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Japan International Cooperation Agency
Ministry of Power
NTPC LTD

THE STUDY ON ENHANCING EFFICIENCY OF OPERATING THERMAL POWER PLANTS IN NTPC-INDIA

Final Report

Volume IV

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Electric Power Development Co., Ltd.
Tokyo, Japan,
Kyusyu Electric Power Co., Inc.
Fukuoka, Japan
and
The Chugoku Electric Power Co., Inc.
Hiroshima, Japan

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PREFACE

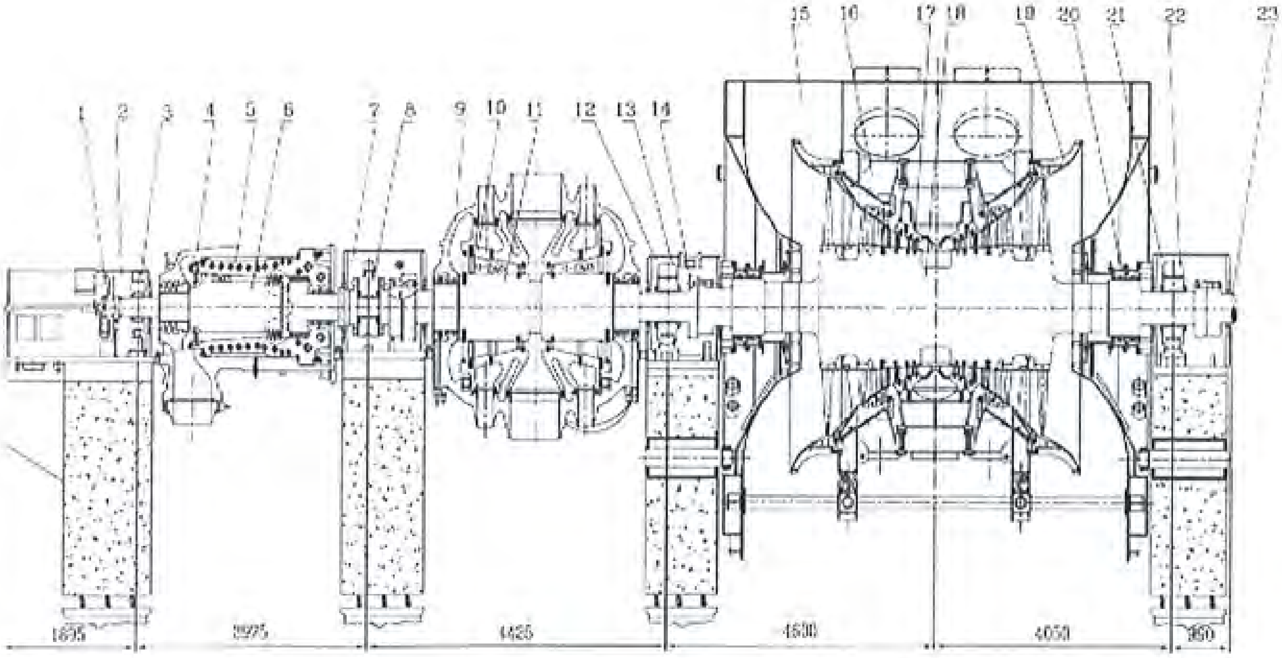
The purpose of this document is to provide a detail report on the studies carried out as defined in technical specifications and scope of work for Steam Turbine (IP & LP) & System Assessments in Unit No. 4, 500Mw at NTPC- Korba, by ALSTOM K.K. in Japan (hereinafter referred to as "Contractor") for the purpose to implement a series of study in conjunction with steam turbine system and the plant (hereinafter referred to as "Study") for National Thermal Power Corp. Ltd. (hereinafter referred to as "Operator") units through the prime contractor, Electric Power Development Co., Ltd. (hereinafter referred to as "Purchaser") for which the JICA fund has been agreed to be applied for.

The detailed report on the above is hereby submitted in 03 volumes.

Volume – I A : **Project Summary.**
Volume – I B : **RLA of IP & LP Turbine.**
Volume – II : **RLA & Stress Analysis of Critical Pipings**
Volume – III : **SPA of IP & LP Turbines.**

ALSTOM	Client	J-Power (Electric Power Development Co. Ltd.,)
	Project	Turbine and System Assessment for NTPC-Korba Unit #4
	Order No.	CGP10028C
	Contractor	ALSTOM K.K. NASL Ltd. (Nominated subcontractor in India)
NTPC ALSTOM **Power Services Pvt. Ltd.**	**Document**	**FINAL REPORT VOL. I A**

Overall Layout sketch of Turbine



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MAIN DATA

1- RATED OUTPUT .... 500 MW
2- RATED SPEED .... 3000 RPM
3- MAIN STEAM PRESSURE ..... 170 ata
4- MAIN STEAM TEMP .... 537 °C
5- REHEAT STEAM TEMP....... 537 °C
6- OVERALL LENGTH .... 18.94 M (approx)
7- OVERALL WIDTH........ 15.1 M (approx)

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Acknowledgement

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Chapter-1 ACKNOWLEDGEMENT

Development of this report has involved the help of dozens of interest groups and individuals. Many have offered comments either informally or formally. These contributions have been invaluable to bring forth the report in final form.

We appreciate the time that organizations and individuals took to share their ideas. In this regard we would like to specially express our heart felt thanks to J-Power & JICA Study Team, who had reposed confidence on us and awarded the assignment. Thanks are due to the Management of NTPC Korba, the on-site management and engineers and also entire team of CENPEEP, OS, R&D of NTPC, who extended all possible help and necessary guidance during site execution and reviews of the findings.

Above all there are no words to express, for the kind courtesy, co-operation and hospitality extended to our team, while conducting the above study and achieving the desired objective of the project.

With Sincere thanks,

Hirotsugu Ohgihara

(Overall Project Coordinator – ALSTOM K.K, Japan)

P. K. Sinha

(Project Director – NASL Ltd., India)

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Team Members

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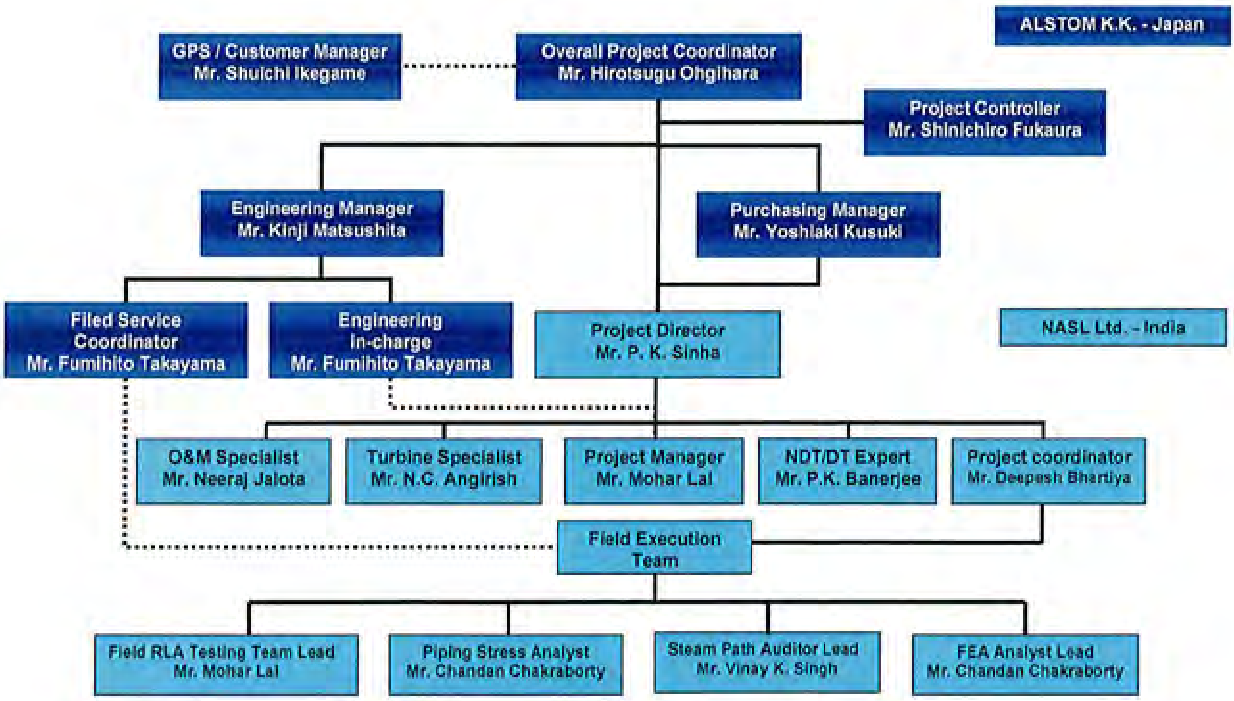
TEAM MEMBERS



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Introduction

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INTRODUCTION

Korba super Thermal Power Station (KSTPS), the prestigious and largest Thermal Power Station running in the state of Chattisgargh (INDIA), is operated by NTPC. It has presently an installed capacity of 2100 MW having six units of 3X200+ 3X500 MW and one unit of 1x500 MW is under commissioning.

Thermal power plants have traditionally been built with an envisaged design life of 20-25 years. Thermal Power Units being highly capital intensive, constant efforts are required to be made to extend the useful life, and allow the unit to run for maximum duration in a reliable manner, rather than retire at the end of design life. Also, during operation of the unit many of them have to be operated at different regimes, which in certain cases could be transgressing the design operating parameters. Consequently regular bench marking study is required to assess and identify the health of the equipment and components and identify the deficiencies to take timely corrective actions. Hence there is general interest world wide to maintain the life of sets by conducting Residual life assessment of major equipments and its auxiliaries for RUN/ REPAIR /REPLACE decisions and revalidate life of unit on the basis of above study.

The materials of the power plant equipment under go degradation in terms of strength and service ability on account of their being subjected to creep, fatigue, corrosion and erosion environment etc. As a consequence, their operating life gets reduced.

Failure rate increases as a result of time dependent material damage. Further running of the unit may become uneconomical and hazardous in cases. However, initiating preventive measures by way of focus and proper maintenance/ refurbishment action / rectification / modification etc. as a result of RLA study would help in timely actions, which would assist in continued trouble free operation.

Over a period of time, especially steam turbines undergo wear & tear, deposits and pitting on the blades and other steam path surfaces, resulting into additional loses/increased heat rate/restriction on power output. Although during each turbine overhauling, some corrective action is undertaken as per OEM guidelines, no quantification of losses occurring at various locations before the overhauling, and the extent of improvement done is available. Such quantification helps in taking cost effective decisions regarding the remedial actions during the overhauling. In this study the Steam Path Audit has been carried out based upon the eSTPE software.

JICA Study Team entrusted the work to ALSTOM K.K. (the Contractor) for RLA study of Turbine (IP&LP), SPA & Piping Assessment under the programme of "STEAM TURBINE AND SYSTEM ASSESSMENTS RELATING TO JICA STUDY ON IMPROVEMENT PLAN OF OPERATION & MAINTENANCE OF THERMAL POWER STATION IN INDIA"., through J Power (the Purchaser) for Unit No. 4, 500MW at NTPC Korba (Owner).

Based on the Assessment studies carried out in the NTPC-Korba Unit-4, the Contractor and its nominated sub-contractor, NASL is expected to assess the condition and residual life of components and advice NTPC Korba STPS for Run /Repair /Replace decision for the Equipments, components & systems through R&M programme of the unit to run the unit reliably, extends its life, and achieve rated (or Higher) load and efficiency.

The Present volume of the RLA studies contains the details of the test readings, findings, interpretations, recommendations, etc for all components as per the scope of work. The entire report forms the following three volumes:

Volume – I A: Project Summary.
Volume – I B: RLA of Turbine.
Volume – II : RLA & Stress Analysis of Critical Pipings
Volume – III: SPA of IP & LP Turbines.

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Chapter – 04

Scope of Work & Schedule

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4. SCOPE OF WORK

4.1 Scope Overview

The offered scope of work and related studies are limited for the following units of NTPC Ltd. in India and the equipments:

NTPC – Korba Unit # 4 (500MW)

- **Residual Life Assessment (RLA) for 1xIP and 1xLP Turbines & Piping.**
- **Main Piping Assessment**
- **Steam Path Audit (SPA) of 1xIP and 1xLP Turbines**

(Refer Scope test matrix (Annexure-I) enclosed here, for the detailed scope of work)

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ALSTOM	Client	J-Power (Electric Power Development Co. Ltd.,)
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Sl no		Test Matrix for RLA							Actual Completed On site.
		Name of Component	**VO**	**LPI/ DPT**	**MPI**	**UT**	**Replica**	**Hardness**	**Special**	
1.0		**IP Turbine**								
	1.1	Rotor	100%	Journal Region	100% accessible region by coil/yoke	Externally accessible region and journal region	6 location	Replicated location		
	a	Integral disc								
	b	Shaft Surface								
	1.2	Blades	100%	No		No	No	No	Deposit analysis*(it shall be collected by using knife and spetchula just after opening of casing and removal of rotors), Eddy current test of moving blades	**100% Completed as per matrix.**
	1.3	Shrouds	100%	No		No	No	No		
	1.4	Sealing grooves (Castellation)	100%	No		No	No	No		
	1.5	Coupling bolts	100%	100%	100%	No	No	No		
2.0		**IP Casing**								
	2.1	Casing Halves	100%	Key & Keyways	Only critical areas	No	4 locations	Replicated locations	Deposit analysis*	**100% Completed as per matrix.(only one stud received) for testing**
	2.2	Parting Plane Stud & Fasteners	100%	No	100% by coil	No	No	H T Studs	Destructive tests on one stud from IP inner casing and one from IP outer casing of dimension of at least 300 mm (length) and 20 mm diameter	

