in order to operate the unit to the next scheduled outage without teardown.

ABC Inspections For Annular/Silo Fleet

There are three types of scheduled inspections for all gas turbines in the GE Annular/Silo fleet; Type A Visual Inspection, Type B Visual Inspection, and Type C Major Inspection. The scope of these inspections is based on the design and fleet experience of the gas turbine types to facilitate a reliable operation and optimized usage of the assembled parts. An overview of the different inspection's scope is given in Figure 37 but may differ due to series/rating specific configurations. Figure 38 lists the recommended visual, combustion, hot gas path and major inspection intervals for current production GE Annular/Silo turbines operating under typical conditions of natural gas fuel, base load, and no water/steam injection.

- **Type A Visual Inspection** – Borescope and visual inspection of GE Gas Turbine and Auxiliary System without gas turbine opening.
- **Type B Visual Inspection** – Scope of A type inspection including functional checks and re-adjustments
- **Type C Major Inspection** – Opening and inspection of the gas turbine including maintenance depending on recommended repair and replacement scope. Functional checks and re-adjustment

Type of Inspection	Type of hours/starts	Hours/Starts			
		6B	7E	9E	
		6B.03	7E.03 (6)	9E.03 (7)	9E.04 (10)
Combustion (Non-DLN)	Factored	12000/600 (2)(5)	8000/900 (2)(5)(11)	8000/900 (2)(5)(11)	32000/900 (2)(11
Combustion (DLN)	Factored	12000/450 (5)	12000/450 (5)(11)	12000/450 (5)(11)	32000/900 (11)
Hot Gas Path	Factored	32000/1200 (13)	32000/1200 (13)	32000/900 (12)	32000/900
Major	Factored	64000/2400 (5)	64000/2400 (5)	64000/2400 (5)	64000/1800 (5)

Type of Inspection	Type of hours/starts	Hours/Starts		
		6F		7F
		6F.01	6F.03	7F.03 (11)
Combustion (Non-DLN)	Factored		8000/400	
Combustion (DLN)	Factored	32000/900	24000/900 (5)	24000/900
Hot Gas Path	Factored	32000/450**	24000/900	24000/900
Major	Factored	64000/1800	48000/2400	48000/2400

Type of Inspection	Type of hours/starts	Hours/Starts					
		7F			9F		
		7F.04	7FB.04	7F.05	9F.03	9F.04	9F.05
Combustion (Non-DLN)	Factored						
Combustion (DLN)	Factored	32000/950 (5)	32000/950 (5)	24000/900	24000/900	32000/1200	12000/450
Hot Gas Path	Factored	32000/1250	32000/1250	24000/900	24000/900	32000/1200	24000/900
Major	Factored	64000/2500	64000/2500	48000/2400	48000/2400	64000/2400	48000/2400

Type of Inspection	Type of hours/starts	Hours/Starts			
		7HA		9HA	
		7HA.01 (8)	7HA.02 (8)	9HA.01 (8)	9HA.02 (8)
Combustion (DLN)	Factored	25000/900	25000/720	25000/900 (9)	25000/720
Hot Gas Path	Factored	25000/900	25000/720	25000/900	25000/720
Major	Factored	50000/1800	50000/1440	50000/1800	50000/1440

Factors that can reduce maintenance intervals:

- Fuel
- Load setting
- Steam/water injection
- Peak load firing operation
- Trips
- Start cycle
- Hardware design
- Off-frequency operation

1. Units with Lean Head End liners have a 400-starts combustion inspection interval.
2. Multiple Non-DLN configurations exist (Standard, MNQC, IGCC). The typical case is shown; however, different quoting limits may exist on a machine and hardware basis. Contact a GE service representative for further information.
3. Combustion inspection without transition piece removal. Combustion inspection with transition pieces removal to be performed every 2 combustion inspection intervals.
4. Hot gas path inspection for factored hours eliminated on units that operate on natural gas fuel without steam or water injection.
5. Precedent technology may have shorter inspection intervals. Upgraded technology (Extendor*, PIP, DLN 2.6+, etc) may have longer inspection intervals. Contact a GE service representative for further information.
6. Also applicable to 7121(EA) models.
7. Applicable to non-AGP units only.
8. Intervals assume Base Tfire
9. CI = 450 Starts for DLN2.6+
10. Applicable to New Units of 9E.04 and Flange-to-Flange Upgrades
11. Non-DLN Standard, DLN, and DLN with AFS configurations exist. Contact a GE service representative for further information.
12. Applies to AGP (Advanced Gas Path) hardware only. Older models may have shorter intervals.
13. Applies to PIP (Performance Improvement Package) hardware only. Older models may have shorter intervals.

*Trademark of General Electric Company

**Applicable to S1B only, all other HGP hardware is 900FFS

Note:

Baseline inspection intervals reflect current production hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For Repair/Replace intervals see *Appendix D.*

Rotor maintenance intervals are calculated independently.

Figure 36. Baseline recommended inspection intervals: base load – natural gas fuel – dry

System	Type A Visual Inspection	Type B Visual Inspection	Type C Major Inspection
Gas Turbine			
Air Inlet System	Visual Inspection	Visual Inspection	Visual Inspection/Cleaning/Maintenance
Bleed Valve/Variable Guide Vane System		Functional Test	Functional Test
GT Compressor	Visual/Borescope Inspection	Visual/Borescope Inspection	Visual Inspection/Cleaning/Repair and Replacement
GT Combustor	Visual/Borescope Inspection	Visual/Borescope Inspection/ Functional Test	Visual Inspection/Cleaning/Functional Test/Repair and Replacement
GT Turbine	Visual/Borescope Inspection	Visual/Borescope Inspection	Visual Inspection/Cleaning/Maintenance/ Repair and Replacement
GT Rotor	Alignment Check	Alignment Check	Visual Inspection/RLM/Alignment Check and Correction
Exhaust Gas System	Visual Inspection	Visual Inspection	Visual Inspection/Maintenance
GT Cooling Air Systems	Visual Inspection	Visual Inspection/Functional Test	Visual Inspection/Functional Test, Leakage Check
Controls, Protection and Monitoring			
GT Control System		Functional Test	Functional Test
Protection/Monitoring		Functional Test	Functional Test
Enclosure/Fire Fighting/ Gas Detection System	Visual Inspection	Visual Inspection/Functional Test	Visual Inspection/Functional Test
Checks Prior to Re-start	General Visual Inspection	General Visual Inspection/ Functional Test	General Visual Inspection/Functional Test
Auxiliary Systems			
Lube Oil System	Leakage Inspection	Leakage Inspection/Functional Test	Leakage Inspection/Functional Test
Cooling Water	Leakage Inspection	Leakage Inspection	Leakage Inspection/Functional Test
Fuel Systems	Leakage Inspection	Leakage Inspection/Functional Test	Leakage Inspection/Functional Test
Compressor Wash/Drain Equipment			Functional Test
Control/Sealing Air System	Leakage Inspection	Leakage Inspection	Leakage Inspection/Functional Test
AC/DC Supply			Visual Inspection/Functional Test
Batteries	Visual Inspection	Visual Inspection	Visual Inspection/Functional Test

Figure 37. ABC Inspections

Baseline Recommended Inspection Intervals: Base Load – Natural Gas Fuel – Dry for GE Annular/Silo Fleet

Series/Rating	GT11N2			GT13E2	
	Baseline EV/SB	Upgrade XL	Upgrade M	Baseline MXL	Upgrade MXL2
Counter Type / Inspection Type	Linear	Linear	Linear Extended	Linear Extended	Linear Extended
1st A	6’000 EOH	8’000 EOH	12’000 EOH	9’000 EOH	12’000 EOH
			12’000 WOH	9’000 WOH	12’000 WOH
			300 WCE	300 WCE	400 WCE
B	12’000 EOH	16’000 EOH	24’000 EOH	18’000 EOH	24’000 EOH
			24’000 WOH	18’000 WOH	24’000 WOH
			600 WCE	600 WCE	800 WCE
2nd A**	18’000 EOH	24’000 EOH	36’000 EOH	27’000 EOH	36’000 EOH
			36’000 WOH	27’000 WOH	36’000 WOH
			900 WCE	900 WCE	1’200 WCE
C	24’000 EOH	32’000 EOH	48’000 EOH	36’000 EOH	48’000 EOH
			48’000 WOH	36’000 WOH	48’000 WOH
			1’200 WCE	1’200 WCE	1’600 WCE

Series/ Rating	GT24			GT 26				
	Baseline A*, AB, B	Baseline (2006) Upgrade MXL	Baseline (2011)Upgrade MXL2	Baseline AB*, B	Baseline (2006)	Upgrade APP	Baseline MXL2	Upgrade MXL2
Counter Type / Inspection Type	Linear*/ Elliptical	Linear Extended	Linear Extended	Linear*/ Elliptical	Elliptical*/ Linear Extended	Linear Extended	Linear Extended	Box
1st A	6’000 EOH	8’000 EOH	9’’000 EOH	6’000 EOH	7’000 EOH	9’’000 EOH	9’’000 EOH	
		7’000 WOH	8’’000 WOH		6’000 WOH	8’’000 WOH	8’’000 WOH	8’’000 WOH
		300 WCE	300 WCE		300 WCE	300 WCE	300 WCE	300 WCE
B	12’000 EOH	16’000 EOH	18’000 EOH	12’000 EOH	14’000 EOH	18’000 EOH	18’000 EOH	
		14’000 WOH	16’000 WOH		12’000 WOH	16’000 WOH	16’000 WOH	16’000 WOH
		600 WCE	600 WCE		600 WCE	600 WCE	600 WCE	600 WCE
2nd A**	18’000 EOH	24’000 EOH	27’000 EOH	18’000 EOH	21’000 EOH	27’000 EOH	27’000 EOH	
		21’000 WOH	24’000 WOH		18’000 WOH	24’000 WOH	24’000 WOH	24’000 WOH
		900 WCE	900 WCE		900 WCE	900 WCE	900 WCE	900 WCE
C	24’000 EOH	32’000 EOH	36’000 EOH	24’000 EOH	28’000 EOH	36’000 EOH	36’000 EOH	
		28’000 WOH	32’000 WOH		24’000 WOH	32’000 WOH	32’000 WOH	32’000 WOH
		1’200 WCE	1’200 WCE		1’200 WCE	1’200 WCE	1’200 WCE	1’200 WCE

(*) Project specific counter type

(**) Based on fleet experience and project specific hardware a reduced number of inspections may apply, e.g. “A-B-C”. Not applicable to HE

EOH – Equivalent Operating Hours
WOH – Weighted Operating Hours
WCE – Weighted Cyclic Events

Figure 38. Annular/Silo Fleet Inspection Intervals

Combustion Inspection Interval

Equations have been developed that account for the earlier mentioned factors affecting combustion maintenance intervals. These equations represent a generic set of maintenance factors that provide guidance on maintenance planning. As such, these equations do not represent the specific capability of any given combustion system. For combustion parts, the baseline operating conditions that result in a maintenance factor of one are normal fired startup and shutdown (no trip) to base load on natural gas fuel without steam or water injection.