3.0		**IP Stationary Blades & Liners**								
	3.1	Stationary Blades	100%	Key & Keyways	100% by coil	No	8 location	Replicated locations	Deposit analysis*	
4		**Babbitted Bearings**								
	4.1	Babbit bonding & Surface	100%	Babbit scanning 100%	No	Babbit scanning 100%	No	No		**100% Completed as per matrix.**
	4.2	Bearing Housing pedestal	100%	No	On parting plane	No	No	No		
5.0	**LP Turbines & Casings**									
	5.1	Rotor	100%	Journal Region	100% accessible region by coil/yoke for each turbine and casing	Externally accessible region	2 points/ **(1 at least at the middle portion of each rotor)**	2 points		**100% Completed as per matrix.**
	5.2	Blades	100%	No		No	No	No	Eddy current test of moving blades	
	5.3	Shrouds	100%	No		No	No	No		
	5.4	Sealing grooves (Castellation)	100%	No		No	No	No		
	5.5	Casing Halves	100%	No	Only critical areas of each casing	No	No	No		
	5.6	Coupling bolts	100%	100%	100%	No	No	No		
	5.7	Rotor last three	NFT & Physical looseness check							**Completed**

		stage								**Jointly**
6.0	**Integral Steam Piping & Valves**									
	6.1	Integral Steam Pipes – HP/IP Casing	100%	No	All butt Weld joints	All butt Weld joints	4 location (total)	Replicated locations	Thickness measurement at bends	**100% Completed as per matrix.**
	6.2	HP/ LP Bypass Main Valves	100%	Seat , Cone Chamber	Spindle, Strainers, Fasteners	No	2 location/ each valve	Replicated locations		
	6.3	HP/IP Governing Valves	100%	Seat , Cone Chamber	Spindle, Strainers, Fasteners	No	4 location/ each valve	Replicated locations		
	6.4	HP/IP Stop Vales	100%	Seat , Cone Chamber	Spindle, Strainers, Fasteners	No	4 location/ each valve	Replicated locations		

Legends:

VO= Visual Observation, LPI/DPT= Dye Penetrate Test, MPI= Fluorescent Magnetic Inspection, UT= Ultra Sonic Test, Replica= In-situ Metallography, Hardness= Portable rebound hardness

Sl no	**Test Matrix for Main Piping Assessment**							**Actual Completed On site.**
	Name of Component	**VO**	**MPI/LPI**	**UT**	**Replica**	**Hardness**	**Notes**	
1	**Main Steam Piping**	100%	At accessible Bend & weld joint	At accessible Bend & weld joints	At accessible bends & welds	At replica locations	Close to hanger supports at accessible locations.	**Completed as per matrix.**
2	**Hot Re-heat Piping**	100%	At accessible Bend & weld joint	At accessible Bend & weld joints	At accessible bends & welds	At replica locations	Close to hanger supports at accessible locations	
3	**Cold Re-heat Piping**	100%	At accessible Bend & weld joint	At accessible Bend & weld joints	Random at 2 location	At replica locations	Close to hanger supports at accessible locations	
4	**Feed Water Piping** (from final feed water heater outlet to boiler Eco inlet)	100%	At accessible Bend & weld joint	At accessible Bend & weld joints	Not required	Not required	Random Close to hanger supports at accessible locations	

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Objective of Project

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5. OBJECTIVE

Objective of Study is:

- Assessment of the present condition of Steam turbine & critical pipings.
- Remaining Life assessment of the said equipments / components.
- To provide recommendations for Run/Repair/Replace decision of the said equipments / components.
- To provide input for planning in advance for the replacement of the critical components and thus avoids downtime of the stations.
- To provide input for planning to modify the operating cycle and parameters thus enhances the life of the said components.
- To ensure safe & reliable operation of said components, through identification of failure prone zones / components.

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Methodology's Adopted for Project.

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METHODOLOGY ADOPTED FOR WORK OF RESIDUAL LIFE ASSESSMENT STUDY

RESIDUAL LIFE ASSESSMENT STUDIES

Thermal power units being highly capital intensive, constant efforts are required to be made to extend the useful life, and allow the unit to run for maximum duration in a reliable manner, rather than retire at the end of design life. **Life assessment is, therefore imperative**. As a result, considerable importance should be attached to implementation of plant life assessment and emphasis is being laid for inclusion of the techniques to comply with safety and statutory regulations.

Components operating under environment of high temperature, high stress, high corrosion, etc., like boiler, turbine & piping, are subjected to **material degradation processes** leading to:

***Loss of thickness/ deformation.**
***Loss of toughness/ loss of hardness/ micro-structural degradation**
***Fatigue & Creep**

The **causes of material degradation** include: Oxide Formation, Erosion; Short-Term/ Long-Term Overheating; & Low Cycle/ High Cycle Fatigue & Creep.

Failure rate increases as a result of time dependent material degradation. Further running of the unit may become uneconomical and hazardous in cases. However, initiating timely intervention as a result of systematic RLA study, and carrying out appropriate maintenance/ refurbishment/ rectification/ modification action, results into continued trouble free operation.

There is now a general interest world over, to carryout Residual Life Assessment (RLA) of major equipments and its auxiliaries for RUN/ REPAIR/ REPLACE decisions and revalidate life of units through R & M program drawn on the basis of such periodic studies.

Methods of remaining life assessment may be classified into two categories:

1) **Methods based on the operational history** in which the expended life of a component is calculated on the basis of operational history and standard material properties.
2) **Methods based on post service examination** and/ or NDT testings on the actual component. This becomes essential, as precise operation data is seldom available in practice. Moreover, since the lower bound stress-rupture properties are considered in the absence of precise knowledge of the material positioning with reference to the standard data, operational history based approach leads to pessimistic life assessment. However, such an exercise would be very useful in identifying the critical components that require closer surveillance.

Based on the RLA studies which includes the NDT, Steam Path Audit, Stress Analysis, Thermal Analysis, Fatigue & Creep Analysis using Finite Element Method, the contractor provides recommendations and advices for Run/ Repair/

Replace decision for the equipments & systems. The decision can be utilized for Renovation and Modernization program of the unit, for extending its life.

6.1 APPROACH FOR RLA STUDY

Fortunately each component has only a few predominating damage mechanisms, which depend upon the operating environment & operating parameters. Based on these damage mechanisms, appropriate diagnostic techniques are employed for condition assessment of each of these components, and compare with initial (previous) as well as predicted end-of-life results for calculating remaining life, rate of degradation, & next safe inspection duration.

Contractor considers RLA as an important assignment, requiring special skills, involving methodology and detailing process. It calls for systematic analysis and evaluation of various tests and factors related to equipment health and plant performance. The exposure and experience on similar assignments coupled with composition of team of experts to handle the assignment, plays a vital role in successful completion of the work. The life extension program provides an assessment of the present physical state of the critical components/ equipment and identifies the repairs, modifications, and specific improvements, required by plants and operational mode, for extending the life span.

The assignment is carried out on "Task Force" concept. The Task Force comprised of:

(a)	Technology Experts	Long experience in Power Station Engineering, operation/ maintenance/ trouble shooting.
(b)	Metallurgical Experts	Expert knowledge of metal behavior under Different conditions of operation.
(c)	Field working Experts	Long experience in carrying out NDT and other In-situ tests.
(d)	Core Specialist	Specific system and equipment Specialist

Involvement of multi-disciplinary team ensures effectively meeting all requirements of RLA, as listed below:

- Knowledge of damage mechanisms
- Type, location & magnitude of current damage spectrum.
- Must include test locations which are likely to show first signs of distress (where to test and what to look for?)
- Ensure that the defect locations are detected.
- End of life criteria for component.

This trend assessment mostly through non-destructive testing, which in some cases, wherever possible, is confirmed through destructive testing, identifies deficiencies to take timely corrective action. Thus a fairly accurate condition assessment is made, without impairing further use of equipment.

The entire RLA study is carried out involving the following basic steps:

Step.1 Review of relevant operating parameters, outage and maintenance history and failure analysis data of the plant.

Step.2 Discussion with operating and maintenance personnel of the plant regarding plant overall performance and details of modifications/ replacements carried out in various systems.

Step.3 Carrying out hot and cold walk down and preparation of detailed inspection plan.

Step.4 Detailed inspection/ assessment and recording of test data.

Step.5 Analysis of various test data (both field and laboratory tests) including analytical study to arrive at the Run/ Repair/Replace recommendations for all equipments/ systems covered in the scope of work as per contract.

Step.6 Remaining Life Calculation

Step.7 Preparation of report.

6.3 DESCRIPTION OF TESTS CONDUCTED AT SITE

Purpose of site testing is to gather important input for making realistic conclusions. Based on well established and documented practices, the required inputs include:

1. **Visual Inspection (VI):**
   Visual Inspection is the simplest NDT method. It is the starting point for any RLA activity, as the location and intensity of testing is decided based on the findings here. VI is performed to assess material deterioration due to corrosion, erosion, swelling, cracking, bowing, sagging, misalignment, warpage, general abnormalities and deviations from design. Normally with the help of magnifying glass, flash light and cleaning, it is possible to observe the above defects, at macro level.

2. **Dye Penetrant Testing (DPT)**
   This testing is carried out primarily to locate surface defects such as cracks, pitting, weld pin holes, porosity, and other flaws. This method involves application of liquid dye, which penetrates into the surface flaw and is highlighted using a developer. The developer absorbs the penetrant by capillary action thereby highlighting the flaw. (Reference ASTM specification E 165-95).

3. **Magnetic Particle Inspection (MPI)**
   Magnetic particle inspection (MPI) is utilized to detect surface and sub- surface flaws in ferromagnetic materials by inducing a magnetic field into the parent material. By

sprinkling wet fluorescent magnetic particles on the surface of the parent material after the magnetic fields are induced, discontinuities are located by observing the patterns formed due to the distortions of the magnetic fields. Magnetizing at least two mutually perpendicular fields ensures detection of defects in all possible directions. (Reference ASTM specification I: 709-95).

Yoke method
It uses magnetic poles with spacing in the range of 75 mm- 150 mm.The magnetic lines of force generated between the poles are modified incase of presence of any defect. The leakage flux thus generated is picked up application of fluorescent magnetic particles suspended in a light petroleum distillate medium.

Prod Method
a) Magnetization shall be accomplished by portable Prod type electrical contacts pressed against the surface under examination.
b) Magnetizing current shall be generated to 90-110 Amp per 25 mm of prod spacing for sections less than 19 mm thickness and 100-125 Amp per 25 mm prod spacing for section 90mm and above, while the prod spacing shall be in the range 75mm to 200 mm.

Coil Method:
a) It shall be used wherever applicable and ampere turns for the generation of magnetic field shall meet the requirement of the field factors as recommended by ASTM E-709-01.The effectiveness of the technique employed shall be checked by "PIE" field indicator.

4. **Ultrasonic Testing (UT-S)**
One of the most effective examination techniques is ultrasonic testing. It is used to determine, with high accuracy, the component internal defects. It is also used to check the extent of de-bonding of Turbine bearings. Ultrasonic testing technique uses high frequency sound waves and their reflection from the boundaries. It employs normal and angle probes - pulse echo manual contact method. Reliable and properly trained technicians using established techniques/ procedures performing the UT examination. (Reference ASTM specification E: 164 & E: 587).

5. **Defects such as Cracks- their location, sizing, & criticality**:
For any failure to occur, initiation of crack and its growth to critical size is essential. Different methods are employed to locate surface, sub-surface, and imbedded cracks. Stresses acting on the component play a decisive role for finalizing the remedial recommendations.

6. **Strain Evaluation:**
As a result of creep & plastic deformation, the high temperature components especially pipes & headers start deforming. These evaluation need to be done at critical locations to ensure that the component has not crossed the secondary creep zone, and advanced corrective actions are taken.

7. **Hardness measurement:**
As a result of creep, the high temperature components become soft, i.e., they start loosing the toughness & strength, and micro-cracks start setting in. A trend in

hardness measurement gives an indication about the rate of degradation taking place in the component. In the absence of previous readings, knowing the material properties, and the age in service, it is possible to correlate hardness with remaining life of the component.

8. **Thickness measurements at bends and other critical locations:**
Due to the oxidation and erosion, the wall thickness reduces, resulting to increase in stress concentration. These components become liable to failure. Thickness measurement at critical locations, comparing the same with original/ design values, and arriving at safe limits are essential for reliable operations.

9. **Replication (In-situ Metallography) (RPL):**
Replication is a NDT technique generally applied on high temperature components operating in creep range, such as turbine rotors, moving & stationary blades, casings, Main steam Pipes, etc., to determine possible creep damage. Due to the ability of this test being performed "in situ", it is the most widely used NDT technique for component health assessment and determination of remaining life. The component to be evaluated is prepared for examination by grinding, polishing, and etching. For examination at higher magnification, the microstructure of the parent metal is recorded for examination in the laboratory on acetate replica tape.

10. **Fatigue Failures:**
Structures subjected to fluctuating service loads are vulnerable to fatigue damage. Repeated cycling of the load causes metal fatigue. It is a progressive localized damage due to fluctuating stresses and strains on the material. Metal fatigue cracks initiate and propagate in regions where the strain is most severe. Cracks close to the bolts in HP & IP Turbines, occurring due to oxide jacking, bolt hole stress and inherent restraint of the casing body, is an excellent example of fatigue failure crack.

A fatigue failure is characterized by three stages:

1. **Crack initiation:** Cracks may initiate from the surface, occupies most of fatigue life. Almost 80% of life is consumed in crack initiation. Fe-safe software is used to predict the life for crack initiation.
2. **Propagation:** Crack growth takes place in a direction normal to applied stress.
3. **Fracture:** Unstable fracture occurs suddenly

Using the Finite Element Analysis the stress and strain at corresponding operating conditions has been calculated. The plant operating cycle data (cold / Hot starts up) has been used in Fe-Safe software to predict the number of cycles for fatigue crack initiation and to predict the location of fatigue crack (i.e. Fatigue Hot Spots). A multi axial strain based fatigue algorithm with mean stress corrections, plasticity correction (Neuber's Correction) are used.

11. **Eddy Current examination:**
Eddy current examination uses the principal of **"electromagnetism"** as the basis for conducting examinations. Eddy currents are generated through a process called **"Electromagnetic Induction"**. When alternating current is applied to a conductor, such as a copper wire, a magnetic field develops in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as

the current is reduced to zero. If another electrical conductor is brought in close proximity to this alternating magnetic field, current will be induced in this second conductor.