An hours-based combustion maintenance factor can be determined from the equations given in *Figure 39* as the ratio of factored hours to actual operating hours. Factored hours considers the effects of fuel type, load setting, and steam/water injection. Maintenance factors greater than one reduce recommended combustion inspection intervals from those shown in *Figure 36* representing baseline operating conditions. To obtain a recommended inspection interval for a specific application, the maintenance factor is divided into the recommended baseline inspection interval.

A starts-based combustion maintenance factor can be determined from the equations given in *Figure 40* and considers the effect of fuel type, load setting, peaking-fast starts, trips, and steam/water injection. An application-specific recommended inspection interval can be determined from the baseline inspection interval in *Figure 36* and the maintenance factor from *Figure 40*. *Appendix B* shows six example maintenance factor calculations using the above hours and starts maintenance factor equations.

Syngas units require unit-specific intervals to account for unit-specific fuel constituents and water/steam injection schedules. As such, the combustion inspection interval equations may not apply to those units.

Hours-Based Combustion Inspection

$$\text{Maintenance Interval} = \frac{\text{Baseline CI } (\textit{Figure 36})}{\text{Maintenance Factor}}$$

$$\text{Maintenance Factor} = \frac{\text{Factored Hours}}{\text{Actual Hours}}$$

Factored Hours = $\Sigma (K_i \cdot Af_i \cdot Ap_i \cdot t_i)$, i = 1 to n in Operating Modes

Actual Hours = $\Sigma (t_i)$, i = 1 to n in Operating Modes

Where:

i = Discrete Operating mode (or Operating Practice of Time Interval)

t_i = Operating hours at Load in a Given Operating mode

Ap_i = Load Severity factor
- Ap = 1.0 up to Base Load
- Ap = For Peak Load Factor See *Figure 10*

Af_i = Fuel Severity Factor
- Af = 1.0 for Natural Gas Fuel(1)
- Af = 1.5 for Distillate Fuel (Non-DLN)
- Af = 2.5 for Distillate Fuel (DLN E/F-Class)
- Af = 2.5 for Crude (Non-DLN)
- Af = 3.5 for Residual Fuel (Non-DLN)

K_i = Water/Steam Injection Severity Factor (% Steam Referenced to Compressor Inlet Air Flow, w/f = Water to Fuel Ratio)
- K = Max(1.0, exp(0.34(%Steam – 2.00%))) for Steam, Dry Control Curve
- K = Max(1.0, exp(0.34(%Steam – 1.00%))) for Steam, Wet Control Curve
- K = Max(1.0, exp(1.80(w/f – 0.80))) for Water, Dry Control Curve
- K = Max(1.0, exp(1.80(w/f – 0.40))) for Water, Wet Control Curve

(1) Af = 10 for DLN 1/DLN 1+ extended lean-lean (excluding Nimonic 263 material components where Af = 4).
Af = 10 for DLN 2.0/DLN 2+ extended piloted premixed operation.

Figure 39. Combustion inspection hours-based maintenance factors

Starts-Based Combustion Inspection

$$\text{Maintenance Interval} = \frac{\text{Baseline CI } (\textit{Figure 36})}{\text{Maintenance Factor}}$$

$$\text{Maintenance Factor} = \frac{\text{Factored Starts}}{\text{Actual Starts}}$$

Factored Starts = $\Sigma (K_i \cdot Af_i \cdot At_i \cdot Ap_i \cdot As_i \cdot N_i)$, i = 1 to n Start/Stop Cycles

Actual Starts = $\Sigma (N_i)$, i = 1 to n in Start/Stop Cycles

Where:

i = Discrete Start/Stop Cycle (or Operating Practice)

N_i = Start/Stop Cycles in a Given Operating Mode

As_i = Start Type Severity Factor
- As = 1.0 for Normal Start
- As = For Peaking-Fast Start See *Figure 13*

Ap_i = Load Severity Factor
- Ap = 1.0 up to Base Load
- Ap = exp (0.009 x Peak Firing Temp Adder in °F) for Peak Load

At_i = Trip Severity Factor
- At = 0.5 + exp(0.0125*%Load) for Trip
- At = 1 for No Trip

Af_i = Fuel Severity Factor
- Af = 1.0 for Natural Gas Fuel
- Af = 1.25 for Distillate Fuel (Non-DLN)
- Af = 1.5 for Distillate Fuel (DLN E/F-Class)
- Af = 2.0 for Crude (Non-DLN)
- Af = 3.0 for Residual Fuel (Non-DLN)

K_i = Water/Steam Injection Severity Factor (% Steam Referenced to Compressor Inlet Air Flow, w/f = Water to Fuel Ratio)
- K = Max(1.0, exp(0.34(%Steam – 1.00%))) for Steam, Dry Control Curve
- K = Max(1.0, exp(0.34(%Steam – 0.50%))) for Steam, Wet Control Curve
- K = Max(1.0, exp(1.80(w/f – 0.40))) for Water, Dry Control Curve
- K = Max(1.0, exp(1.80(w/f – 0.20))) for Water, Wet Control Curve

Figure 40. Combustion inspection starts-based maintenance factors

Hot Gas Path Inspection Interval

The hours-based hot gas path criterion is determined from the equations given in *Figure 41*. With these equations, a maintenance factor is determined that is the ratio of factored operating hours and actual operating hours. The factored hours consider the specifics of the duty cycle relating to fuel type, load setting and steam or water injection. Maintenance factors greater than one reduce the hot gas path inspection interval from the baseline (typically 24,000 hour) case. To determine the application specific maintenance interval, the maintenance factor is divided into the baseline hot gas path inspection interval, as shown in *Figure 41*.

The starts-based hot gas path criterion is determined from the equations given in *Figure 42*. With the advent of non-synchronous generation, and increased interest on gas turbines to power soft and industrial grids, power generating units are more often considered to contain large load steps, defined as more than +/- 20% of GT rated load change in 10 seconds or less.

As previously described, the limiting criterion (hours or starts) determines the maintenance interval. Examples of these equations are in *Appendix A*.

Hours-Based HGP Inspection

$$\text{Maintenance Interval (Hours)} = \frac{\text{Baseline HGPI } (\textit{Figure 36})}{\text{Maintenance Factor}}$$

$$\text{Maintenance Factor} = \frac{\text{Factored Hours}}{\text{Actual Hours}}$$

$$\text{Factored Hours} = \Sigma_{i=1}^{n} (S_i \cdot Af_i \cdot Ap_i \cdot t_i)$$

$$\text{Actual Hours} = \Sigma_{i=1}^{n} (t_i)$$

i = 1 to n discrete operating modes (or operating practices of time interval)

t_i = Fired hours in a given operating mode

Ap_i = Load severity factor for given operating mode
- Ap = 1.0 up to base load
- Ap = For peak load factor see *Figure 10.*

Af_i = Fuel severity factor for given operating mode
- Af = 1.0 for natural gas
- Af = 1.5 for distillate (=1.0 when Ap > 1, at minimum Af · Ap = 1.5)
- Af = 2 to 3 for crude*
- Af = 3 to 4 for residual*

S_i = Water/steam injection severity factor = $K_i + (M_i \cdot I_i)$*
- I = Percent water/steam injection referenced to compressor inlet air flow
- M&K = Water/steam injection constants

* N/A for HA-class

M	K	Control	Water/Steam Inj.	S2N/S3N Material
0	1	Dry	<2.2%	All
0	1	Dry	>2.2%	Non-FSX-414
0.18	0.6	Dry	>2.2%	FSX-414
0.18	1	Wet	>0%	Non-FSX-414
0.55	1	Wet	>0%	FSX-414

Figure 41. Hot gas path maintenance interval: hours-based criterion

Starts-Based HGP Inspection

$$\text{Maintenance Interval (Starts)} = \frac{S}{\text{Maintenance Factor}}$$

Where:

$$\text{Maintenance Factor} = \frac{\text{Factored Starts}}{\text{Actual Starts}}$$

$$\text{Factored Starts} = 0.5N_A + N_B + 1.3N_P + P_sF + \Sigma_{i=1}^{n} (a_{Ti} - 1)\, T_i + \Sigma_{i=1}^{k} (a_{Li} - 1)\, L_i$$

$$\text{Actual Starts} = (N_A + N_B + N_P)$$

S = Baseline Starts-Based Maintenance Interval *(Figure 36)*

N_A = Annual Number of Part Load Start/Stop Cycles (<60% Load)

N_B = Annual Number of Base Load Start/Stop Cycles

N_P = Annual Number of Peak Load Start/Stop Cycles (>100% Load)

P_s = Peaking-Fast Start Factor (See *Figure 13*)

F = Annual Number of Peaking-Fast Starts

T = Annual Number of Trips

a_T = Trip Severity Factor = f(Load) (See *Figure 19*)

n = Number of Trip Categories (i.e. Full Load, Part Load, etc.)

L = Annual Number of Load Steps ≥ 20%

a_L = Exp(0.0137 x % Load Step)

k = Number of Load Step Levels

Figure 42. Hot gas path maintenance interval: starts-based criterion

GE Annular/Silo Fleet Inspection Intervals

Inspection intervals are primarily based on the hot gas path lifetime (i.e. turbine and combustor) and determine the intervals of visual and major inspections, whereas part repair or replacement is not expected to be necessary during visual inspections.

- Counting Methods and Parameters
  - Linear (initial BE-class) EOH = (S*V + TPE*W + OH*X) * Z
  - Elliptical (initial F-class) EOH = √[((V*S)2 + (A*OH)2)*Z]
  - Extended Linear (BEF-class) EOH = WOH + 10x WCE
    (later upgrades new/service) WOH = OH * X * Z / WCE = CE * V* Z
  - Box
    (future, latest F-upgrade) WOH = OH * X * Z / WCE = CE * V* Z

EOH	Equivalent Operating Hours
WOH	Weighted Operating Hours
OH	Operating hours
WCE	Weighted Cyclic Events
S	Starts
V, X, W, A	Penalty factors
Z	Fuel factor
TPE, CE	Protective/cyclic events

Fuel and penalty factors are GT Type and upgrade specific

Figure 43. Legacy Alstom Inspection Interval Counting Methods

Rotor Inspection Interval

Like hot gas path components, the unit rotor has a maintenance interval involving removal, disassembly, and inspection. This interval indicates the serviceable life of the rotor and is generally considered to be the teardown inspection and repair/replacement interval for the rotor. The disassembly inspection is usually concurrent with a hot gas path or major inspection; however, it should be noted that the maintenance factors for rotor maintenance intervals are distinct from those of combustion and hot gas path components. As such, the calculation of consumed life on the rotor may vary from that of combustion and hot gas path components. Customers should contact GE 1 to 2 years prior to their rotor reaching the end of its serviceable life for technical advisement.

Figure 44 describes the procedure to determine the hours-based maintenance criterion. Peak load operation is the primary hour maintenance factor for all rotors and will act to increase the hours-based maintenance factor and to reduce the rotor maintenance interval. For B/E-class units time on turning gear also affects rotor life. For HA, rotor maintenance factor can be reduced via the use of technology, such as evaporative coolers.

The starts-based rotor maintenance interval is determined from the equations given in *Figure 45*. Adjustments to the rotor maintenance interval are determined from rotor-based operating factors as described previously. In the calculation for the starts-based rotor maintenance interval, equivalent starts are determined for cold, warm, and hot starts over a defined time period by multiplying the appropriate cold, warm, and hot start operating factors by the number of cold, warm, and hot starts respectively. Additionally, equivalent starts for rapid/forced/crank cool downs are added. The total equivalent starts are divided by the actual number of starts to yield the maintenance factor. The rotor starts-based maintenance interval is determined by dividing the baseline rotor maintenance interval starts number by the calculated maintenance factor. The baseline rotor maintenance interval is also the maximum

Hours-Based Rotor Inspection

$$\text{Maintenance Interval (Hours)} = \frac{R}{\text{Maintenance Factor}}$$

$$MF = \frac{\text{Factored Hours}}{\text{Actual Hours}} = \frac{H + 2P^{(1)}}{H + P} \qquad \text{MF for B/E-class} = \frac{H + 2P + 2T_G^{(2)}}{H + P}$$

H = Non-peak load operating hours

P = Peak load operating hours

T_G = Hours on turning gear

R = Baseline rotor inspection interval

Machine	R[3]
FA.05 & HA Class	Refer to unit specific documentation.
F-class	144,000
B & E Class	200,000

(1) Maintenance factor equation to be used unless otherwise notified in unit-specific documentation.

(2) To diminish potential turning gear impact, major inspections must include a thorough visual and dimensional examination of the hot gas path turbine rotor dovetails for signs of wearing, galling, fretting, or cracking. If no distress is found during inspection or after repairs are performed to the dovetails, time on turning gear may be omitted from the hours-based maintenance factor.

(3) Baseline rotor inspection intervals to be used unless otherwise notified in unit-specific documentation.

Figure 44. Rotor maintenance interval: hours-based criterion

interval, since calculated maintenance factors less than one are not considered.

When the rotor reaches the earlier of the inspection intervals described in *Figures 44 and 45*, a GE Rotor Life Extension shall be completed on the rotor components in both the compressor and turbine. It should be expected that some rotor components will either have reached the end of their serviceable life or will have a minimal amount of residual life remaining and will require repair or replacement at this inspection point. Depending on the extent of refurbishment and part replacement, subsequent inspections may be required at a reduced interval.

Starts-Based Rotor Inspection

$$\text{Maintenance Interval (Starts)} = \frac{5{,}000^{(1)}}{\text{Maintenance Factor}}$$

$$\text{Maintenance Factor} = \frac{\text{Factored Starts}}{\text{Actual Starts}}$$

For units with published start factors:

$$\text{Maintenance Factor} = \frac{(F_{h1} \cdot N_{h1} + F_{h2} \cdot N_{h2} + F_{w1} \cdot N_{w1} + F_{w2} \cdot N_{w2} + F_c \cdot N_c + F_{FC} \cdot N_{FC})}{(N_{h1}+N_{h2}+N_{w1}+N_{w2}+N_c)}$$

For B/E-class units

$$\text{Maintenance Factor} = \frac{N_S + (2.3 \cdot N_{FC})}{N_S}$$

For all other units additional start factors may apply.

Number of Starts

- N_{h1} = Number of hot 1 starts
- N_{h2} = Number of hot 2 starts
- N_{w1} = Number of warm 1 starts
- N_{w2} = Number of warm 2 starts
- N_c = Number of cold starts
- N_{FC} = Number of Rapid/Forced/Crank Cool Shutdowns
- N_s = Total number of fired starts

Start Factors [2]

- F_{h1} = Hot 1 start factor (down 0-1 hr)
- F_{h2} = Hot 2 start factor (1 hour < downtime ≤ 4 hours)
- F_{w1} = Warm 1 start factor (4 hours < downtime ≤ 20 hours)
- F_{w2} = Warm 2 start factor (20 hours < downtime ≤ 40 hours)
- F_c = Cold start factor (downtime > 40 hours)
- F_{FC} = Rapid/Forced/Crank Cooling Shutdown Factor

(1) Baseline rotor inspection interval for B, E, and F class rotors is 5,000 fired starts unless otherwise notified in unit-specific documentation. Refer to unit specific documentation for FA.05 and HA class rotors for baseline starts number.

(2) Start factors for certain F-class units are tabulated in *Figure 21*. For all other machines, consult unit-specific documentation to determine if start factors apply.

Figure 45. Rotor maintenance interval: starts-based criterion

GE Annular/Silo Fleet Welded Rotor Inspection

Rotors are constructed with the intention of achieving four C- inspection intervals. Detailed minimum expected lifetime data in terms of Operating Hours (OH) can be found in *Figure 46*.

GE Annular/Silo Rotors – Creep Life

GE Annular/Silo – B-Fleet		
GT Type (all sub-ratings included)		**Minimum expected Lifetime of Rotor (OH)**
GT8	B	100000
	C	100000
	C2	100000
GT9	B, C, D	200000
GT11	B, C, D, N	130000
GT11	N2	150000
GT13	B, C, D	130000
GE Annular/Silo – E-Fleet		
GT Type (all sub-ratings included)		**Minimum expected Lifetime of Rotor (OH)**
GT13	E1	144000
	E2	144000
GE Annular/Silo – F-Fleet		
GT Type (all sub-ratings included)		**Minimum expected Lifetime of Rotor (OH)**
GT24	All Ratings	150000
GT26	All Ratings	150000
* Impact of GT26 HE to be evaluated on a case by case basis		

Figure 46. Annular/Silo Fleet Rotor Life

Rotor Life-time Monitoring (RLM) programs are recommended to be applied in order to increase project specific rotor lifetime capabilities. As part of RLM inspection, GE recommends performing "RLM Creep" location specific deformation measurements at every C-inspection to enable creep-based life trending for rotor life enhancement. Similarly, GE recommends performing "RLM Cyclic" based inspections based on fired starts & fatigue degradations as can be found in GE Annular/Silo Fleet safety TILs. These safety TILs outline details associated with when to start RLM Cyclic inspections based on fired starts, safety critical inspection fired starts limits, and maximum expected fired starts limits with proper application of RLM cyclic monitoring over the full life of the GT rotor.

Personnel Planning

It is essential that personnel planning be conducted prior to an outage. It should be understood that a wide range of experience, productivity, and working conditions exist around the world. However, an estimate can be made based upon maintenance inspection labor assumptions, such as the use of a crew of workers with trade skill (but not necessarily direct gas turbine experience), with all needed tools and replacement parts (no repair time) available. These estimated craft labor hours should include controls/accessories and the generator. In addition to the craft labor, additional resources are needed for technical direction, specialized tooling, engineering reports, and site mobilization/demobilization.

Inspection frequencies and the amount of downtime varies within the gas turbine fleet due to different duty cycles and the economic need for a unit to be in a state of operational readiness. Contact your local GE service representative for the estimated labor hours and recommended crew size for your specific unit.

Depending upon the extent of work to be done during each maintenance task, a cooldown period of 4 to 24 hours may be required before service may be performed. This time can be utilized productively for job move-in, correct tagging and locking equipment out-of-service, and general work preparations. At the conclusion of the maintenance work and systems check out, a turning gear time of two to eight hours is normally allocated prior to starting the unit. This time can be used for job clean-up and preparing for start.

Local GE field service representatives are available to help plan maintenance work to reduce downtime and labor costs. This planned approach will outline the replacement parts that may be needed and the projected work scope, showing which tasks can be accomplished in parallel and which tasks must be sequential. Planning techniques can be used to reduce maintenance cost by optimizing lifting equipment schedules and labor requirements. Precise estimates of the outage duration, resource requirements, critical-path scheduling, recommended replacement parts, and costs associated with the inspection of a specific installation may be sourced from the local GE field services office.

Conclusion

GE heavy-duty gas turbines are constructed to have high availability. To achieve increased gas turbine availability, an owner must understand not only the equipment but also the factors affecting it. This includes the training of operating and maintenance personnel, following the manufacturer's recommendations, regular periodic inspections, and the stocking of spare parts for immediate replacement. The recording and analysis of operating data is also essential to preventative and planned maintenance. A key factor in achieving this goal is a commitment by the owner to provide effective outage management, to follow published maintenance instructions, and to utilize the available service support facilities.

It should be recognized that, while the manufacturer provides general maintenance recommendations, it is the equipment user who controls the maintenance and operation of equipment. Inspection intervals for optimum turbine service are not fixed for every installation but rather are developed based on operation and experience. In addition, through application of a Contractual Service Agreement to a particular turbine, GE can work with a user to establish a maintenance program that may differ from general recommendations but will be consistent with contractual responsibilities.

The level and quality of a rigorous maintenance program have a direct effect on equipment reliability and availability. Therefore, GE provides a knowledge based gas turbine user solution that reduces costs and outage time while improving reliability and profitability.

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Appendix

A.1) Example 1 – Hot Gas Path Maintenance Interval Calculation

A 7E.03 user has accumulated operating data since the last hot gas path inspection and would like to estimate when the next one should be scheduled. The user is aware from GE publications that the baseline HGP interval is 24,000 hours if operating on natural gas, with no water or steam injection, and at base load. It is also understood that the baseline starts interval is 1200, based on normal startups, no trips, no peaking-fast starts. The actual operation of the unit since the last hot gas path inspection is much different from the baseline case. The unit operates in four different operating modes:

1. The unit runs 3200 hrs/yr in its first operating mode, which is natural gas at base or part load with no steam/water injection.
2. The unit runs 350 hrs/yr in its second operating mode, which is distillate fuel at base or part load with no steam/water injection.
3. The unit runs 120 hrs/yr in its third operating mode, which is natural gas at peak load (+100°F) with no steam/water injection.
4. The unit runs 20 hrs/yr in its fourth operating mode, which is natural gas at base load with 2.4% steam injection on a wet control curve.