Without any conductive material in the neighbourhood, probe coil behaves as if it were the primary of a transformer without any secondary circuit. The basic philosophy of this simplified theory is that the probe coil can be considered as the primary of an electrical transformer, whereas the Eddy currents flowing in the material being tested form the closed secondary circuit of the transformer. It is assumed that there might be a deep crack in the surface immediately underneath the coil. It will interrupt or reduce the eddy current flow as a resistance against the current in the circuit, thus decreasing the loading on the coil and increasing its effective impedance.

Eddy current is used for detection of defects or cracks on the root of turbine blades or the steeple region of the turbine disks. **With increase in frequency, sensitivity of defect-detection increases. With tight crack, peak of the signal observed to be sharper,** providing guidelines for differentiation of configuration of the signal of defect-crack, scratches, engraving marks etc. Actual depth of the crack/defects may not be estimated accurately for turbine blades.

Limitations

- There could be difficulties in estimation of crack-depth on the root region by dynamics, phase or gain of signal.
- For installed blades, with lesser space between blades of two neighbouring stages, and with uneven root region, specific probe with bent tip and long shaft may be needed and there may be difficulty in stable lift-off, even with viscous coupling.

Eddy current testing was carried out only on the free standing blades of LP rotor.

12. Deposit Analysis:

Sample deposits are removed from the equipment/ components for laboratory analysis. The samples are tested in laboratory for chemical analysis/properties. Some of the typical chemical analysis performed are:

- Chemical composition verification
- Deposit weight and chemical analysis

13. Sample Analysis:

Samples are removed or obtained from the equipment/ component for laboratory analysis. The samples are tested in the laboratory for chemical, metallurgical and mechanical properties.

14. Natural Frequency Test:

The NFT technique is used to determine the natural frequency of blading involves exciting of blade packets by hammering (to simulate an impulse load) with an instrumented hammer and the resulting vibration, as picked up by an accelerometer is recorded using a digital storage oscilloscope and subsequently converted into a frequency domain transfer function record of the original signal using a Fast Fourier Transform (FFT) algorithm. The natural frequency of the first three vibrational modes is subsequently extracted from this transfer function record.

In a turbine, a blade of the rotor is one of the components most prone to failure due to the mechanism of Natural Frequency. Among different turbine stages, the blading associated with the low pressure stages - the free standing blades – are the most prone to excessive vibrations excited by various disturbing forces encountered in a turbine. It is thus important that the fundamental vibration frequency of the low-pressure blading be accurately determined using the above test procedure, to identify and take suitable corrective actions.

Instrumentation System & Accelerometer:
The portable conditioning monitoring system consists of portable fast Fourier transform vibration analyzer. This vibration analyzer can be used for fault detection by recording and storing vibration spectra from each of the measurement points. Each newly recorded spectrum can be compared with a reference spectrum that was recorded at that particular measurement point, when the machine was known to be in good condition. Any significant increase in the amplitudes in the new spectrum indicates a fault that needs further investigation. The vibration analyzer also has certain diagnostic capability to identify the problems such as looseness of assembled rotor blades, faulty belt drives, gear-boxes, and loose bearings. If a rotor requires balancing, the vibration analyzer can be used to compute the location and magnitudes of the correction masses necessary to rebalance the rotor.
An accelerometer is an instrument that measures the acceleration of a vibrating body. Accelerometers are widely used for vibration measurement and also record earthquakes. they are preferred because of their smaller size and superior frequency response, dynamic range, reliability over long periods and robustness. when an accelerometer is used as vibration pick up, the velocity and displacement can be obtained from integrators built in the analyzer. Thus, the user can choose between acceleration, velocity and displacement as the monitoring parameter, any of these three spectra can be used for the condition monitoring of a machine.

15. Stress Analysis using CAESAR II Analysis:

The methodology adopted for CAESAR II analysis:

- Based on drawings and design documents CAESAR II Analysis generates the Hanger Load & Travel, Forces & Moments at the equipment connections and identify the stress point in the piping system.
- Spring hanger positions of the piping systems were noted to assess movement from hot to cold. These hanger travel values can be compared with the design value available in the design documents and as established in the CAESAR II Output Report.

Outcome of CAESAR II Analysis:

- Recommend change for the Hanger Loading & Travels.
- Identifying high stress points in the piping for NDT/Monitoring and corrective actions.

16. Methodologies for Finite Element Analysis USING ABAQUS/FESAFE:

Computer simulation using powerful numerical technique, Finite Element Method, is used to analyze piping system subjected to thermal and mechanical loading.

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Thermal and mechanical loading (gravity + internal pressure) cycle is analyzed using non-linear, elasto-plastic FEM analysis, to identify the critical failure locations and residual life of piping.

FEA is carried out to assess-

1. Stresses, strains (elastic and plastic), temperatures and deflections at all points in the assembly.
2. Fatigue hot spot, and number of cycles for fatigue crack initiation.
3. Remaining Life.

6.4 METHODOLOGY ADOPTED FOR REMAINING LIFE CALCULATION:

The Remaining Life Assessment is performed for all major critical components. Based on dominating damage mechanisms on each of these components, appropriate inspection techniques are adopted.

Following methodologies are used for evaluating the remaining life:

A) Methodology using NDT, especially In-situ Metallography, life spent etc.

B) Methodology using Finite Element Analysis.

6.4.1 Procedure for life assessment using NDT (A):

The Remaining Life Assessment is performed for all major critical components. Based on dominating damage mechanisms on each of these components, appropriate inspection techniques are adopted. An extensive Non-Destructive Test (NDT) of all components is made at all vulnerable locations such as butt welds, fillet welds, stub welds, ligaments etc. NDT techniques such as Magnetic Particle Inspection, Dye Penetrant Examination, Ultrasonic testing, in-situ replication, and Eddy current Examination are applied to detect the cracks/flaws.

Components which are operating at or above 350 deg.C undergo changes in properties, which can be correlated with time. Non-destructive tests, such as replication, enable assessment of accumulated damage and consequently the remaining life. The creep and fatigue damage can be calculated to estimate total life from which relevant fractions of exhausted life are deducted to arrive at remaining life.

Important components such as Pipings, which are operating in creep zone are also examined for their present condition. Assessment is based on findings of various non-destructive tests, performed at locations decided on basis of visual inspection, operating history and failures experienced in the past. Extensive in-situ metallography is carried out by replica method to examine microstructure of various critical components. Microstructure changes are most important assessment indications for high temperature components.

Remaining / Expended Life Calculation Theory:

We have used the following three procedures for the calculating the Remaining / Expended Life:

1. Calculations based on Larson Miller Parameters (LMP)
2. Evaluation based on Microstructural Assessment (Neubauer Classifications) & Classification based on VGB guidelines.
3. Creep damage classification & expended life fraction as per Sampietri et al.

We applied above 2, 3 for turbine part, 1, 2,3 for major piping, and 2 for valves.

1. Calculations based on LMP:

The following formula has been used to find out the remaining life based on LMP:

LMP=A-B*logσ

A & B are material constants.
σ is the hoop stress, MPa

Note : here we have taken 1.25 times the hoop stress to accommodate other stress during service. This final σ is required to be put in to the following formula.

LMP=T(20+log tr)

T- Temperature in ° K
tr – Time to rupture, hours

After getting the tr, hours deduct the operating hours of the unit, that will give the remaining life of the component under hoop stress.

6.4.2 Evaluation based on Microstructural Assessment (Neubauer Classifications)

Since creep strain and structural changes are progressively accumulated in the components operating at high temperature and pressure, non destructive metallography technique is used to quantify the microstructural damage in such components.

The following are the parameters to evaluate the microstrural degradation:

- Exposure to creep without any cavitations i.e. only diffusional degradation
- Exposure to creep and formation of creep voids.
- Accumulation of these creep voids.
- Formation of micro cracks.

Based on the above evaluation and literature available from Neubauer & Wedel, expended life fraction has been derived.

Below table shows the simplified gradations based on Neubauer classification.

Grade	Microstructure	Picture
0	New material	**NA**

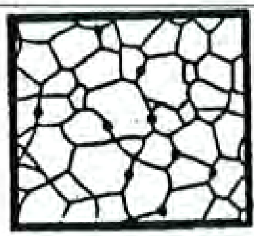
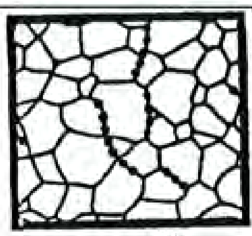
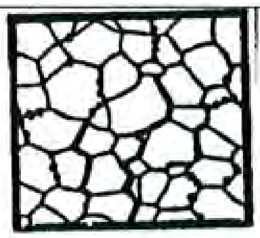
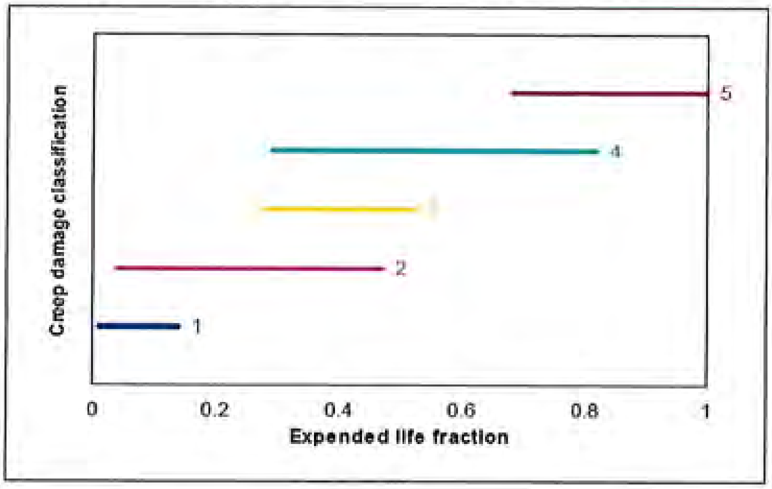
1	Normal (no cavities)	**NA**
2	Presence of isolated microcavities	
3	Presence of directional oriented microcavities	
4	Presence of microcracks	
5	Presence of macrocracks	

Figure shows the classification based on microstructure developed by Neubauer and Wedel.

6.4.3 Creep damage classification & expended life fraction as per Sampietri et al.

Finally Creep damage classification and expended life fraction is arrived using the guidelines give by Sampietri et al & such results are further checked. Below table shows the details:

Figure 6 Creep Damage Classification and Expended Life Fraction



Creep Damage and expended life fraction

Damage level	Expended life fraction
1	0.181
2	0.442
3	0.691
4	0.889
5	1.000

Conclusion:

Based on above, VGB guidelines and practices the following Microstructure Based Classification Scheme has been used for the estimation of the Residual Life.

S. No.	Micro-Structural State	Degree of life expended (for a 1 Cr -0.5 Mo steel), (t/t_c)	Classification Code	Advise to Plant Operator
1	Ferrite, bainite/pearlite, & carbides (M_3C, M_2C)	0	IL (D-1L)	No action
2	Ferrite, early stage decomposition of pearlite/bainite, M_3C, Increasing M_2C & $M_{23}C_6$	0.12	IIL (D-2L)	No action
3	Ferrite, full decomposition of pearlite / bainite, (M_3C, & M_2C decrease while $M_{23}C_6$, & M_6C increase	Upto 0.45	IIIL (D-3L)	RLA every 5 years
4	Ferrite, & Coarsened carbides		IVL (D-4L)	RLA every 5 years
5	Isolated cavitations in the microstructure	0.46	VL (C-1L) Also Called Grade A microstructure	RLA every 3 years
6	Microstructure shows oriented cavities	0.50	VIL (C-2L) Also called Grade B Microstructure	Reexamine every 1-2 years
7	Appearance of micro cracks in the material	0.84	VIIL (C-3L) Also called Grade C Microstructure	Reexamine every 6 months
8	Gross macro cracking	1.00	VIIIL (C-4L) Also called Grade D Microstructure	Repair or Replace

Sample Calculation:

A) Through LMP:

Component	Pressure, Kg/cm2	OD, (cm)	Thk (cm)	Hoop Stress (Mpa)	Hoop Stress Kg/cm2	A	B	LMP	T °K	Log tr	't 'rupture, hours	Remaining life in hours, (t-198000 hrs)	Remaining life in years,
MS line design life calculation	187	54.5	8.4	59.47	606.00	26890	3413	20834	818	5.46	288000	288000	**33.0 years.**
MS-operating line with 1.25 factor of safety.	212	54.5	8.4	67.43	687.74	26890	3413	20648	813	5.40	249787	51787	**5.91 years**

B) Evaluation based on Microstructure degradation.

The damage level (classification code) of MS Line = IIL to IVL.

c) Creep damage classification & expended life fraction as per Sampietri et al.

The level of degradation observed is 2, hence from the table under 6.4.3, the expended life fraction is 0.44, stating that 44% of the life is over. Hence 44% of 33 yrs = 14.52 yrs. Then, 33-14.52 = 18.48 yrs.

6.5 Procedure for life assessment based on FEA using ABAQUS & FESAFE (B):

In Finite element analysis, the physical system is digitally represented on a computer. The geometric features are captured in a 3D CAD model. The CAD is descritised to create the FEM model. Using this model physical realities of the material and the operating conditions are prescribed. With this a virtual system is available for analysis, which will give the results of stress, strain, temperature, deflection in the entire 3D geometry. The steps involved in the simulation are as follows;

- Create 3D CAD model of IP & LP components and assembly (CATIA V5).
- Create finite element mesh (using Hypermesh).
- A deck is created for finite element modeling and analysis of IP/LP rotors and casing.
- Impose boundary conditions (Operating conditions, loading parts etc, cyclic loading, warm-hot-cold start series, etc.).
- Physical operating conditions are mimicked for computer simulation.
- Do finite element analysis (thermo-mechanical using Abaqus).

- Stresses, strains, temperatures, and deflections are obtained at all points in the assembly.
- Conduct thermo-mechanical fatigue analysis (using FESAFE).
- Obtain the fatigue hot spot, and number of cycles for fatigue crack initiation.
- Calculate the remaining life based on damage accumulated.

Figure below shows the effect of Fatigue, creep & combine effect of Creep & fatigue:

Creep and fatigue damage interaction diagram defines how creep damage and fatigue damage interact to cause failure. To account for the significant additional damage due to the interaction of creep damage and fatigue damage, the interaction diagram is often used.