The hours-based hot gas path maintenance interval parameters for these four operating modes are summarized below:

		Operating Mode (i)			
		1	**2**	**3**	**4**
Fired hours (hrs/yr)	t	3200	350	120	20
Fuel severity factor	Af	1	1.5	1	1
Load severity factor	Ap	1	1	$[e^{(0.018*100)}] = 6$	1
Steam/water injection rate (%)	I	0	0	0	2.4

For this particular unit, the second- and third-stage nozzles are FSX-414 material. From *Figure 41*, at a steam injection rate of 2.4% on a wet control curve,

$M_4 = 0.55, K_4 = 1$

The steam severity factor for mode 4 is therefore,

$= S_4 = K_4 + (M_4 \cdot I_4) = 1 + (0.55 \cdot 2.4) = 2.3$

At a steam injection rate of 0%,

$M = 0, K = 1$

Therefore, the steam severity factor for modes 1, 2, and 3 are

$= S_1 = S_2 = S_3 = K + (M \cdot I) = 1$

From the hours-based criteria, the maintenance factor is determined from *Figure 39.*

$$MF = \frac{\Sigma_{i=1}^{n} (S_i \cdot Af_i \cdot Ap_i \cdot t_i)}{\Sigma_{i=1}^{n}) (t_i)}$$

$$= \frac{(1 \cdot 1 \cdot 1 \cdot 3200) + (1 \cdot 1.5 \cdot 1 \cdot 350) + (1 \cdot 1 \cdot 6 \cdot 120) + (2.3 \cdot 1 \cdot 1 \cdot 20)}{(3200 + 350 + 120 + 20)}$$

$MF = 1.22$

The hours-based adjusted inspection interval is therefore,

Adjusted Inspection Interval = 24,000/1.22 = 19,700 hours

[Note, since total annual operating hours is 3690, the estimated time to reach 19,700 hours is 19,700/3690 = 5.3 years.]

Also, since the last hot gas path inspection the unit has averaged 145 normal start-stop cycles per year, 5 peaking-fast start cycles per year, and 20 base load cycles ending in trips ($a_T = 8$) per year. The starts-based hot gas path maintenance interval parameters for this unit are summarized below:

	TOTAL CYCLES					
	Normal Start		**Peaking Fast Start**			
	Normal Shutdown	**Trip from Load**	**Normal Shutdown**	**Trip from Load**		**Sum**
Part Load Cycles	40	0	0	0	N_A	40
Base Load Cycles	100	20	5	0	N_B	125
Peak Load Cycles	5	0	0	0	N_P	5

From the starts-based criteria, the maintenance factor is determined from *Figure 42*.

$Ps = 3.5$

$F = 5$

$a_T = 8$

$$MF = \frac{0.5N_A + N_B + 1.3N_P + P_sF + \Sigma_{i=1}^{n} (a_{Ti} - 1) T_i}{N_A + N_B + N_P}$$

$$MF = \frac{0.5\,(40) + 125 + 1.3\,(5) + 3.5\,(5) + (8 - 1)20}{40 + 125 + 5}$$

$MF = 1.8$

The adjusted inspection interval based on starts is

Adjusted Inspection Interval = 1200/1.8 = 667 starts

[Note, since the total annual number of starts is 170, the estimated time to reach 667 starts is 667/170 = 3.9 years.]

In this case the unit would reach the starts-based hot gas path interval prior to reaching the hours-based hot gas path interval. The hot gas path inspection interval for this unit is therefore 667 starts (or 3.9 years).

A.2) Example 2 – Hot Gas Path Factored Starts Calculation

A 7E.03 user has accumulated operating data for the past year of operation. This data shows number of trips from part, base, and peak load, as well as peaking-fast starts. The user would like to calculate the total number of factored starts in order to plan the next HGP outage. *Figure 42* is used to calculate the total number of factored starts as shown below.

Operational history:

	TOTAL CYCLES					
	Normal Start		Peaking Fast Start			
	Normal Shutdown	Trip from Load	Normal Shutdown	Trip from Load		Sum
Part Load Cycles	35	5	0	1	N_A	41
Base Load Cycles	25	35	4	2	N_B	66
Peak Load Cycles	40	10	0	0	N_P	50

Total Trips

1. 50% load (a_{T1} = 6.5), T_1 = 5 + 1 = 6
2. Base load (a_{T2} = 8), T_2 = 35 + 2 = 37
3. Peak load (a_{T3} = 10), T_3 = 10

Additional Cycles

Peaking-fast starts, F = 7

From the starts-based criteria, the total number of factored starts (FS) and actual starts (AS) is determined from *Figure 42*.

Ps = 3.5

F = 7

$$FS = 0.5N_A + N_B + 1.3N_P + P_sF + \Sigma_{i=1}^{n} (a_{Ti} - 1)\, T_i$$

$$= 0.5 \cdot 41 + 66 + 1.3 \cdot 50 + 3.5 \cdot 7 + (6.5 - 1)\, 6 + (8 - 1)\, 37 + (10 - 1)\, 10 = 558$$

$$AS = N_A + N_B + N_P = 41 + 66 + 50 = 157$$

$$\text{Maintenance Factor} = \frac{FS}{AS} = \frac{558}{157} = 3.6$$

A.3) Example 3 – Load Step Maintenance Factor Calculation

A 6F.03 gas turbine is selected to power an electro-intensive steel mill. The system is remote, not interconnected to the national grid. In order to preserve island grid stability, any sudden and uncontrolled change of the arc furnace demand is swiftly compensated by automatic change of unit power, through its built-in governor controls. Within the observed period, the un-controlled process events led the unit to execute 30 load steps beyond ±20% load. *Figure 42* is used to calculate the total number of factored starts resulting from the load steps.

Load Step Amplitude (% load step)	Number of load steps	Factored Starts
±20%	6	1.9
±25%	3	1.2
±30%	4	2.0
±35%	4	2.5
±40%	2	1.5
±45%	2	1.7
±50%	3	3.0
±55%	1	1.1
±60%	0	0.0
±65%	1	1.4
±70%	0	0.0
±75%	1	1.8
±80%	0	0.0
±85%	1	2.2
±90%	1	2.4
±95%	1	2.7
±100%	0	0.0

The gas turbine contained all grid events to avoid process outage, resulting in total Load Step Factored Starts of 25.4

B) Examples – Combustion Maintenance Interval Calculations (Reference *Figures 39 and 40*)

DLN 1 Peak Load with Power Augmentation

+50F Tfire Increase		Natural Gas Fuel	
3.5% Steam Augmentation		6 Hours/Start	
Peaking Start		Wet Control Curve	
Normal Shutdown (No Trip)			
Factored Hours = Ki * Afi * Api * ti =			34.5 Hours
Hours Maintenance Factor =		(34.5/6)	**5.8**
Where	Ki =	2.34 Max(1.0, exp(0.34(3.50-1.00))) Wet	
	Afi =	1.00 Natural Gas Fuel	
	Api =	2.46 exp(0.018(50)) Peak Load	
	ti =	6.0 Hours/Start	
Factored Starts = Ki * Afi * Ati * Api * Asi * Ni =			17.4 Starts
Starts Maintenance Factor =		(17.4/1)	**17.4**
Where	Ki =	2.77 Max(1.0, exp(0.34(3.50-0.50))) Wet	
	Afi =	1.00 Natural Gas Fuel	
	Ati =	1.00 No Trip at Load	
	Api =	1.57 exp(0.009(50)) Peak Load	
	Asi =	4.0 Peaking Start	
	Ni =	1.0 Considering Each Start	

Standard Combustor Base Load on Crude Oil

No Tfire Increase		Crude Oil Fuel	
1.0 Water/Fuel Ratio		220 Hours/Start	
Normal Start		Dry Control Curve	
Normal Shutdown (No Trip)			
Factored Hours = Ki * Afi * Api * ti =			788.3 Hours
Hours Maintenance Factor =		(788.3/220)	**3.6**
Where	Ki =	1.43 Max(1.0, exp(1.80(1.00-0.80))) Dry	
	Afi =	2.50 Crude Oil, Std (Non-DLN)	
	Api =	1.00 Base Load	
	ti =	220.0 Hours/Start	
Factored Starts = Ki * Afi * Ati * Api * Asi * Ni =			5.9 Starts
Starts Maintenance Factor =		(5.9/1)	**5.9**
Where	Ki =	2.94 Max(1.0, exp(1.80(1.00-0.40))) Dry	
	Afi =	2.00 Crude Oil, Std (Non-DLN)	
	Ati =	1.00 No Trip at Load	
	Api =	1.00 Base Load	
	Asi =	1.00 Normal Start	
	Ni =	1.0 Considering Each Start	

DLN 2.6 Base Load on Distillate

No Tfire Increase		Distillate Fuel	
1.1 Water/Fuel Ratio		220 Hours/Start	
Normal Start		Dry Control Curve	
Normal Shutdown (No Trip)			
Factored Hours = Ki * Afi * Api * ti =			943.8 Hours
Hours Maintenance Factor =		(943.8/220)	**4.3**
Where	Ki =	1.72 Max(1.0, exp(1.80(1.10-0.80))) Dry	
	Afi =	2.50 Distillate Fuel, DLN	
	Api =	1.00 Base Load	
	ti =	220.0 Hours/Start	
Factored Starts = Ki * Afi * Ati * Api * Asi * Ni =			5.3 Starts
Starts Maintenance Factor =		(5.3/1)	**5.3**
Where	Ki =	3.53 Max(1.0, exp(1.80(1.10-0.40))) Dry	
	Afi =	1.50 Distillate Fuel, DLN	
	Ati =	1.00 No Trip at Load	
	Api =	1.00 Base Load	
	Asi =	1.00 Normal Start	
	Ni =	1.0 Considering Each Start	

DLN 2.6 Base Load on Natural Gas with Trip @ Load

No Tfire Increase		Natural Gas Fuel	
No Steam/Water Injection		168 Hours/Start	
Normal Start		Dry Control Curve	
Trip @ 60% Load			
Factored Hours = Ki * Afi * Api * ti =			168.0 Hours
Hours Maintenance Factor =		(168.0/168)	**1.0**
Where	Ki =	1.00 No Injection	
	Afi =	1.00 Natural Gas Fuel	
	Api =	1.00 Base Load	
	ti =	168.0 Hours/Start	
Factored Starts = Ki * Afi * Ati * Api * Asi * Ni =			2.6 Starts
Starts Maintenance Factor =		(2.6/1)	**2.6**
Where	Ki =	1.00 No Injection	
	Afi =	1.00 Natural Gas Fuel	
	Ati =	2.62 0.5+exp(0.0125*60) for Trip	
	Api =	1.00 Base Load	
	Asi =	1.00 Normal Start	
	Ni =	1.0 Considering Each Start	

DLN 1 Combustor Base Load on Distillate

No Tfire Increase		Distillate Fuel	
0.9 Water/Fuel Ratio		500 Hours/Start	
Normal Start		Dry Control Curve	
Normal Shutdown (No Trip)			
Factored Hours = Ki * Afi * Api * ti =			1496.5 Hours
Hours Maintenance Factor =		(1496.5/500)	**3.0**
Where	Ki =	1.20 Max(1.0, exp(1.80(0.90-0.80))) Dry	
	Afi =	2.50 Distillate Fuel, DLN 1	
	Api =	1.00 Part Load	
	ti =	500.0 Hours/Start	
Factored Starts = Ki * Afi * Ati * Api * Asi * Ni =			3.7 Starts
Starts Maintenance Factor =		(3.7/1)	**3.7**
Where	Ki =	2.46 Max(1.0, exp(1.80(0.90-0.40))) Dry	
	Afi =	1.50 Distillate Fuel, DLN	
	Ati =	1.00 No Trip at Load	
	Api =	1.00 Part Load	
	Asi =	1.00 Normal Start	
	Ni =	1.0 Considering Each Start	

DLN 2.6 Peak Load on Natural Gas with Peaking Start

+35F Tfire Increase		Natural Gas Fuel	
3.5% Steam Augmentation		4 Hours/Start	
Peaking Start		Dry Control Curve	
Normal Shutdown (No Trip)			
Factored Hours = Ki * Afi * Api * ti =			12.5Hours
Hours Maintenance Factor =		(12.5/4)	**3.1**
Where	Ki =	1.67 Max(1.0, exp(0.34(3.50-2.00)))	
	Afi =	1.00 Natural Gas Fuel	
	Api =	1.88 exp(0.018(35)) Peak Load	
	ti =	4.0 Hours/Start	
Factored Starts = Ki * Afi * Ati * Api * Asi * Ni =			12.8 Starts
Starts Maintenance Factor =		(12.8/1)	**12.8**
Where	Ki =	2.34 Max(1.0, exp(0.34(3.50-1.00))) Dry	
	Afi =	1.00 Natural Gas Fuel	
	Ati =	1.00 No Trip at Load	
	Api =	1.37 exp(0.009(35)) Peak Load	
	Asi =	4.0 Peaking Start	
	Ni =	1.0 Considering Each Start	

C) Definitions

Reliability: Ability of generating units to perform their intended function. Also defined as probability of not being forced out of service when the unit is needed. Includes forced outage hours (FOH) while in service, while on reserve shutdown and while attempting to start normalized by period hours (PH) — units are %.

Reliability	=	(1-FOH/PH) (100)
FOH	=	total forced outage hours
PH	=	period hours

Availability: Fraction of time in which a unit is capable of providing service and accounts for outage frequency and duration. Also defined as probability of being available, independent of whether the unit is needed. – Includes all unavailable hours (UH) – normalized by period hours (PH) – units are %.

Availability	=	(1-UH/PH) (100)
UH	=	total unavailable hours (forced outage, failure to start, scheduled maintenance hours, unscheduled maintenance hours)
PH	=	period hours

Starting Reliability: A measure of the probability that a generating unit will start successfully when required. Includes actual starts (SS) – normalized by attempted starts (AS) – units are %.

Starting Reliability = SS/AS x 100

Service Factor: Measure of operational use, usually expressed on an annual basis – units are %. Sometimes service hours are approximated by operational hours (include idle running).

SF	=	OH/PH x 100
OH	=	Operating Hours on an annual basis
PH	=	Period Hours (8760 hours per year)

Operating Duty Definition:

Duty	Service Factor	Fired Hours/Start
Stand-by	< 1%	1 to 4
Peaking	1% – 17%	3 to 10
Cycling	17% – 50%	10 to 50
Continuous	> 90%	>> 50

D) Estimated Repair and Replacement Intervals (Natural Gas Only)

Repair/replace intervals reflect current production hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. Consult previous revisions of GER 3620 or other unit-specific documentation for estimated repair/replacement intervals of previous generation gas turbine models and hardware.

Contact your GE service representative for repair options. GE uses our unique proprietary knowledge of the part environment and use of specific inspection methods to address operational related damage that could potentially increase the interval replacement recommendation.

6B.03

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	4 (CI)	4 (CI) / 5 (CI)(1)
Caps	CI	4 (CI)	5 (CI)
Transition Pieces	CI	4 (CI)	4 (CI) / 5 (CI)(1)
Fuel Nozzles	CI	2 (CI)	2 (CI) / 3 (CI)(4)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
Flow Divider (Distillate)	CI	3 (CI)	3 (CI)
Fuel Pump (Distillate)	CI	3 (CI)	3 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 1 Buckets	HGPI	3 (HGPI)(2)	3 (HGPI)
Stage 2 Buckets	HGPI	3 (HGPI)(3)	4 (HGPI)
Stage 3 Buckets	HGPI	3 (HGPI)	4 (HGPI)

Note: Repair/replace cycles reflect current production (6B.03) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*. Applies to Performance Improvement Program (PIP). See your GE service representative for other configurations.

CI = Combustion Inspection Interval
HGPI = Hot Gas Path Inspection Interval
(1) 4 (CI) for non-DLN / 5 (CI) for DLN
(2) 3 (HGPI) with strip and recoat at first HGPI
(3) 3 (HGPI) for current design only. Consult your GE Energy representative for replace intervals by part number.
(4) 2 (CI) for non-DLN / 3 (CI) for DLN

Figure D-1. Estimated repair and replacement intervals

7E.03 (7)

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	3 (CI) / 5 (CI)(1)	5 (CI)
Caps	CI	3 (CI)	5 (CI)
Transition Pieces	CI	4 (CI) / 6 (CI)(5)	6 (CI)
Fuel Nozzles	CI	2 (CI) / 3 (CI)(6)	3 (CI)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
Flow Divider (Distillate)	CI	3 (CI)	3 (CI)
Fuel Pump (Distillate)	CI	3 (CI)	3 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 1 Buckets	HGPI	3 (HGPI)(2)(3)	3 (HGPI)
Stage 2 Buckets	HGPI	3 (HGPI)(4)	4 (HGPI)
Stage 3 Buckets	HGPI	3 (HGPI)	4 (HGPI)

Note: Repair/replace intervals reflect current production (7121(EA) or 7E.03) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*. Applies to Performance Improvement Program (PIP) HGP Hardware. See your GE service representative for other configurations.

CI = Combustion Inspection Interval
HGPI = Hot Gas Path Inspection Interval
(1) 3 (CI) for DLN / 5 (CI) for non-DLN
(2) Strip and Recoat is required at first HGPI to achieve 3 HGPI replace interval.
(3) Uprated 7E machines (2055 Tfire) require GE approved repair process at first HGPI to achieve 3 HGPI replace interval.
(4) 3 (HGPI) interval requires meeting tip shroud engagement criteria at prior HGP repair intervals. Consult your GE service representative for details.
(5) 4 (CI) for DLN / 6 (CI) for non-DLN
(6) 2 (CI) for DLN / 3 (CI) for non-DLN
(7) Also applicable to 7121(EA) models.

Figure D-2. Estimated repair and replacement intervals

9E.03 [6]

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	3 (CI) / 5 (CI)[1]	5 (CI)
Caps	CI	3 (CI)	5 (CI)
Transition Pieces	CI	4 (CI) / 6 (CI)[4]	6 (CI)
Fuel Nozzles	CI	2 (CI) / 3 (CI)[5]	3 (CI)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
Flow Divider (Distillate)	CI	3 (CI)	3 (CI)
Fuel Pump (Distillate)	CI	3 (CI)	3 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	4 (HGPI)
Stage 1 Buckets	HGPI	3 (HGPI)[2]	3 (HGPI)
Stage 2 Buckets	HGPI	3 (HGPI)[3]	4 (HGPI)
Stage 3 Buckets	HGPI	3 (HGPI)	4 (HGPI)

Note: Repair/replace intervals reflect current production (9171(E)) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*. Applies to Performance Improvement Program (PIP). See your GE service representative for other configurations.

CI = Combustion Inspection Interval
HGPI = Hot Gas Path Inspection Interval

(1) 3 (CI) for DLN / 5 (CI) for non-DLN
(2) Strip and Recoat is required at first HGPI to achieve 3 HGPI replace interval.
(3) 3 (HGPI) interval requires meeting tip shroud engagement criteria at prior HGP repair intervals. Consult your GE service representative for details.
(4) 4 (CI) for DLN / 6 (CI) for non-DLN
(5) 2 (CI) for DLN / 3 (CI) for non-DLN
(6) Applicable to non-AGP units only

Figure D-3. Estimated repair and replacement intervals

6F.03

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	2 (CI)	2 (CI)
Caps	CI	3 (CI)	2 (CI)
Transition Pieces	CI	3 (CI)	2 (CI)
Fuel Nozzles	CI	2 (CI)	2 (CI)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
End Covers	CI	4 (CI)	2 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Buckets	HGPI	3 (HGPI)	2 (HGPI)
Stage 2 Buckets	HGPI	2 (HGPI)	3 (HGPI)
Stage 3 Buckets	HGPI	3 (HGPI)	3 (HGPI)

Note: Repair/replace intervals reflect current production (6F.03 DLN 2.6) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*.

CI = Combustion Inspection Interval
HGPI = Hot Gas Path Inspection Interval

Figure D-4. Estimated repair and replacement intervals

7F.03

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	2 (CI)	2 (CI)
Caps	CI	2 (CI)	2 (CI)
Transition Pieces	CI	2 (CI)	2 (CI)
Fuel Nozzles	CI	2 (CI)	2 (CI)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
End Covers	CI	2 (CI)	2 (CI)
Stage 1 Nozzles	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Nozzles	HGPI	2 (HGPI)	2 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Buckets	HGPI	3 (HGPI)(2)	2 (HGPI)(4)
Stage 2 Buckets	HGPI	3 (HGPI)(1)	3 (HGPI)(1)
Stage 3 Buckets	HGPI	3 (HGPI)(3)	3 (HGPI)

Note: Repair/replace intervals reflect current production (7F.03 DLN 2.6 24k Super B and non-AGP) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*.

CI = Combustion Inspection Interval

HGPI = Hot Gas Path Inspection Interval

(1) 3 (HGPI) for current design. Consult your GE service representative for replacement intervals by part number.

(2) GE approved repair procedure required at first HGPI for designs without platform cooling.

(3) GE approved repair procedure at 2nd HGPI is required to meet 3 (HGPI) replacement life.