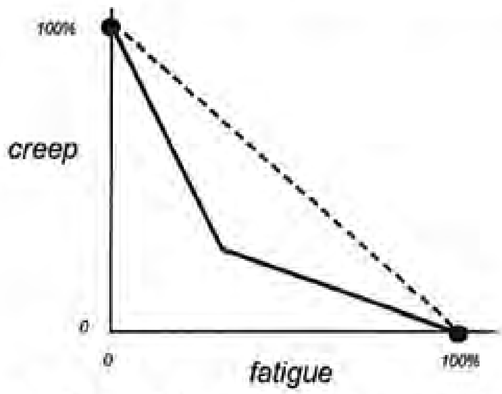


Figure1. Creep fatigue interaction diagram

Cracking will occur when the fatigue damage-creep damage coordinates are outside the envelope (Cracking will occur If the coordinates are outside the dark and dotted line as shown in figure 1 above).

Total life Calculation:

Piping component	**Fatigue life (years)**	**Creep life (years)**	**creep + fatigue life (Years) =N**	**Remaining life (Years) =(N-25)**
Minors damage (rule)	**N1**	**N2**	**25/N=(25/N1+25/N2)**	
MS Line	500000	48	48	23

Say for the same MS line the FEA resulted the actual fatigue life = 1e10 cycles.

From the 25 years till date approx. 50 cycles are over.
Hence, 50 /25 = 02 cycles per year.

Therefore, the remaining fatigue life = 1e10 /02 = 500000 cycles.(infinte)
(Assumed infinte value as 500000 years.
By using Miner's damage rule and combining the fatigue damage

N1 =Fatigue life of the piping system in years
N2 = Creep life of the piping system in years
The power plant has completed 25 years of operation
N = Total life of the piping due to fatigue and creep
= (25/N)= (25/N1)+(25/N2)

Hence after calculating from the above the remaining life of the MS line come to be 23 years.

Conclusion of Remaining Life assessment of MS line:
By LMP (with factor of safety) = 5.91 years.
By FEA = 23. 00 years.
By Microstructure Evaluation = 18.48 years.

From the above remaining life of MS line is considered to be 5.91 years.

6.6 Methodology for the Steam Path Audit:

The purpose of the steam path audit is to assess the thermal performance of the steam turbine. The results of this audit identified specific problem areas and quantified the impact of the problems in order to assist the Korba Super Thermal Power Station , Unit # 4, 500 Mw, in making decisions whether to repair or replace steam path components.

NASL created a valves-wide-open turbine heat balance to characterize the unit's performance in its new-and-clean condition. Steam path audit data were taken during the outage to determine the condition of the steam path.

Areas Addressed in the Audit

The specific areas of concern addressed by the audit are:

1)Leakages:
- past stationary stage blading
- past rotating stage blading
- past shaft end packing where rotors emerge from casings
- across poorly fitting joints
- other miscellaneous leakages

2) Surface finish degradation:
- deposits
- corrosion
- solid particle erosion
- mechanical damage

3) Flow blockages from:
- deposits
- foreign objects
- mechanical damage

4) Flow path modification from:
- solid particle erosion
- water droplet erosion
- mechanical damage

A detailed procedure is widely explained in the Volume – III of Steam Path Audit.

6.6 ANALYTICAL INVESTIGATIONS:

➢The analytical studies are undertaken in order to assess the remaining life of identified critical components. Analytical or empirical methods are used to estimate life expenditure based on fracture mechanics. Stress and strain values are computed taking into account operating history, component geometry and material properties. In order to get a quantitative damage fraction and also to identify the cause of such damage, analytical approach provides a reasonably reliable and realistic solution. This is based on certain judicious assumptions made in the data used for such computations. The analytical approach and methodology to life assessment/ extension used in this study are outlined below.

➢**Procedure for Life Assessment as mentioned in above methodology.**

The residual life assessment relies upon determining accurately three kinds of information about a component, which is detailed in above.

a) Present state of structural integrity, due to past operation (NDT).
b) Rate of damage accumulation in the absence of repair (SPA).
c) Assessing value of damage required to cause catastrophic failure (FEA).

If an estimate of current damage, along with a rule for damage accumulation and failure criterion are known, then component residual life can be assessed.

6.7 PARTICULAR NOTES FOR KORBA UNIT NO.4

In principle, residual life assessments are better to be implemented periodically (e.g. every 5 yrs) so that the actual conditions of each component is correctly assessed and further measures are correctly judged. In addition, it was revealed that this is the first time to assess the subjected equipment and systems since the unit came into operation more than 20 yrs ago. Therefore there is certain uncertainty in terms of remaining life time evaluation only with the conventional methods.

Therefore, this time the contractor adopted two-step approach to determine remaining life assessments and also identify hot spots to support creation of further maintenance strategies of the equipment and systems.

In this regard, beside using conventional NDT Techniques to determine present condition of the components and therefore providing run/repair/replacement recommendation mainly by experiences of experts, the contractor has utilized following techniques to estimate remaining life calculation and provide a realistic recommendation/conclusion.

1. Calculation/Evaluation of life estimation by following established theories:
   a) Larson Miller Parameter (LMP)-Used typically in Piping System.
   b) Microstructural Assessment by both Neubauer Classification & VGB Guidelines.
   c) Creep Damage Classification & Expended life fraction as per Sampietri at all.

2. The above analysis & calculations, based on conventional techniques is supplement by finite element analysis (FEA) using comprehensive thermo mechanical stress analysis by CAESAR II Software and creep fatigue analysis by ABAQUS & FESAFE software. Hot Spots are identified to ease future investigation. As an input to ABAQUS to create finite element mesh, 3D CAD Model of each component was generated using CATIA V5.

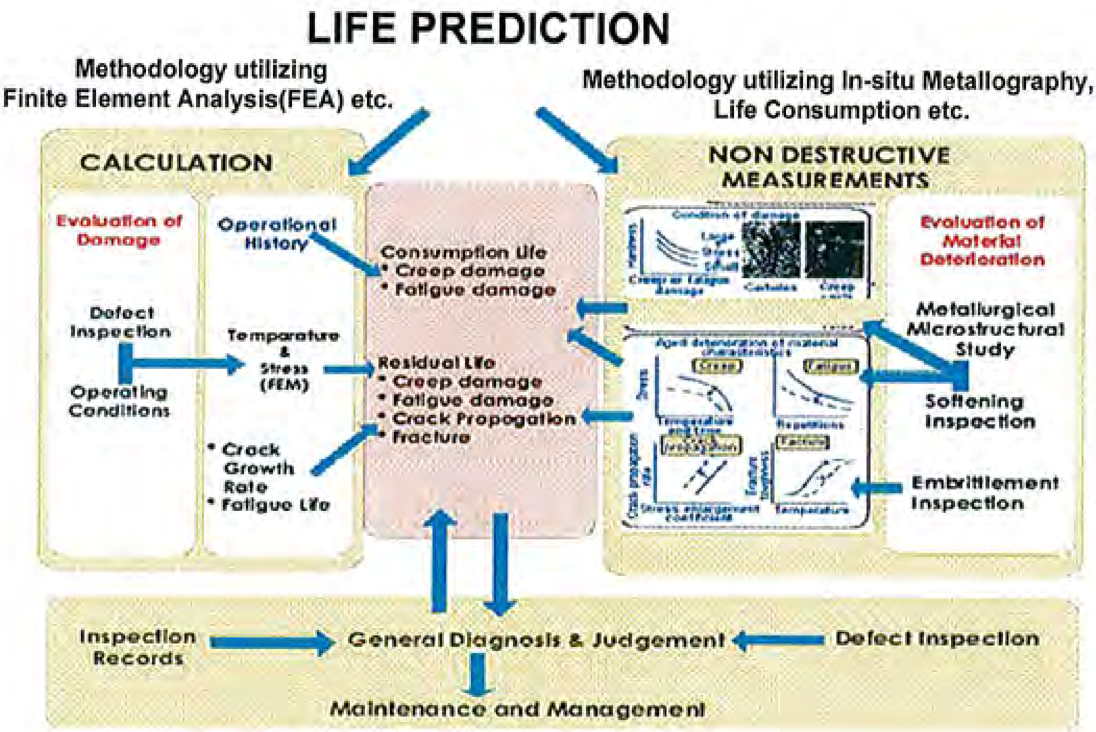
With this approach, the owner is able to access the mesh models of the equipment and systems, ready to be mimicked for computer simulation for different boundary conditions in the form of

a) Operating Parameters.
b) Loading Pattern.
c) Cyclic /Thermal Loading etc.

The two-step approach to blend conventional methods & extensive software analysis including full range of modeling has probably not been implemented in India in the past.

6.8 TYPICAL LIFE PREDICTION DIAGRAM

Below diagram shows typical approach for life prediction. Each item doesn't exactly meet the study contents executed by the Contractor, but basic flow-line is consistent with the diagram.



ALSTOM

Volume- I-A

Chapter – 7

Executive Summary of the Project

NTPC ALSTOM
Power Services Pvt. Ltd.

(40)

OVERALL EXECUTIVE SUMARY

Customer	***: J- POWER (Electronic Power Development Co. Ltd)***
Station	**: Korba Super Thermal Power Station**
Unit	**: 04 (Four)**
Rating	**: 500 MW**
Make	**: KWU**
Operating Hours	**: 1, 98, 11,000 Hrs, upto May 2010.**

Introduction

JICA Study Team entrusted to ALSTOM K.K. (the Contractor) for RLA study of Unit # 4(500 MW) Turbine (IP&LP), SPA & Piping Assessment for the purpose to implement a series of study in conjunction with steam turbine system and the plant for National Thermal Power Corp. Ltd., through J Power (the Purchaser).

It was been planned to carryout the series of study as mentioned above for the Unit no. 6 of NTPC Korba, and accordingly the hot walk down and collection of data was started by NASL. However on reaching at the site, unfortunately due to the some problems, Unit-4 of the same capacity was shutdown and thus NTPC korba requested to carryout the same study in the unit 4 instead of unit 6. hence the Hot walk down of the unit 4 was carried out after the recomissioning of the unit which resulted in the extension of the desired schedule of work period.

This final report pertains to the findings during Residual Life Assessment studies of IP & LP Turbine, Steam Path Audit & Main Piping Assessments for Unit #4, Korba Super Thermal Power Station, NTPC Ltd. The purpose is to provide categorized options to maximize the reliability and efficiency of Korba Unit # 4. Information contained within this study is to be considered proprietary and confidential. Disclosure to any third party is not permitted without permission of the Contractor.

Purpose of Study

- To provide Improvement plan of Operation & Maintenance of Thermal Power Station.
- To assess the structural integrity of critical components of Steam Turbine (IP & LP) for continued operation.
- Identify repair/ replace strategies to ensure reliable operation till next RLA.
- Suggest measures to bring down the heat rate of the machine (Efficiency improvement).

Methodology

The engineering analysis for this study is based on industry wide data, operational experience with Turbines, Power Station systems, Operation and Maintenance practices etc. and tests/ studies conducted as below:

- Cold and Hot walk down studies on the Unit to identify Critical components.
- Evaluating present operational data especially from point of view of higher steam consumption in the Turbine to get the rated output.

- Estimating useful (remaining) life, based on metallurgical, micro-structural and non-destructive testing, SPA & FEA of various components.
- Identify components requiring repairs, replacement, refurbishment and retrofits for better heat rate (efficiency).
- Identify corrective actions to be taken up to improve machine efficiency.

Recommendations

The recommendations have been arranged in Run/Repair/Replace & remaining life evaluation taking into account their relative benefits and likelihood of occurrence.

Summary recommendations are given in the following order of priority:

(Please refer the Executive Summary Sheets 1, 2 3, 4 & 5 attached)

ES-1: Overall Summary of IP Turbine

ES-2: Overall Summary of LP Turbine.

ES-3: Overall Summary of the Valves.

ES-4: Overall Summary of the Critical Piping.

ES-5: Remaining Life Overview

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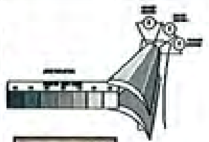
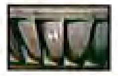
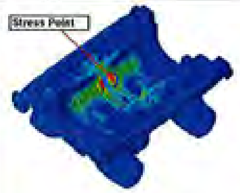
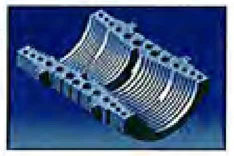
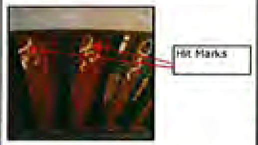
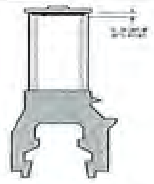
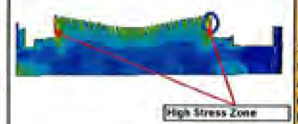
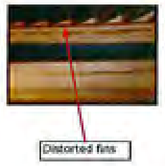
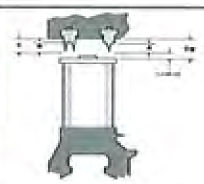
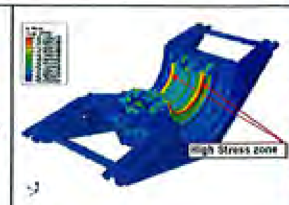
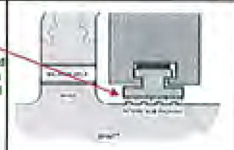
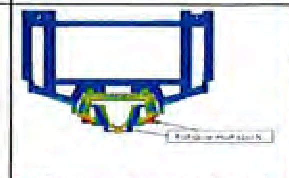
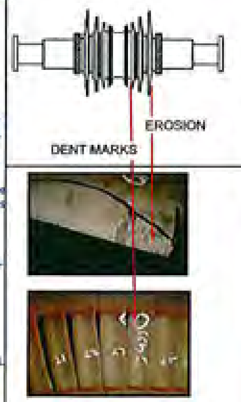
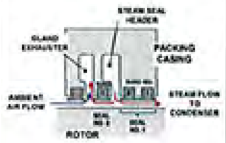
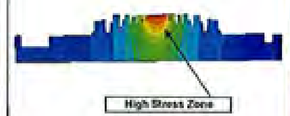
OVERALL EXECUTIVE SUMMARY OF THE PROJECT

Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

			Findings from Destructive Test (DT) / Non-Destructive Test (NDT)		Findings from Steam Path Audit (SPA)		Remaining Life & Other Findings				Conclusions	Recommendations
Sl No		Component	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Larson Miller Parameters (LMP)	In-situ Metallography (IM)	Finite Element Analysis (FEA)			
1	IP Turbine	IP Inner & Outer Casing	# Visual observations reveal that the Casing and Stationary blades have no significant damage. Some sealing fins are found in damaged condition, which were repaired during the Overhaul. # MPI, DPT & UT of Journal & Coupling Area has not revealed any defect. # Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry. # Microstructural degradation level is II-L. The expended creep life fraction is 0.181. Hardness value of casing is observed in the range of 168-172 BHN at the steam entry side, & 190-200 BHN at the steam exist side.		# Surface Roughness: The opening audit loss due to surface roughness was 3350.3 kW and an increase in heat rate 50.86 kJ/kWh and in closing loss was 1756.9 kW and heat rate was 26.63 kJ/kWh. Total of 1593.4 kW and 24.23 kJ/kWh are recovered.	 	Not considered.	Based on Microstructural degradation of II-L & the degree of Life expended comes to be 0.12 thus confirming the damage level-1 with expended creep life fraction as 0.181 which proves that the 18% of the life is over of the component.	Observations: # IP Inner casing is highly stressed (530 MPa- Peak transient stress) near the inlet and first stage as shown in the figure. # The FE-SAFE analysis shows the probability of crack initiation in IP casing assembly from the inlet and first stage, over a period of time.		1) NDT/DT showed that the IP turbine assembly is in good condition. No significant defect was observed. 2) Major losses are observed in Surface Roughness of rotating & stationary blades. The followings stages showed the maximum losses: IP Gen side, Stage - 14 : Power loss = 266.9 kW IP Tur side, Stage - 14: Power loss = 266.9 kW 3) FEA results show that stresses are within safe limit of the material. Creep & Fatigue analysis predicted some hot spots, which are most prone to crack initiate, over a period of time. The same analyses need to be periodically carried out during overhauls. 4) From the observations/results of DT/NDT, SPA, FE simulations and fatigue computations, it can be concluded that the life of the rotor is evaluated to be minimum of 16 years, & casing is >20 years, subject to the recommended O&M practice. (it doesn't consider life time for blades and other loose items)	1) Stressed locations as marked in the figures, need to be checked during the inspection/Overhauls and microstructure analysis should also be carried out so as to ascertain the material degradation and damage level. 2) Emphasis is to be given during the overhauling activities to clean the blades surfaces to minimize the surface losses as loss contribution of surface roughness is maximum in steam path components. 3) Although the conclusion of remaining life is found to be 16 years for rotor & 22 years for casing, we recommend to carry out further RLA of the component in 5 years/Overhauls to evaluate the deterioration level.
					# Interstage Packing:- The opening audit loss due to interstage packing was -7.7 kW and an increase in heat rate -0.11 kJ/kWh and in closing loss was -138.3 kW and heat rate was -2.09 kJ/kWh. Total of 130.6 kW and 1.98 kJ/kWh are recovered.				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 22 years.			
2	IP Turbine	IP Rotor	# Visual observations reveal that the IP rotor has no significant damage. Coupling holes and coupling bolts are also in good condition. # MPI, DPT & UT of Journal & Coupling Area has not revealed any defect. # Microstructural degradation is II-L and the expended creep life fraction is 0.181. Hardness value of rotor is found to be 204 to 210 BHN at the steam entry side and 221 to 223 BHN at the steam exit side. # Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry.		# Cover Deposits: The opening audit loss due to cover deposits was 186.7 kW and an increase in heat rate 2.83 kJ/kWh. Due to the blasting cover deposit have been removed. Total of 186.7 kW and 2.83 kJ/kWh are recovered.		Not considered.	Based on Microstructural degradation of II-L & the degree of Life expended comes to be 0.12 thus confirming the damage level-1 with expended creep life fraction as 0.181 which proves that the 18% of the life is over of the component.	Observations: IP rotor is stressed (at 360 Map- peak transient stress) near the inlet and last stage. Inlet becomes critical because of higher temperature and pressure of steam.			
					# Tip Spill Strip:- The opening audit loss due to tip spill strips was -210.2 kW and an increase in heat rate -3.18 kJ/kWh and in closing loss was -104.3 kW and heat rate was -1.58 kJ/kWh. Total of -105.9 kW and -1.6 kJ/kWh are recovered				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 16 years.	 The analysis shows the probability of crack initiation in IP shaft from the steam inlet location and first stage, over a period of time. (Figure shows the details).		
					# End packing:- The opening audit loss due to End packing was 64.2 kW and an increase in heat rate 0.97 kJ/kWh and in closing loss was 26.2 kW and heat rate was 0.40 kJ/kWh. Total of 38.0 kW and 0.57 kJ/kWh are recovered.							
3	IP Turbine	Fasteners	# No significant indications observed in the Visual observations & DPT. # Results of DT of one stud of outer casing showed that the actual & the predicted Charpy Value are matching.		NA		NA		NA		It can be concluded that the condition is normal.	NA
		Bearing No. 03	No significant indication was observed in Visual observations. In DPT, Minor loose bonding observed on the edge portion, the same was checked during the UT and found within acceptable limits.		NA		NA		NA		Based on the VI, DPT & UT, Bearing No. 03 is acceptable for operation for the next five years.	It is recommended to recheck the bearing in every overhauls, especially the babbit bonding.

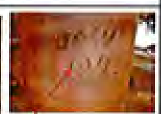
OVERALL EXECUTIVE SUMMARY OF THE PROJECT

Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

Sl No		Component	Findings from Destructive Test (DT) / Non-Destructive Test (NDT): Key Observations/ Findings/ condition assessment	Findings from DT / NDT: Reference Location/Sketch	Findings from Steam Path Audit (SPA): Key Observations/ Findings/ condition assessment	Findings from SPA: Reference Location/Sketch	Remaining Life & Other Findings: Larson Miller Parameters (LMP)	Remaining Life & Other Findings: In-situ Metallography (IM)	Remaining Life & Other Findings: Finite Element Analysis (FEA)		Conclusions	Recommendations
4	LP Turbine	LP Casing	# Visual observations reveal that the inner-outer casing, erosion has been observed on the weld area as marked in the figures. Stationary blades have no significant damage. Sealing fins are found in good condition. # MPI, DPT & UT of parting plane area has not revealed any significant defect. # No measurable deposits found, indicating good water chemistry.		# Surface Roughness:- The opening audit loss due to surface roughness was 3585,0 kW and an increase in heat rate 54.45 kJ/kWh and in closing loss was 1140.9 kW and heat rate was 17.28 kJ/kWh. Total of 2444.1 kW and 37.17 kJ/kWh are recovered.		Not considered.	Not Considered (due to low temp. zone)	In LP casing assembly, Inner casing shows the stress of 256MPa (Peak transient stress) near the third stage of the turbine.		1) NDT testing & FE analysis results show that stress is within safe limit of the material. 2) Major losses are observed in Surface Roughness of rotating & stationary blades. The followings stages showed the maximum losses: LP Gen side, Stage - 2 : Power loss = 488.2 kW LP Tur side, Stage - 2: Power loss = 487.2 kW 3) Fatigue analysis predicted some hot spots, which are most prone to crack initiation over a period of time. 4) From observations of DT/NDT, SPA, FE simulations and fatigue computations, it can be concluded that the life of the casing is enough more than >20 years, subject to following recommended O&M practice. (it doesn't consider life time for blades and other loose items)	
					# Interstage Packing:- The opening audit loss due to Interstage packing was 245.3 kW and an increase in heat rate 3.71 kJ/kWh and in closing loss was 212.5 kW and heat rate was 3.21 kJ/kWh. Total of 32.8 kW and 0.50 kJ/kWh are recovered				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 113 years.	 For LP casing cracks may initiate from the 3rd stage as shown in the figure.		
5	LP Turbine	LP Rotor	# Erosion observed on the steam exit side of the last stages i.e. TS-6 & GS-6 of blades. # Minor erosion observed on blades of second last stages i.e. TS-5 & GS-5. # Minor pitting is also observed on the blades of stages TS-3 & GS-3. # Erosion observed on leading edge of some of the blades during eddy current inspection. # Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry. # No erosion in balancing weights observed. # There is no significant drop observed in NFT measurements of last 3 stages free standing blades, with respect to design value. # The microstructural degradation level is I-L and the expended creep life fraction is less than 0.181. # Hardness value of rotor is found to be 268 to 278 BHN at the inlet side and 261 to 271 BHN at the collar region (exit side).		# End Packing:- The opening audit loss due to end packing was 2.3 kW and an increase in heat rate 0.03 kJ/kWh and in closing loss was -3.2 kW and heat rate was -0.05 kJ/kWh. Total of 5.5 kW and 0.08 kJ/kWh are recovered.		Not considered.	Based on Microstructural degradation of I-L the expended creep life fraction comes to be less than 0.1, thus confirming the damage level-0, which proves that approx. only 10% of the life is consumed of the component. The component is normal in condition and can be in operation for many more years.	In LP rotor high stress (360 MPa) is observed near the inlet. This is due to higher pressure and temperature of steam at inlet.		In the light of the inspection and analysis made in different stages and critical locations of LP turbine rotor, the following conclusions are derived: 1) Overall condition of the LP rotor moving blades is found to be satisfactory. 2) Erosion observed on leading edge of some of the blades during eddy current inspection. 3) NFT of free standing blades of last three stages shows that the natural frequency is within the acceptable limits. 4) From observations of DT/NDT, SPA, FE simulations and fatigue computations, it can be concluded that the life of the rotor is enough more than 20 years, subject to following recommended O&M practice. (it doesn't consider life time for blades and other loose items)	1) Stressed locations as marked in the figures, need to be checked during the inspection/Overhauls and microstructure analysis should also be carried out. 2) Based on explicit observations in various locations i.e. blade root area , leading edge , trailing edge and blade surface of LP turbine rotor, no immediate action is required. However the last stage moving blades of both sides needs to be replaced in the next overhaul.
					# Tip Spill Strip:- The opening audit loss due to end packing was 161.3 kW and an increase in heat rate 2.44 kJ/kWh and in closing loss was 122.6 kW and heat rate was 1.85 kJ/kWh. Total of 38.6 kW and 0.59 kJ/kWh are recovered.				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 47 years.	 The analysis shows the probability of crack initiation in LP shaft from the steam inlet location and first stage, over a period of time.		
6	LP Turbine	Fasteners	No significant indications observed in the Visual observations & MPI.		NA		NA		NA		Based on the VI & MPI it is concluded that the condition is normal.	NA
		Bearing No. 04	No significant indication was observed in Visual observations & DPT. UT testing revealed the indications are within acceptable limits.		NA		NA		NA		Based on the VI, DPT & UT, Bearing No. 04 is acceptable for operation for the next five years.	It is recommended to recheck the bearing in every overhauls, especially the babbit bonding.

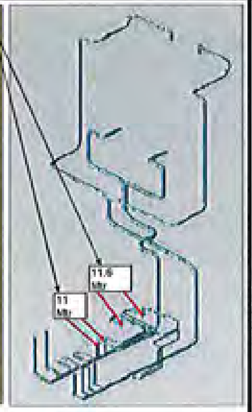
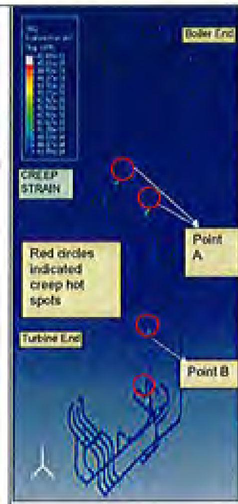
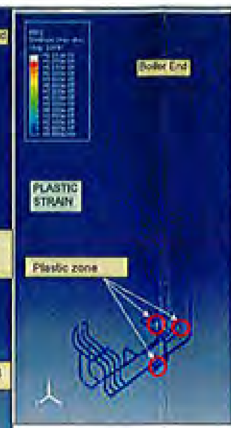
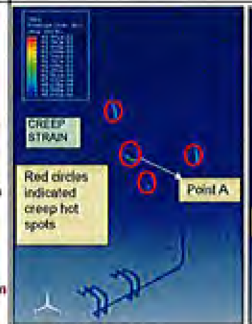
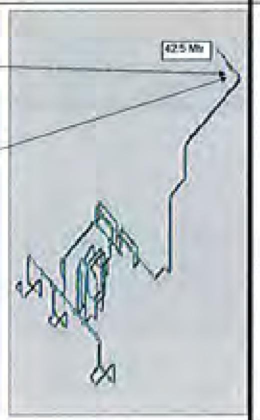
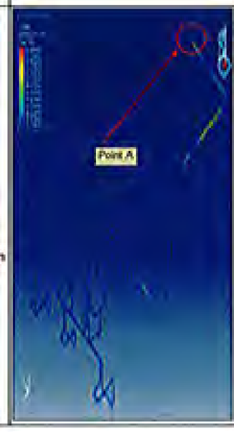
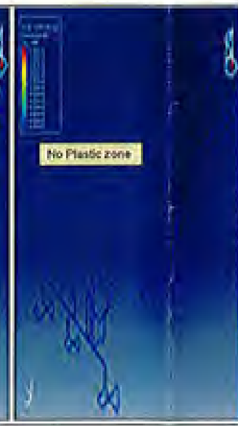
OVERALL EXECUTIVE SUMMARY OF THE PROJECT

Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

			Findings from Destructive Test (DT) / Non-Destructive Test (NDT)		Findings from Steam Path Audit (SPA)		Remaining Life & Other Findings			Conclusions	Recommendations
Sl No		Component	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Larson Miller Parameters (LMP)	In-situ Metallography (IM)	Finite Element Analysis (FEA)		
7	VALVES	HPSV (Total 04 nos)	# The measured hardness values in Bonnet, cone & valve body are found with the acceptable range, 150 -201 BHN. # No significant physical damage like erosion, cut marks observed in Visual observations & DPT on Spindle, Cone, Seat and valve body. # Microstructure on Cone, bonnet & body shows fine tempered Bainite and ferrite with spherodisation of carbides, Diffusion degradation Level is II-L to IV-L & the Expended Creep life fraction is 0.442.		NA		NA	Based on Microstructural degradation of II-L to IV-L & the degree of life expended come to be 0.45, thus confirming the Damage level-2, with expended life fraction near to 0.442 which proves that approx. 44% life is consumed of the component.	NA	Based on IM, the life consumed is 44% . The plant has been in operation from last 25 years and hence relating it with materials degradations, the remaining life is considered as > 20 years.	Although there is no significant erosion, damaged observed in stem, cone & body seat, it is recommended to inspect this areas in each maintenance / overhaul opportunity.
8	VALVES	HPCV (Total 04 nos)	# The measured hardness values in Bonnet, cone & valve body are found with the acceptable range, 155 -188 BHN. # No significant physical damage like erosion, cut marks observed in Visual observations & DPT on Spindle, Cone, Seat and valve body. # Microstructure on Cone, bonnet & body shows fine tempered Bainite and ferrite with spherodisation of carbides, Diffusion degradation Level is II-L to IV-L & the Expended Creep life fraction is 0.442.		NA		NA	Based on Microstructural degradation of II-L to IV-L & the degree of life expended come to be 0.45, thus confirming the Damage level-2, with expended life fraction near to 0.442 which proves that approx. 44% life is consumed of the component.	NA	Based on IM, the life consumed is 44% . The plant has been in operation from last 25 years and hence relating it with materials degradations, the remaining life is considered as > 20 years.	Although there is no significant erosion, damaged observed in stem, cone & body seat, it is recommended to inspect this areas in each maintenance / overhaul opportunity.
9	VALVES	IPCV (Total 04 nos)	# The measured hardness values in Bonnet, cone & valve body are found with the acceptable range, 140 -161 BHN. # No significant physical damage like erosion, cut marks observed in Visual observations & DPT on Spindle, Cone, Seat and valve body. # Microstructure on Cone, bonnet & body shows fine tempered Bainite and ferrite with spherodisation of carbides, Diffusion degradation Level is II-L to IV-L & the Expended Creep life fraction is 0.442.		NA		NA	Based on Microstructural degradation of II-L to IV-L & the degree of life expended come to be 0.45, thus confirming the Damage level-2, with expended life fraction near to 0.442 which proves that approx. 44% life is consumed of the component.	NA	Based on IM, the life consumed is 44% . The plant has been in operation from last 25 years and hence relating it with materials degradations, the remaining life is considered as > 20 years.	Although there is no significant erosion, damaged observed in stem, cone & body seat, it is recommended to inspect this areas in each maintenance / overhaul opportunity.
10	VALVES	IPSV (Total 04 nos)	# The measured hardness values in Bonnet, cone & valve body are found with the acceptable range, 140 -164 BHN. # VI inspection showed a minor hit mark in IPSV-2 on the stem surface area. The location was checked by DPT where it is found acceptable. Spindle, Cone, Seat and valve body found acceptable. # Microstructure on Cone, bonnet & body shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusion degradation Level is II-L to IV-L & the Expended Creep life fraction is 0.442.	  Hit Mark Observed	NA		NA	Based on Microstructural degradation of II-L to IV-L & the degree of life expended come to be 0.45, thus confirming the Damage level-2, with expended life fraction near to 0.442 which proves that approx. 44% life is consumed of the component.	NA	Based on IM, the life consumed is 44% . The plant has been in operation from last 25 years and hence relating it with materials degradations, the remaining life is considered as > 20 years.	Although there is no significant erosion, damaged observed in stem, cone & body seat, it is recommended to inspect this areas in each maintenance / overhaul opportunity.

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

Findings & Recommendations of Critical Piping of NTPC-Korba Unit No 4, 500 MW.

Sl No	Component	Findings from Destructive Test (DT) / Non-Destructive Test (NDT)	CAESAR II / Hot & Cold Walk Down Findings		Remaining Life & Other Findings					Conclusions	Recommendations
		Key Observational Findings/ condition assessment	Key Observational Findings/ condition assessment	Reference Location/Sketch	Larson Miller Parameters (LMP)	In-situ Metallography (IM)	Finite Element Analysis (FEA)				
1	MS -CRH -HPBP	Visual observations do not show any surface damage. During MPI and UT no significant defect was observed. Partial Bainite and Pearlite Degradation were observed in MS pipe lines. The spherodisation level (diffusion degradation) observed is II–L to IV L. No creep cavities have been observed.	1) The maximum risk node points having highest stress components are marked with elevation. 2) In pipe support No.MST-18,the hanger scale is damaged. 3) In HPBP-02 the spring is topped out. In HPBP-18 the spring casing is missing. 4) Hanger no CRH-17 has no load on the spring. 5) Hanger no CRH-20 is found missing.	Code Stress Ratio (%) 58.5 @Node 2140 Code Stress: 66.9132 MPa Allowable: 114.453 MPa (Sustained Load) 	Remaining Life of Piping System based LMP is: For MS Line = 5.91 yrs. For CRH line is > 20 years. For HPBP line is > 20 years.	Based on Microstructural degradation of IIL to IVL & the degree of life expended come to be 0.45 thus confirming the damage level-2 with expended creep life fraction as 0.442, which proves that the 44% of the life is over of the component.	Conclusions: From the above Analysis and based on Miner's Rule, Remaining life is 21 years.	1)Maximum Stress due thermo mechanical load is 168 Map (localized Point A) ,average stress value is 60 to 70 MPa which is within allowable limit,& strain observed is 0.00112.(Elastic Strain 0.001 + Plastic Strain 0.00012) 2)Maximum Permanent Deformation after 25 Yrs of open due to Creep is 88 mm (Point B) 3) Displacement (plastic) of following hangers over a period of 25 years is more than 60 mm. a) MST 044, b) HPB 012, c) CRH 030, d) CRH 032		i) Evaluated Remaining Life through FEA & IM is >20 years (Lower amongst the two). ii) Evaluated Remaining Life through LMP is 5.91 years. The wide difference between the evaluated remaining life as above is due to a conservative approach taken in LMP methodology. A safety factor of 1.25 upon operating pressure is taken - to cover the probability of variation in operation, undue stresses due to change in loading pattern & spent life of the pipe. It may be noted that probability of failure is generally located in the hot spot zone as identified in FEA analysis. However evaluated life changes drastically to 25 yrs if 10 % safety factor is taken or in other words if pressure does not rise above design pressure. Based upon above result, we conclude that the expected remaining life could be prolonged up to 20 years under strict compliance of the following: 1) Operating pressure will not exceed design pressure 2) Corrective action of resetting the hangers and supports are taken 3) Close monotiring of weak zones are carried out as recommended. Please note that CRH & HPBP line is evaluated that the remaining life is >20 years.	It is suggested that the critical locations identified be subjected to the following tests in every annual overhauling, mandatory at next annual overhauling: 1. In situ Metallography (IM) to know the material degradation level. 2. Thickness Survey. 3. Online line monitoring systems using the installation of the High temperature strain gauges at identified hot spot locations & thus the real time strain data will be acquired and used for further life estimations. 4. EMAT - Electromagnetic acoustic transducer test / high frequency (20MHz) small diameter probe UT, can be implemented to check the state of steam side surface corrosion. / pitting of the main steam pipe in the critical locations. 5. Indicated hangers required to be corrected.
2	HRH - LPBP	Visual observations do not show any surface damage. During MPI and UT no significant defect was observed. Partial bainite and pearlite degradation was observed in HRH pipe lines. The spherodisation level (diffusional degradation) observed is II–L to III L . No creep cavities have been observed.	1)The maximum risk node points having highest stress components are marked with elevation. 2) A horizontal restraint provided between LPBH13 and LPBPH-14 is in dismantled condition. Bolts to be tightened.	Code Stress Ratio (%) 71.8 @Node 275 Code Stress: 33.5433 MPa Allowable: 46.7189 MPa (Sustained Load) Code Stress Ratio (%) 82.9 @Node 8005 Code Stress: 152.8681 MPa Allowable: 184.3416 MPa (Expansion Load) 	Remaining Life of Piping System based on LMP is: For HRH > 20 years. For LPBP >20 years.	Based on Microstructural degradation of II-L to III-L & the degree of life expended come to be 0.45 thus confirming the damage level-2 with expended creep life fraction as 0.442, which proves that the 44% of the life is over of the component.	Conclusions: From the above Analysis and based on Miner's Rule, Remaining life = 13.6 years.	1)Maximum Stress due thermo mechanical load is 102 Mpa (localized Point A) ,average stress value is 50 to 70 MPa which is within allowable limit,& strain observed is 0.00818.(Elastic Strain 0.00712 + Pastic Strain 0.00106) 2)Maximum Permanent Deformation after 25 Yrs of open due to Creep is 100 mm (Point A) 3) Displacement (plastic)of HRH hangers over a period of 25 years is less than 5 mm.		Based on the overall analysis, the condition of piping system is satisfactory. Remaining life is evaluated to 13.6 years.	Run-Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. Repair / Replace: Indicated hangers required to be corrected.
3	BFD	Visual observations do not show any surface damage. During MPI and UT no significant defect was observed.	1)The maximum risk node points having highest stress components are marked with elevation.. 2) Spring supports below the Feed control station at about 20 M elevation are not accessible for hanger measurements. However, visual inspection in this region shows no damages.	Code Stress Ratio (%) 35.6 @Node 1175 Code Stress: 49.1281 MPa Allowable: 137.8951 MPa (Sustained) Code Stress Ratio (%) 13.1 @Node 1195 Code Stress: 38.8209 MPa Allowable: 296.5034 MPa (Expansion) 	Not considered	Not considered	Remaining Life of Piping System based on FEA is > 20 Years.	1)Maximum Stress due thermo mechanical load is 142 Map (localized Point A) ,average stress value is 60 to 70 MPa which is within allowable limit.& strain observed is 0.00066.(Elastic Strain 0.00066 + Plastic Strain 0.0)		Based on the overall analysis, the condition of piping system is satisfactory. Remaining life may be concluded > 20 years.	Run-Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service.

Remaining Life Overview

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System/Components	Predictied Remaining Life (yrs) or Consumed Life (%)			
	LMP	IM	FEA	**Conclusion**
TURBINE				
IP Casing	N/A	**18%**	**22 yrs**	**> 20 yrs**
IP Rotor	N/A	**18%**	**16 yrs**	**16 yrs**
LP Casing	N/A	N/A	**113 yrs**	**> 20 yrs**
LP Rotor	N/A	**10%**	**47 yrs**	**> 20 yrs**
VALVE				
HP SV&CV	N/A	**44%**	N/A	**> 20 yrs**
IP SV&CV	N/A	**44%**	N/A	**> 20 yrs**
PIPINS SYSTEM				
MS-CRH-HPBP Piping	**5.9 yrs**	**44%**	**21 yrs**	**(5.9 yrs/>20yrs)**
HRH-LPBP Piping	**> 20 yrs**	**44%**	**13.6 yrs**	**13.6 yrs**
BWP Piping	N/A	N/A	**> 20 yrs**	**> 20 yrs**

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References

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Chapter 8. References

1. ABAQUS documentation manual
2. FESAFE User Manual
3. ASTM, ASME sections.
4. IP Inner Casing (0-10602-02000C) Sheet 1
5. IP Inner Casing (0-10602-02000C) Sheet 2
6. IP Inlet Assembly(0-10612-02000C) Sheet 1
7. IP Shaft sealing (0-10606-02000C) Sheet 1
8. IP Shaft (0-10201-02000C) Sheet 1
9. IP Outer casing (0-1060**18/2) Sheet 1
10. IP Casing assembly (0-10601025000C) Sheet 1
11. IP Casing assembly (0-10601-02500C) Sheet 2
12. Blade plan IPT (9-102-04-05000C) Sheet 1
13. LP Shaft (0-10301-02000) Sheet 1
14. IP Outer casing (0-10601-02000C) Sheet 1
15. IP Outer casing (0-10601-02000C) Sheet 2
16. IP Outer casing(0-10601-02000C) Sheet 3
17. Blade plan LPT (9-103-04-05000C) Sheet 1
18. LP Shaft (0-10301-02000C) Sheet 1
19. LPC Outer end assembly G.S. (0-10740-02200C) Sheet 1
20. Inner Casing assembly (0-10743-02000C) - Sheet no.1
21. L.P. Inner outer Casing (0-10741) Not clear
22. L.P. Outer casing(0-10740-02000C) - Sheet no1
23. Inner Casing assembly (01074302000C) Sheet no 2

24. Main Steam Line from Boiler Stop Valve to Common Header (Left){0-80-502-01223}
25. Main Steam Line to High Pressure Bypass Valve-II{0-80-511-01227}
26. High Pressure Bypass Valve I to Cold Reheat Line {0-80-528-01237}
27. Main Steamline to High Pressure Bypass Valve-I {0-80-510-01226}
28. MS from Strainer to Turbine Bottom Left {1-80-508-015-43}
29. MS Header From HP Bypass Tap off to Strainer {MSE-1-80-505-1595/Bhel-1-88-505-1595}
30. MS from Strainer to Turbine {PE-1-052-141-001}
31. Main Steam Line up to Boiler Stop valve (Right) {0-80-501-01222}
32. G Piping & Hanger(MS) {0-80-504-01225}
33. Main Steam Line from Boiler Stop Valve to Common Header (Right) {0-80-503-01224}
34. Main Steam Line up to Boiler Stop valve (Left) {0-80-500-01221}
35. Main Steam Piping SH 1 of 2 {TCE-790-ME-SK-37}
36. Layout of MS HRH & LP Bypass Piping (Bhel Scope){PE-1-052-141-001}
37. Hanger Assy. For Tag. No. MST 005 TVH 3-80-831-06401
38. Hanger Assy. For Tag. No. MST 006 DYR 3-80-831-06402
39. Hanger Assy. For Tag. No. MST 019 TCH 3-80-831-06415
40. Hanger Assy. For Tag. No. MST 018 SCH 3-80-831-06414
41. Hanger Assy. For Tag. No. MST 017 SCH 3-80-831-06413
42. Hanger Assy. For Tag. No. MST 016 SCH 3-80-831-06412
43. Hanger Assy. For Tag. No. MST 015 SCH 3-80-831-06411
44. Hanger Assy. For Tag. No. MST 014 SCH 3-80-831-06410
45. Hanger Assy. For Tag. No. MST 013 SCH 3-80-831-06409
46. Hanger Assy. For Tag. No. MST 012 SCH 3-80-831-06408