(4) 2 (HGPI) for current design with GE approved repair at first HGPI. 3 (HGPI) is possible for redesigned bucket with platform undercut and cooling modifications.

Figure D-5. Estimated repair and replacement intervals

7F.04/7FB.04

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	2 (CI)	2 (CI)
Caps	CI	2 (CI)	2 (CI)
Transition Pieces	CI	2 (CI)	2 (CI)
Fuel Nozzles	CI	2 (CI)	2 (CI)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
End Covers	CI	2 (CI)	2 (CI)
Stage 1 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Nozzles	HGPI	4 (HGPI)	4 (HGPI)
Stage 1 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	3 (HGP)
Stage 1 Buckets	HGPI	3 (HGPI)	3 (HGPI)
Stage 2 Buckets	HGPI	3 (HGPI)	3 (HGPI)
Stage 3 Buckets	HGPI	3 (HGPI)	3 (HGPI)

Note: Repair/replacement intervals reflect current production (7F.04 DLN 2.6) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*.

CI = Combustion Inspection Interval

HGPI = Hot Gas Path Inspection Interval

Figure D-6. Estimated repair and replacement intervals

9F.03

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	2 (CI)	3 (CI)
Caps	CI	2 (CI)	3 (CI)
Transition Pieces	CI	2 (CI)	3 (CI)
Fuel Nozzles	CI	2 (CI)(1)	3 (CI)(1)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
End Covers	CI	2 (CI)	3 (CI)
Stage 1 Nozzles	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Nozzles	HGPI	2 (HGPI)	2 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Buckets	HGPI	2 (HGPI)(2)	2 (HGPI)(4)
Stage 2 Buckets	HGPI	3 (HGPI)(5)	3 (HGPI)(3)
Stage 3 Buckets	HGPI	3 (HGPI)(5)	3 (HGPI)

Note: Repair/replace intervals reflect current production (9F.03 DLN 2.6+) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*.

CI = Combustion Inspection Interval
HGPI = Hot Gas Path Inspection Interval

(1) Blank and liquid fuel cartridges to be replaced at each CI

(2) 2 (HGPI) for current design with GE approved repair at first HGPI. 3 (HGPI) is possible for redesigned bucket with platform undercut and cooling modifications.

(3) Recoating at 1st HGPI may be required to achieve 3 HGPI replacement life.

(4) GE approved repair procedure at 1 (HGPI) is required to meet 2 (HGPI) replacement life.

(5) GE approved repair procedure is required to meet 3 (HGPI) replacement life.

Figure D-7. Estimated repair and replacement intervals

9F.05

	Repair Interval	Replace Interval (Hours)	Replace Interval (Starts)
Combustion Liners	CI	4 (CI)	4 (CI)
Caps	CI	4 (CI)	4 (CI)
Transition Pieces	CI	4 (CI)	4 (CI)
Fuel Nozzles	CI	2 (CI)(1)	2 (CI)(1)
Crossfire Tubes	CI	1 (CI)	1 (CI)
Crossfire Tube Retaining Clips	CI	1 (CI)	1 (CI)
End Covers	CI	4 (CI)	4 (CI)
Stage 1 Nozzles	HGPI	1 (HGPI)	1 (HGPI)
Stage 2 Nozzles	HGPI	2 (HGPI)	2 (HGPI)
Stage 3 Nozzles	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 2 Shrouds	HGPI	2 (HGPI)	2 (HGPI)
Stage 3 Shrouds	HGPI	3 (HGPI)	3 (HGPI)
Stage 1 Buckets	HGPI	1 (HGPI)	1 (HGPI)
Stage 2 Buckets	HGPI	1 (HGPI)	1 (HGPI)
Stage 3 Buckets	HGPI	1 (HGPI)	1 (HGPI)

Note: Repair/replace intervals reflect current production (9F.05) hardware, unless otherwise noted, and operation in accordance with manufacturer specifications. They represent initial recommended intervals in the absence of operating and condition experience. For factored hours and starts of the repair intervals, refer to *Figure 36*.

CI = Combustion Inspection Interval
HGPI = Hot Gas Path Inspection Interval

(1) Blank and liquid fuel cartridges to be replaced at each CI

Figure D-8. Estimated repair and replacement intervals

E) Borescope Inspection Ports

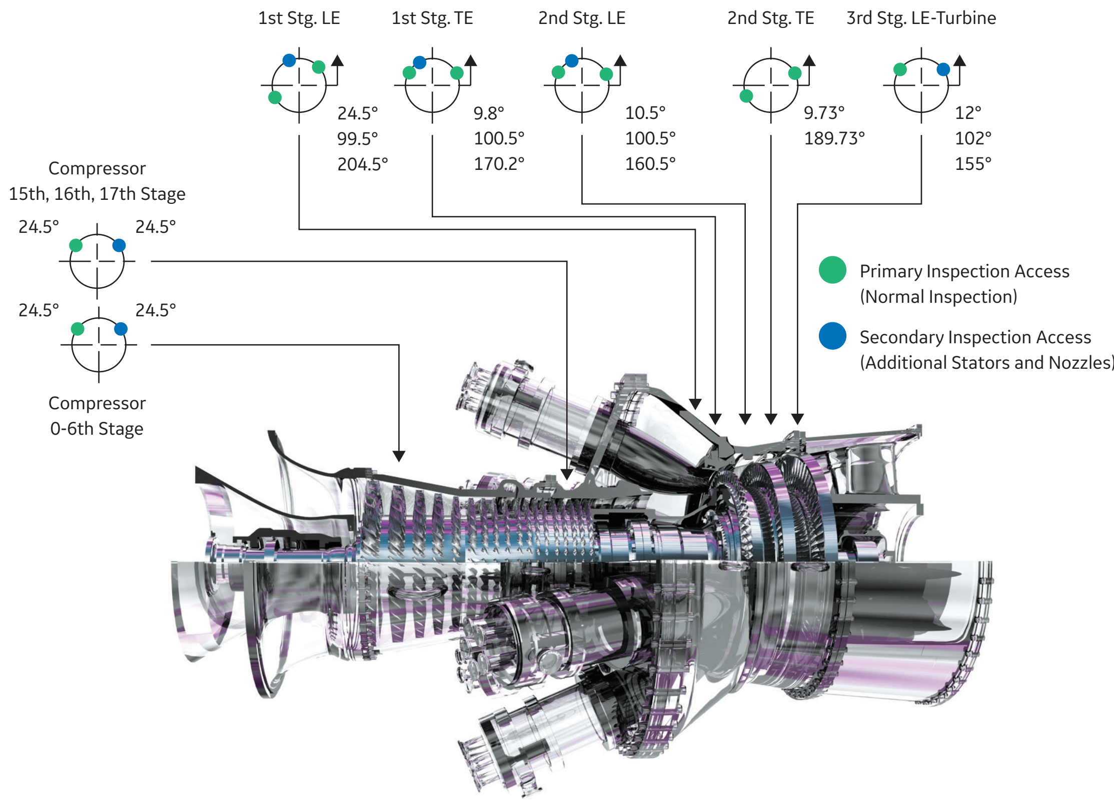

Figure E-1. Borescope inspection access locations for 6FA.03

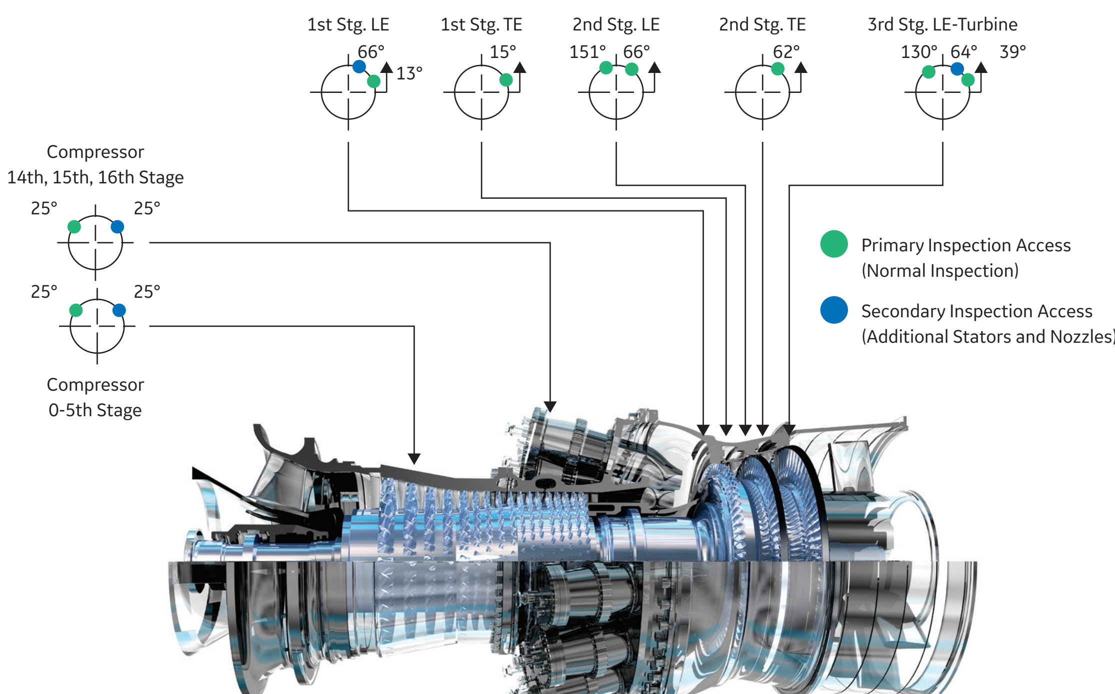

Figure E-2. Borescope inspection access locations for 7F.03, 7F.04,7FB.01, 9F.03, 9F.05