47. Hanger Assy. For Tag. No. MST 011 SCH 3-80-831-06407
48. Hanger Assy. For Tag. No. MST 010 SCH 3-80-831-06406
49. Hanger Assy. For Tag. No. MST 009 SCH 3-80-831-06405
50. Hanger Assy. For Tag. No. MST 009 TCH 3-80-831-06405
51. Hanger Assy. For Tag. No. MST 008 TCH 3-80-831-06404
52. Hanger Assy. For Tag. No. MST 008 TCH 3-80-831-06404
53. Hanger Assy. For Tag. No. MST 007 TCH 3-80-831-06403
54. Hanger Assy. For Tag. No. MST 007 TCH 3-80-831-06403
55. Hanger Assy. For Tag. No. MST 006 DYR 3-80-831-06402
56. Hot Reheat Piping From Turbine Inlet Manifold to Strainer 1-80-515-01789
57. Hot Reheat from Reheater to Common Header (Left) 0-80-512-01228
58. Hot Reheat eader upto Turbine Inlet Manifold 0-80-514-01230
59. Hot Reheat Piping TCE-790-ME-SK-36
60. HRH from Strainer to Turbine TOP Right 1-80-517-01546
61. HRH from Strainer to Turbine TOP Left 1-80-516-01545
62. HRH from Strainer to Turbine Bottom Right 1-80-519-01548
63. Hot Reheat Piping from Reheater to Common Header (Right) 0-80-513-01229
64. HRH from Strainer to Turbine Bottom Left 0-80-518-01547
65. Hanger Assy. For Tag. No. HRH 035 SYR 3-80-832-06469
66. Hanger Assy. For Tag. No. HRH 036 SVH 3-80-832-06470
67. Hanger Assy. For Tag. No. HRH 037 DYR 3-80-832-06471
68. Hanger Assy. For Tag. No. HRH 037 TCH 3-80-832-06472
69. Hanger Assy. For Tag. No. HRH 039 TCH 3-80-832-06473
70. Hanger Assy. For Tag. No. HRH 040 TCH 3-80-832-06474
71. Hanger Assy. For Tag. No. HRH 041 SCH 3-80-832-06475

72. Hanger Assy. For Tag. No. HRH 042 SCH 3-80-832-06476
73. Hanger Assy. For Tag. No. HRH 043 SCH 3-80-832-06477
74. Hanger Assy. For Tag. No. HRH 044 DZR 3-80-832-06478
75. Hanger Assy. For Tag. No. HRH 045 DZR 3-80-832-06479
76. Hanger Assy. For Tag. No. HRH 046 DYR 3-80-832-06480
77. Hanger Assy. For Tag. No. HRH 047 DXR 3-80-832-06481
78. Hanger Assy. For Tag. No. HRH 048 DZS 3-80-832-06482
79. Hanger Assy. For Tag. No. HRH 01 3-80-862-06553
80. Hanger Assy. For Tag. No. HRH 02 3-80-862-06554
81. Hanger Assy. For Tag. No. HRH 03 3-80-862-06555
82. Hanger Assy. For Tag. No. HRH 04 3-80-862-06556
83. Hanger Assy. For Tag. No. HRH 05 3-80-862-06557
84. Hanger Assy. For Tag. No. HRH 06 3-80-862-06558
85. Hanger Assy. For Tag. No. HRH 07 3-80-862-06559
86. Hanger Assy. For Tag. No. HRH 08 3-80-862-06560
87. Hanger Assy. For Tag. No. HRH 09 3-80-862-06561
88. Hanger Assy. For Tag. No. HRH 10 3-80-862-06562
89. Hanger Assy. For Tag. No. HRH 11 3-80-862-06563
90. Hanger Assy. For Tag. No. HRH 12 3-80-862-06564
91. Hanger Assy. For Tag. No. HRH 13 3-80-862-06565
92. Hanger Assy. For Tag. No. HRH 14 3-80-862-06566
93. Hanger Assy. For Tag. No. HRH 15 3-80-862-06567
94. Hanger Assy. For Tag. No. HRH 16 3-80-862-06568
95. Hanger Assy. For Tag. No. HRH 17 3-80-862-06569
96. Hanger Assy. For Tag. No. HRH 18 3-80-862-06570

97. Hanger Assy. For Tag. No. HRH 19 3-80-862-06571

98. Hanger Assy. For Tag. No. HRH 20 3-80-862-06572

99. Hanger Assy. For Tag. No. HRH 21 3-80-862-06573

100. Hanger Assy. For Tag. No. HRH 22 3-80-862-06574

101. Hanger Assy. For Tag. No. HRH 001 SVH 3-80-800-05922

102. Hanger Assy. For Tag. No. HRH 002 SVH 3-80-832-06437

103. Hanger Assy. For Tag. No. HRH 003 TVH 3-80-832-06438

104. Hanger Assy. For Tag. No. HRH 004 SYR 3-80-832-06439

105. Hanger Assy. For Tag. No. HRH 005 SVH 3-80-832-06440

106. Hanger Assy. For Tag. No. HRH 006 DYR 3-80-832-06441

107. Hanger Assy. For Tag. No. HRH 007 TCH 3-80-832-06442

108. Hanger Assy. For Tag. No. HRH 008 TCH 3-80-832-06443

109. Hanger Assy. For Tag. No. HRH 009 TCH 3-80-832-06444

110. Hanger Assy. For Tag. No. HRH 010 SCH 3-80-832-06445

111. Hanger Assy. For Tag. No. HRH 011 SCH 3-80-832-06446

112. Hanger Assy. For Tag. No. HRH 012 SCH 3-80-832-06447

113. Hanger Assy. For Tag. No. HRH 013 TCH 3-80-832-06448

114. Hanger Assy. For Tag. No. HRH 014 SCH 3-80-832-06449

115. Hanger Assy. For Tag. No. HRH 015 SCH 3-80-832-06450

116. Hanger Assy. For Tag. No. HRH 016 SCH 3-80-832-06451

117. Hanger Assy. For Tag. No. HRH 017 SCH 3-80-832-06452

118. Hanger Assy. For Tag. No. HRH 018 TCH 3-80-832-06453

119. Hanger Assy. For Tag. No. HRH 019 TCH 3-80-832-06454

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123. Hanger Assy. For Tag. No. HRH 023 TVH 3-80-832-06458
124. Hanger Assy. For Tag. No. HRH 024 SVH 3-80-832-06459
125. Hanger Assy. For Tag. No. HRH 025 SVH 3-80-832-06460
126. Hanger Assy. For Tag. No. HRH 026 SVH 3-80-832-06461
127. Hanger Assy. For Tag. No. HRH 027 SVH 3-80-832-06462
128. Hanger Assy. For Tag. No. HRH 028 TVH 3-80-832-06463
129. Hanger Assy. For Tag. No. HRH 029 TVH 3-80-832-06464
130. Hanger Assy. For Tag. No. HRH 030 TVH 3-80-832-06465
131. Hanger Assy. For Tag. No. HRH 031 TVH 3-80-832-06466
132. Hanger Assy. For Tag. No. HRH 032 SVH 3-80-800-05923
133. Hanger Assy. For Tag. No. HRH 033 SVH 3-80-832-06467
134. Hanger Assy. For Tag. No. HRH 034 TVH 3-80-832-06468
135. Hanger Assy. For Tag. No. MST 007 TCH 3-80-831-06403
136. Hanger Assy. For Tag. No. MST 007 TCH 3-80-831-06403
137. Hanger Assy. For Tag. No. MST 006 DYR 3-80-831-06402
138. Boiler Feed Discharge Header UP to Heaters and Bypass Line 0-80-533-01239
139. BFD from Heaters to SG Terminal Point 1-80-536-01815
140. BFP Discharge From Pump A to Header 1-80-530-01596
141. BFP Discharge From Pump B to Header 1-80-531-01597
142. Boiler Feed Discharge Line Through Heaters 5B & 6B 1-80-535-01600
143. BFP Discharge from Pump C to Header 1-80-532-01598
144. Boiler Feed Discharge line from Heaters to Steam Generator Terminal Point 0-80-536-01240
145. Boiler Feed Discharge Line Through Heaters 5B & 6B 1-80-535-01600

146. The Grade 22 Low Alloy Steel Handbook. EPRI

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END

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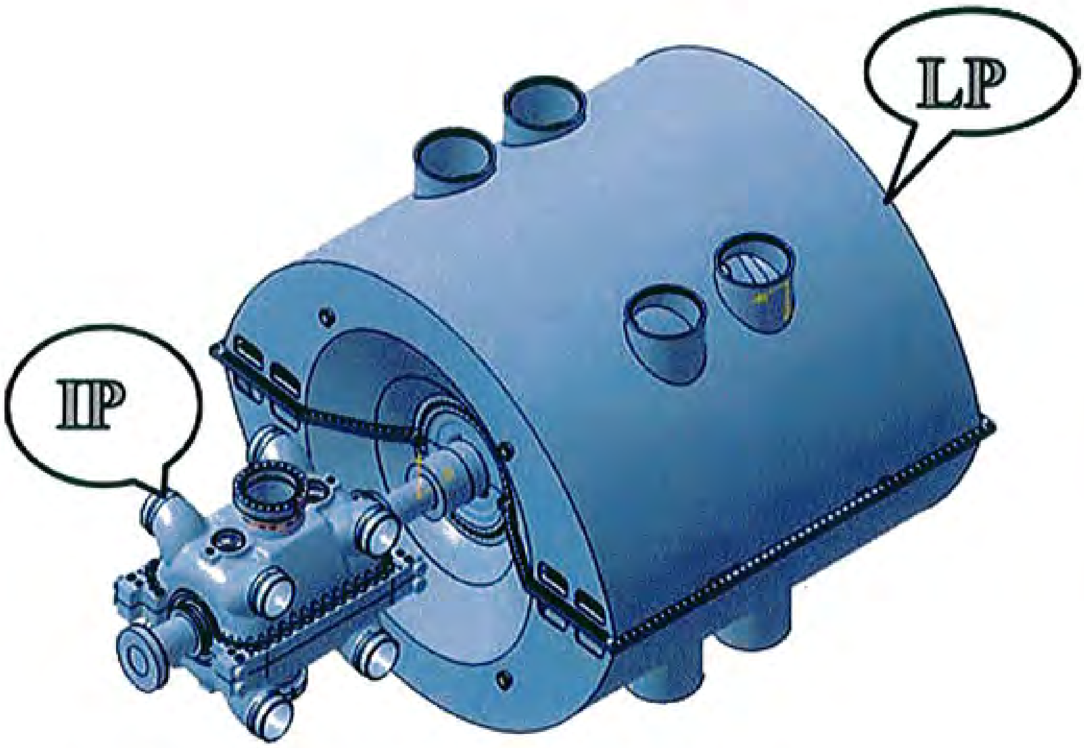

Volume- I-B

RLA of Turbine (IP & LP)

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Volume- I-B

Chapter – 01

Introduction to RLA

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INTRODUCTION TO RLA

Based on the Assessment studies carried out in the NTPC-Korba Unit-4, the Contractor is expected to assess the condition and residual life of components and advice NTPC Korba STPS for Run /Repair /Replace decision for the Equipments, components & systems through R&M programme of the unit to run the unit reliably, extends its life, and achieve rated (or Higher) load and efficiency.

The Present volume of the RLA studies contains the details of the test readings, findings, interpretations, recommendations, etc for all components as per the scope of work. The entire report forms the following three volumes:

Volume – I A: Project Summary.
Volume – I B: RLA of Turbine.
Volume – II : RLA & Stress Analysis of Critical Pipings
Volume – III: SPA of IP & LP Turbines.

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Volume- I-B

Chapter – 02

Objective of RLA

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2. OBJECTIVE OF RLA

- Assessment of the present condition of Steam turbine & components.
- Remaining Life assessment of the said equipments / components.
- To provide recommendations for Run/Repair/Replace decision of the said equipments / components.

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Chapter – 03

Methodology Adopted

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Chapter-3

METHODOLOGY ADOPTED FOR RLA

The RLA study is carried out involving the following basic steps:

Step.1 Review of relevant operating parameters, outage and maintenance history and failure analysis data of the plant.

Step.2 Discussion with operating and maintenance personnel of the plant regarding plant overall performance and details of modifications/ replacements carried out in various systems.

Step.3 Carrying out hot and cold walk down and preparation of detailed inspection plan.

Step.4 Detailed NDT inspection/ assessment and recording of test data.

Step.5 Analysis of various test data (both field and laboratory tests) including analytical study to arrive at the Run/ Repair/Replace recommendations for all equipments/ systems covered in the scope of work as per contract.

Step.6 Remaining Life Calculation based on LMP & IM.

NASL METHODOLOGY ADOPTED FOR REMAINING LIFE CALCULATION:

The Remaining Life Assessment is performed for all major critical components. Based on dominating damage mechanisms on each of these components, appropriate inspection techniques are adopted.

Following methodologies are used for evaluating the remaining life:

A) Methodology using NDT, especially In-situ Metallography, life spent etc.

B) Methodology using Finite Element Analysis.

***Note : Please refer detailed methodology explained in the Vol-IA, Chapter-6.**

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Volume- I-B

Chapter – 04

Assumptions & Other Remarks

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Chapter-4

ASSUMPTIONS & OTHER REMARKS

- For Insitu Metallography, samples were collected from most critical locations of the assembly.
- For LMP the hoop stress with a 1.25 factor was considered for the calculation of life by LMP.
- NDT was carried out on the accessible areas only.
- Cycles were extrapolated based on the operation data of 15 years for the total operation of machine for 25 years.
- No Corrosion effect was considered in the FEA analysis.
- Turbine model is considered without any damage of the component.
- Materials properties are being taken from the relevant codes & standards.

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Chapter – 05

Summary of Observations & Recommendations

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SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
01.	**IP Rotor (shaft surface, shrouds, sealing grooves, blades)**	VI	No significant observation except deposit on surface of the blades	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair / Replace**: None **Conclusion:** 18% of the life is consumed by the component.
		UT(on General area)	No recordable indication observed.	
		MPI	No surface or sub surface indication observed.	
		DPT	No surface indication observed.	
		Replica	Microstructure shows fine tempered Bainite with spherodisation. Diffusional degradation level observed is II L & the degree of expended life is 0.12, thus confirming the damage level –I.	
		Hardness	215 BHN -218 BHN.	
		Deposit	The major oxide component is of Iron Oxide which as usual. No abnormal constituent like Cl, Cu etc. are not present. Water chemistry seems to be good.	