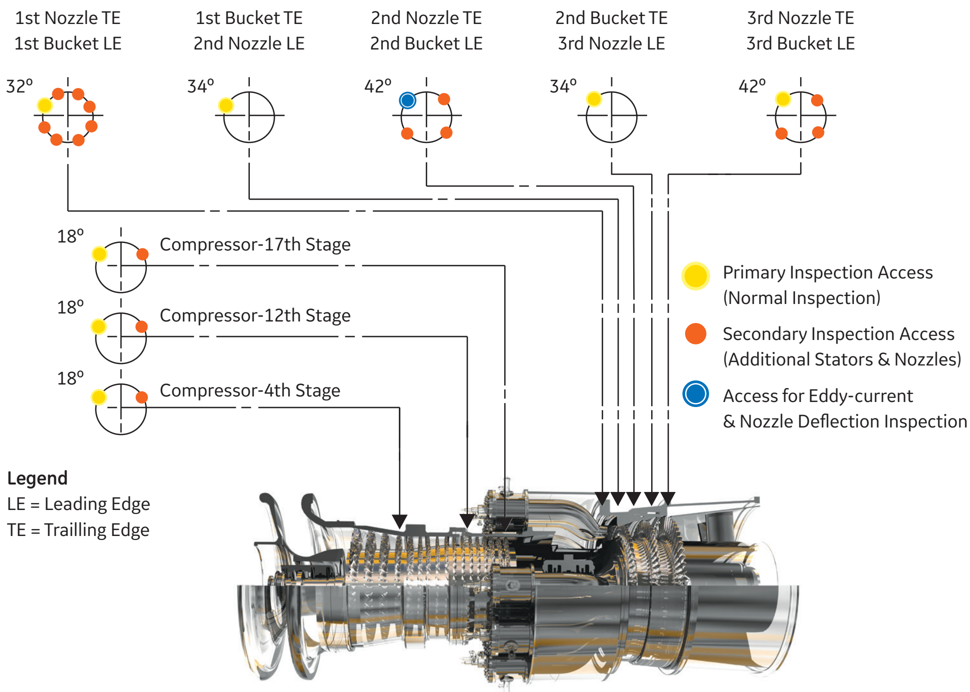

Figure E-3. 7E.03 gas turbine borescope inspection access locations

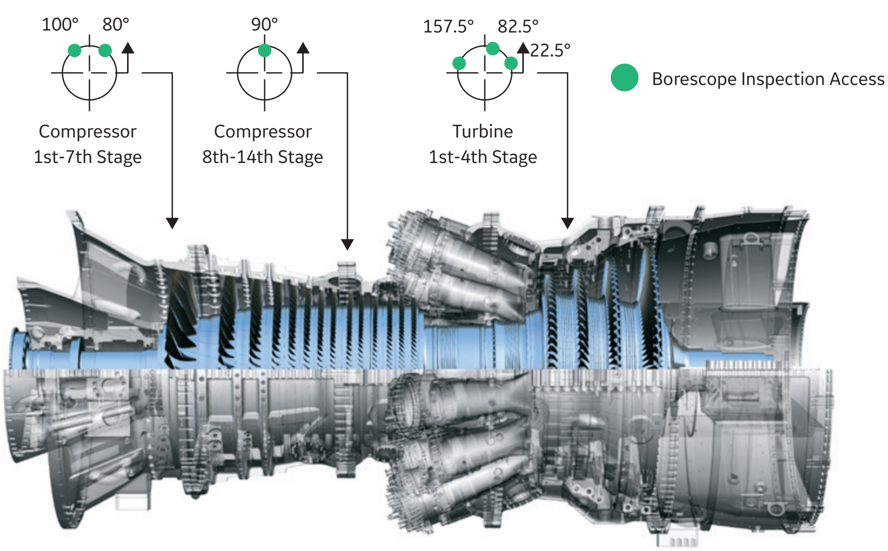

Figure E-4. 7HA.01 gas turbine borescope inspection access locations

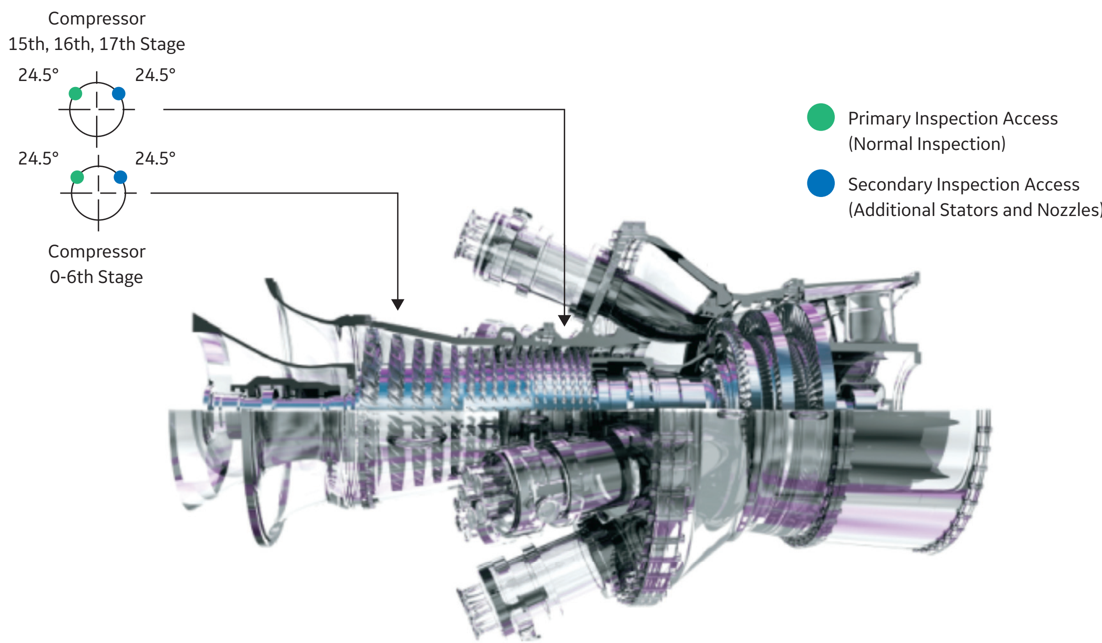

Figure E-5. 6FA.03 Borescope port locations

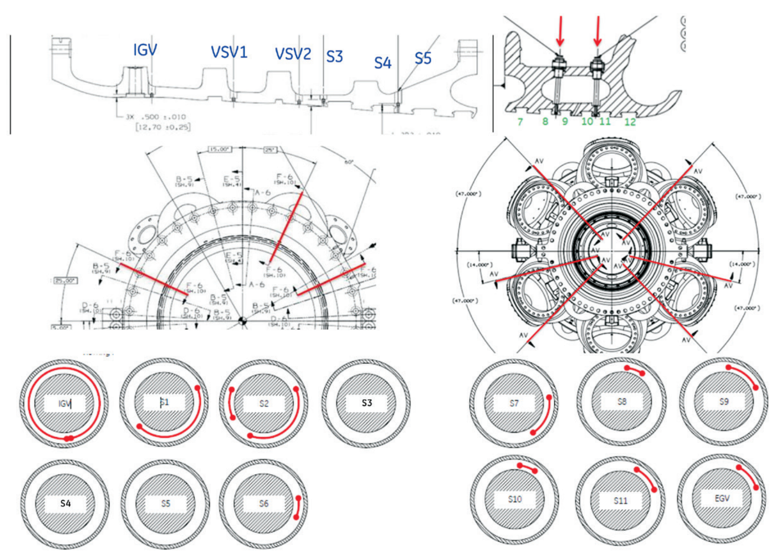

Figure E-6. Typical arrangement. See unit specific information.

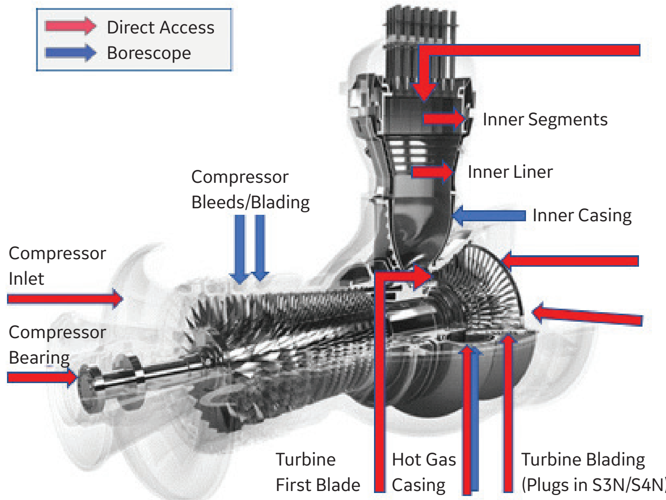

Figure E-7. GT11N2 (Sample B – Fleet with Silo Combustor)

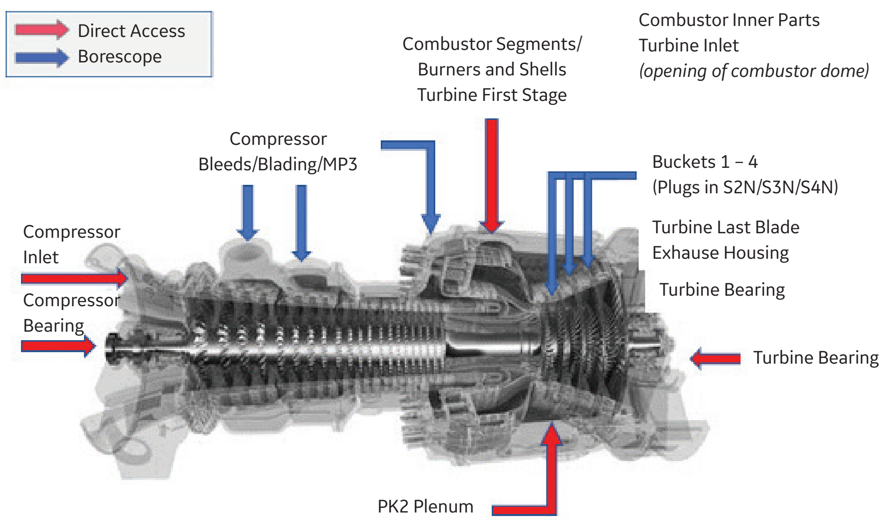

Figure E-8. GT13E2 (E-Fleet with Annular Combustor

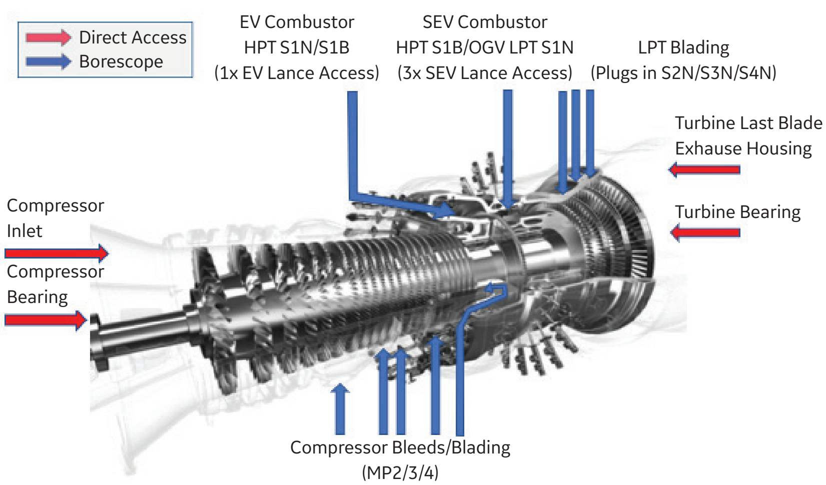

Figure E-9. GT24/GT26 (F – Fleet with Annular Combustor)

F) Turning Gear/Ratchet Running Guidelines

Scenario	Turning Gear (or Ratchet) Duration
Following Shutdown:	
Case A.1 – Normal. Restart anticipated for >48 hours	Until wheelspace temperatures <150°F.[1] Rotor classified as unbowed. Minimum 24 hours.[2]
Case A.2 – Normal. Restart anticipated for <48 hours	Continuously until restart. Rotor unbowed.
Case B – Immediate rotor stop necessary. (Stop >20 minutes) Suspected rotating hardware damage or unit malfunction	None. Classified as bowed.
Before Startup:	
Case C – Hot rotor, <20 minutes after rotor stop	0–1 hour[3]
Case D – Warm rotor (rotor wheelspace temperatures >150°F[1] at turning gear speed prior to rotor stopping and wheelspace temperatures still >150°F[1] at turning gear speed after rotor turning initiated) – Rotor stopped for >20 minutes but <6 hours	4 hours
Case E.1 – Cold rotor, unbowed (all rotor wheelspace temperatures cooled below 150°F[1] at turning gear speed prior to rotor stopping) – Off turning gear <48 hours prior to restart	4 hours
Case E.2 – Cold rotor, unbowed (all rotor wheelspace temperatures cooled below 150°F[1] at turning gear speed prior to rotor stopping) – Off turning gear >48 hours prior to restart	6 hours
Case F – Cold rotor, bowed (rotor cooled down without reaching wheelspace temperatures <150°F[1]at turning gear speed prior to rotor stopping, Case B condition exists, or off turning gear for >6 hours)	8 hours[4]
During Extended Outage:	
Case G – When idle	1 hour daily
Case H – Alternative	No TG; 1 hour/week at full speed (no load).[5]

(1) Time depends on frame size and ambient environment.

(2) Cooldown cycle may be accelerated using starting device for forced cooldown. Turning gear, however, is recommended method.

(3) 1 hour on turning gear is recommended following a trip, before restarting. For normal shutdowns, use discretion.

(4) Follow bowed rotor startup procedure, which may be found in the unit O&M Manual.

(5) Avoids high cycling of lube oil pump during long outages.

Figure F-1. Turning gear guidelines

G) B/E-, F-, and H-class Gas Turbine Naming

Frame	New Names	Former Names				
6F		6F 3-Series	6F-3	6FA	PG6101FA	6FA.01
	6F.03			6FA+e	PG6111FA	6FA.03
						6F Syngas
7F	7F.03 7F.04	7F 3-Series	7F-3	7FA	PG7221FA	7FA.01
				7FA+	PG7231FA	7FA.02
				7FA+E	PG7241FA	7FA.03
						7FA.04
						7FB
						7F Syngas
	7F.05	7F 5-Series	7F-5	7FA.05		
7HA	7HA.01	7F 7-Series	7F-7			
	7HA.02					
9F		9F 3-Series	9F-3	9FA	PG9311FA	9FA.01
				9FA+	PG9331FA	9FA.02
	9F.03			9FA+e	PG9351FA	9FA.03
	9F.04					9FA.04
		9F 5-Series	9F-5			9FB.01
						9FB.02
	9F.05					9FB.03
9HA	9HA.01	9F 7-Series	9F-7			9FB.05
	9HA.02					
6B		6B 3-Series	6B-3		PG6521B	
					PG6531B	
					PG6541B	
					PG6551B	
					PG6561B	
					PG6571B	
	6B.03				PG6581B	
	6B.03					
6F.01	6F.01	6C	6C	6C	PG6591C	
7EA		7E 3-Series	7E-3		PG7111EA	
					PG7121EA	
	7E.03					
7H	7H.01	7H 7-Series	7H-7	7H	GS7072	
9E		9E 3-Series		9E	PG9141E	
				9E	PG9151E	
				9E	PG9161E	
			9E-3	9E	PG9171E	
				9E		
	9E.03			9E		
				9E		9E Syngas
	9E.04/9E Max					
9EC	9EC.01	9E 5-Series	9E-5	9EC	GS9053	
9H	9H.02	9H 7-Series	9H-7	9H	GS9048	Commercial/Block 2
				9H B2A	GS9069	Block 2A
					G9069S	Block 2A Spares

Figure G-1. B/E-, F-, and H-class Turbine Naming"

GE Annular/Silo Fleet Gas Turbine Naming

Series	Class	Combustor System	Rating Names	Upgrade Names	
GT8	B	Silo SB	B	BC	XL
		Silo EV	C		XL
		Annular EV	C2		
GT9		Silo SB Horizontal	C		
		Silo SB/U-Duct SB	D	DC+	
GT11		Silo/SB/EV/U-Duct SB	D	DM/DMC	DM XL
		Silo SB/EV	N	NM/NMC	XL/XP
		Silo SB/EV/LBtu	N2	XL	M
GT13		Silo SB/EV	B, C, D	DM	L/P
		Silo SB/EV	E1	MXL/ MXLC	
	E	Annular EV/AEV	E2	MXL	MXL2
GT24	F	Sequential Annular EV + SEV	A, AB, B	MXL	MXL2
			2006		MXL2
			2011		
GT26			AB, B	APP	HE
			2006	APP	HE
			MXL2	–	HE

SB – Single Burner
Lbtu – Low Btu Burner
EV/SEV – EnVironmental Burner/Sequential EnVironmental Burner
AEV – Advanced EnVironmental Burner

Figure G-2. Annular/Silo Fleet Turbine Naming

Revision History

9/89 Original

8/91 Rev A

9/93 Rev B

3/95 Rev C

- Nozzle Clearances section removed
- Steam/Water Injection section added
- Cyclic Effects section added

5/96 Rev D

- Estimated Repair and Replacement Cycles added for F/FA

11/96 Rev E

11/98 Rev F

- Rotor Parts section added
- Estimated Repair and Replace Cycles added for FA+E
- Starts and hours-based rotor maintenance interval equations added

9/00 Rev G

11/02 Rev H

- Estimated Repair and Replace Cycles updated and moved to Appendix D
- Combustion Parts section added
- Inlet Fogging section added

1/03 Rev J

- Off Frequency Operation section added

10/04 Rev K

- GE design intent and predication upon proper components and use added
- Added recommendation for coalescing filters installation upstream of gas heaters
- Added recommendations for shutdown on gas fuel, dual fuel transfers, and FSDS maintenance
- Trip from peak load maintenance factor added
- Lube Oil Cleanliness section added
- Inlet Fogging section updated to Moisture Intake
- Best practices for turning gear operation added
- Rapid Cool-down section added
- Procedural clarifications for HGP inspection added
- Added inspections for galling/fretting in turbine dovetails to major inspection scope
- HGP factored starts calculation updated for application of trip factors
- Turning gear maintenance factor removed for F-class hours-based rotor life
- Removed reference to turning gear effects on cyclic customers' rotor lives
- HGP factored starts example added
- F-class borescope inspection access locations added
- Various HGP parts replacement cycles updated and additional 6B table added
- Revision History added

11/09 Rev L

- Updated text throughout
- Casing section added
- Exhaust Diffuser section added
- Added new Fig. 26: F-class axial diffuser
- Added new Fig. 27: E-class radial diffuser
- Revised Fig. 3, 5, 7, 8, 11, 19, 20, 23, 35, 37, 38, 40, 41, 42, 43, 44, E-1, and E-2
- Appendix D – updated repair and replacement cycles
- Added PG6111 (FA) Estimated repair and replacement cycles
- Added PG9371 (FB) Estimated repair and replacement cycles

10/10 Correction L.1

- Corrected Fig. D-4, D-5, and D-11 combustion hardware repair and replacement cycles

5/14 Rev M

- Updated text throughout
- Added Fig. 14, 15, 25
- Revised Fig. 8, 10, 12, 22, 29, 34, 35, 37, 39, 41, 42, 43, 44, 45
- Updated Appendix A
- Updated Appendix D
- Added 7F.04 Estimated repair and replacement intervals
- Added Appendix G

10/17 Rev N

- Updated text throughout
- Updated Introduction section
- Removed reference to Fig. 3
- Moved Fig. 3 to Appendix E
- Renumbered figures
- Renumbered figure references
- Renumbered figure references in Fig. 13, 14, 37, 38, 39, 40, 42, D-1, D-2, D-3, D-4, D-5, D-6, D-7, D-8, D-9, D-10, D-11
- Updated Firing Temperatures section
- Revised and renumbered Fig. 25 (now 24)
- Updated Moisture Intake
- Removed Fig. 30 and Fig. 31
- Updated Combustion Inspection section
- Revised Fig. 34
- Updated Reference section
- Updated Appendix E figure captions
- Added Fig E-3 (formerly Fig. 3), E-4, E-5, E-6
- Removed Fig. 3, Fig 30, and Fig. 31 from List of Figures and renumbered
- Append existing Revision History:
- Revise Fig. 43 to include affect of forced cooling on rotor MF.
- Revise Fig. 31 to include VSVs
- Revise Fig. 32 to include 4th stage buckets
- Revise Fig. 36 to include 6F.01, 7F.05,7HA.01, 7HA.02, 9HA.01, and 9HA.02
- Major Inspection Maintenance Interval Basis changed from actual to factored starts/hours
- Added Digital Asset Management section
- Added Legacy Alstom Inspection Interval section
- Added Welded Rotor section
- Added Fig. 6 to illustrate EOH counting methodology
- Added double wall casing and new seal technology inspection activities.

2/21 Rev P

- Updated text throughout
- Added GE Annular/Silo nomenclature to introduction
- Added maintenance recommendations for GE Annular/Silo fleet
- Updated B/E-Class rotor MF
- Updated Fig. 24
- Added GE Annular/Silo combustion system configurations
- Revised Combustion Parts section
- Revised Exhaust Diffuser section
- Updated Off Frequency Operation
- Added ABC Inspections for GE Annular/Silo fleet
- Removed Frame 3 and Frame 5 from document
- Revised Fig. 36 to update existing notes and add new notes
- Increased HGP and MI interval for 6B.03, 7E.03, and 9E.03
- Revised 6F.01 HGPI starts interval
- Revised 6F.03 CI interval
- Update Fig. 39 to include available combustion systems
- Update Fig. 40 to include available combustion systems
- Update Fig. 42 to include load step factor
- Added GE Annular/Silo rotor creep life
- Revised Appendix A to include load step MF calculation
- Updated Appendix C
- Updated Appendix D to include PIP and reference GE proprietary repair methods
- Updated Appendix E to include GT11N2, GT13E2, GT24, and GT26
- Updated Appendix G to include GT8, GT9, GT11, GT13, GT24, and GT26

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