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SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
02.	**IP CASINGS (Top/Bottom) (Parting plane/ stationary blades, shrouds, sealing grooves).**	VI	Distortion in sealing fins observed, some portion of the sealing fins damaged	**Run-** Component fit for further operation re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair / Replace-** Distortion Sealing fin to be corrected. **Conclusion:** 18% of the life is consumed by the component.
		UT(parting plane area)	No recordable indication observed	
		MPI	No surface or sub surface indication observed.	
		DPT	No surface indication observed.	
		Replica	Microstructure shows fine tempered Bainite with spherodisation. Diffusional degradation level observed is II L & the degree of expended life is 0.12, thus confirming the damage level –I.	
		Hardness	Top-168BHN -172 BHN. Bottom-175BHN -189 BHN.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
03.	IP /LP studs	VI	No significant indication observation.	**Run-** Component fit for further operation re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None. **Replace**- None
		Hardness	240BHN-289 BHN.	
		DPT	No surface indication observed.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
04.	IP Integral Piping (steam admission pipe , 'T' pipe, expansion bellow(only DPT)	VI	Minor Scaling is observed.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace**- None **Conclusion:** 44% of the life is consumed by the component.
		UT(Butt weld joint)	No recordable indication observed.	
		MPI(weld joint)	No surface or sub surface indication observed.	
		DPT	No significant indication observed.	
		Replica	**Parent Metal :** Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation level IVL is observed with degree of expended life 0.45 thus confirming the damage level –II with Expended Creep life fraction as 0.442.	
		Hardness	PM-158BHN-161 BHN. W- 180BHN-186 BHN.	
		OD	556 mm – 561 mm.	
		Thickness	31.6mm– 33.2 mm	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
05.	LP Rotor (Rotor surface, sealing groves, journal, shrouds, blades ,coupling face)	VI	• Erosion on the steam exit side of the last stages i.e. TS-6 & GS-6 of blades. • Minor erosion observed on blades of second last stages i.e. TS-5 & GS-5. • Minor pitting is also observed on the blades of stages TS-3 & GS-3.	**Run-** Component fit for further operation re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair**- None **Replace**- Last stages blades (i.e.TS-6&GS-6) to be replace next capital overhauling. **Conclusion:** 10% of the life or less is consumed by the component.
		UT (on general area).	No recordable indication observed	
		MPI	No surface or sub surface indication observed.	
		DPT	No significant indication observed.	
		ET	No recordable indication observed. Except Last stage blades erosion.	
		NFT(only last three stages)	No abnormality observed.	
		Replica	Microstructure shows tempered bainite. No significant degradation.	
		Hardness	261BHN-278 BHN.	

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SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
06.	LP CASINGS (Inner Outer & Inner-Inner).	VI	Steam erosion observed in TOP Inner –outer casing.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair / Replace** : The rectified erosion area needs to be rechecked in next overhauling.
		UT(Parting plane accessible area)	No recordable indication	
		MPI	No surface or sub surface indication	
		Deposit	The major oxide component is of Iron Oxide which as usual. No abnormal constituent like Cl, Cu etc. are not present. Water chemistry seems to be good.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
07.	HP Integral Piping	VI	Minor Scaling observed.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace**- Nonr **Conclusion:** 44% of life is consumed by the component.
		UT(Butt weld joint)	No recordable indication observed	
		MPI(weld joint)	No surface or sub surface indication observed.	
		Replica	**Parent Metal :** Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation level IVL is observed with degree of life expended is 0.45, thus confirming the damage level-II & expended creep life fraction as 0.442.	
		Hardness	(CRH) PM-151BHN-168 BHN .W- 212-208 BHN. PM(MSL BEND)-132BHN-138 BHN	
		OD	641mm – 642 mm.	
		Thickness	26.2mm – 26.9 mm.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
08.	Bearings no. 3 & 4	VI	No significant indication observed. Minor scattered porosity is observed in brg. No. 3.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace-** None
		UT	No recordable indication observed.	
		DPT	No surface indication observed except Minor scattered porosity is observed in brg. No. 3.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
09.	Coupling Bolts	VI	No significant indication observation	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace**- None
		DPT	No surface indication observed.	

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SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
10.	HP / IP valves(Seat, stem, cone, Bonnet and valve body)	VI	No significant indication observed.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace-** None **Conclusion:** 44% of life is consumed by the component.
		DPT	No surface indication observed	
		Replica (HP SV-4) Bonnet	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L is observed with degree of life expended is 0.45, thus confirming the damage level-II & expended creep life fraction as 0.442.	
		Hardness	Bonnet- 130-135 BHN Cone-199-201 BHN.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
11.	HP / IP Stop valves (Seat, stem, cone, Bonnet and valve body)	VI	No significant observation	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace**- None **Conclusion:** 44% of life is consumed by the component.
		DPT	No surface indication observed.	
		Replica(Valve Body)	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation level-IV L is observed with degree of life expended is 0.45, thus confirming the damage level-II & expended creep life fraction as 0.442.	
		Hardness	Bonnet-151-164 BHN. Cone- 191-200 BHN.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
12.	HP Bypass valves	VI	No significant indication observation	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace**- None **Conclusion:** 18% of life is consumed by the component.
		DPT	No significant Defect	
		Replica	**Parent Metal :** Microstructure shows fine tempered bainite and ferrite with spherodisation of carbides. Diffusional degradation level IIL is observed is observed with degree of life expended is 0.12, thus confirming the damage level-I & expended creep life fraction as 0.181.	
		Hardness	Body- 122-136 BHN.	

SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
13.	LP Bypass valves	VI	Minor external scale is observed on the LP by Pass line.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** None **Replace-** None **Conclusion:** 18% of life is consumed by the component.
		DPT	No significant Defect	
		Replica	**Parent Metal :** Microstructure shows fine tempered bainite and ferrite with spherodisation of carbides. Diffusional degradation level IIL is observed is observed with degree of life expended is 0.12, thus confirming the damage level-I & expended creep life fraction as 0.181.	
		Hardness	Body-185 – 196 BHN.	

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SUMMARY OF FINDINGS AND ACTION PROPOSED REPORT
RLA of IP/LP Turbines of Unit#4at NTPC-Korba.

Unit : # 4

Sl. No	Component	Testing	Key Observations/ Findings/ condition assessment	Recommendation
19.	T-pipe (Turbine floor).	VI	No significant indication observation.	**Run-** Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. **Repair-** No. **Replace**- No.
		UT	No recordable indication observed.	
		MPI	No surface or sub surface indication observed.	
		Hardness	PM-203-209 BHN. WELD180BHN.B-186 BHN. PM – 158BHN.-162 BHN.	
		OD	LHS 608mm-610 mm.	
			RHS-608mm-610 mm.	
		Thickness	LHS 57.12mm, 57.25 mm.	
			RHS 56.12 mm, 56.50 mm.	

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Volume- I-B

Chapter – 06

Detail Test Reports

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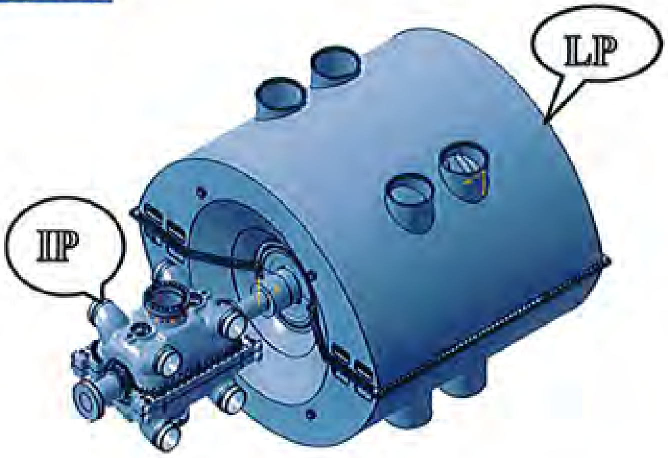
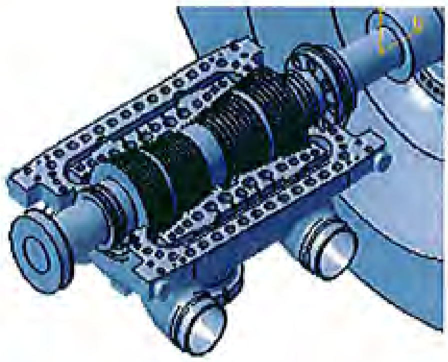
6.1 IP TURBINE





ROTOR, CASINGS, DIAPHRAGMS and FASTENERS

- INTRODUCTION
- VISUAL INSPECTION
- NON DESTRUCTIVE TESTING
- DESTRUCTIVE TESTING-FATT
- INSITU METALLOGRAPHY & HARDNESS MEASUREMENT
- ANALYSIS OF FINDINGS

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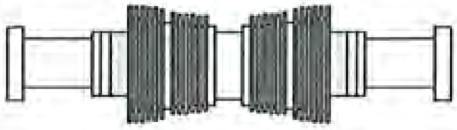
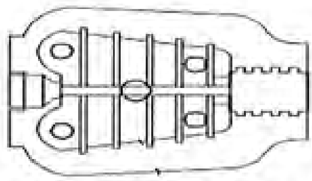


6.1. a: IP ROTOR

This is a single flow turbine rotor with 14X 2 reaction stages. The moving blades of all these 14 X 2 stages are provided with T-roots and their cover plates are machined integral with the blades and make shroud of the blades (i.e. integral shroud). The insertion slot in the shaft is closed by locking blade which is fixed by grub screw. Only one journal bearing support towards LP side is provided.



6.1. b: IP CASING

The casing of the IP turbine is split horizontally and is of double shell type construction. Generally the material of construction for these casing is creep resistant Chromium-Molybdenum-Vanadium steel Casting. The composite assembly is made in two halves and secured steam tight with the help of creep resistant fasteners (made of forged Cr-Mo-V steels).
Diaphragms are mounted in the casing itself.

Critical regions in the casing include the parting plane, stationary blades of diaphragm, etc.

6.1.1 Visual Inspection

No significant deposits were observed. Integral seals are intact. Blade tips are Ok.
No rubbing marks were observed on rotor surfaces. Visual Inspection of the IP casing and diaphragms revealed no significant abnormality. There is minor erosion on the stationary blades of stages. (Refer

Rubbing marks

The view of erosion observed on blades.

6.1.2 NDT (LPI, MPI & UT)

NDT (LPI, MPI & UT) of the casing, casing internals (guide blade stages, front sealing housing, rear sealing housing, parting plane studs and cap nuts, IP rotor and moving blades of all stages was carried out. No significant defect was observed.

Refer Report 7.1 for LPI
Refer Report 7.2 for MPI
Refer Report 7.3 for UT

6.1.3 In situ Metallography and Hardness Measurements (refer report 7.4)

In situ Metallography and Hardness Measurements were conducted at locations as mentioned In the table below, covering the highest temperature (inlet) to the lower temperature (exhaust) regions.

- On IP Rotor ---Four replicas at 90° apart at steam inlet region ---Two replicas on both colder ends.
- On Inner Casings---Seven replicas have been taken(including blades)
- On outer casing --- Four replicas two on steam entry side and two on steam exit side have been taken.

The microstructure and hardness at the colder side are considered as the baseline since severity of temperature and pressure is least when compared to the casing internal pressure faces, which are exposed to steam flow. The base microstructure shows a microstructure of tempered Bainite with platelet type Bainite morphology having an average hardness as per table 1 given below.

Sr No	Area of inspection	Hardness, BHN	Observation	Remarks
1	IP TOP Casing Location: At steam entry (Fig. 7,9)	Inlet 168-172 BHN	Fine tempered Bainite with precipitation of carbides. Diffusional degradation level II L.	Microstructural degradation is II L and the expended creep life fraction is 0.10.
	IP TOP Casing Top Location: At steam exit (Fig. 8,10)	Outlet 190-200 BHN	Fine tempered Bainite with precipitation of carbides. Diffusional degradation level II L.	Microstructural degradation is II L and the expended creep life fraction is 0.10.
2	IP INNER Casing Bottom Location: At steam entry ,steam exit and blades	Inlet 168-170 BHN	Fine tempered Bainite with precipitation of carbides. Diffusional degradation level II L.	Microstructural degradation is II L and the expended creep life fraction is 0.10.
		Outlet 171-176 BHN	Fine tempered Bainite with precipitation of carbides. Diffusional degradation level II L.	
3	IP Rotor Location: At steam entry (Fig. 1,2,5,6)	Steam Inlet 204-210 BHN	Fine tempered Bainite with precipitation of carbides. Diffusional degradation level II L.	Microstructural degradation is II L and the expended creep life fraction is 0.10.
	IP Rotor Location: At exit area (Fig. 3,4)	Steam Outlet 221-223 BHN	Fine tempered Bainite with precipitation of carbides. Diffusional degradation level II L.	Microstructural degradation is II L and the expended creep life fraction is 0.10.

4	IP Stationary Blades		Fine tempered Martesite.	No significant microstructural degradation observed.
5	Parting Plane Fasteners	As per table-1		

6.1.4 Table: 1 Hardness Testing

Item Description	Hardness (BHN)	Item Description	Hardness (BHN)
Fastener No	-	Fastener No	-
101	251-253-254	141	276-278-280
102	261-268-265	142	262-263-264
103	256-258-261	143	241-248-250
104	249-250-259	144	256-257-258
105	241-242-248	145	268-269-271
106	261-266-268	146	246-24-248
107	251-258-259	147	243-244-245
108	241-248-249	148	241-242-249
109	245-251-256	149	271-272-276
110	260-268-270	150	260-262-268
111	271-273-278	151	264-266-268
112	263-266-268	152	261-262-263
113	241-248-249	153	241-244-246
114	245-246-248	154	247-252-253
115	249-252-256	155	271-276-278
116	261-262-266	156	268-270-272
117	241-242-246	157	280-283-286

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Item Description	Hardness (BHN)	Item Description	Hardness (BHN)
118	248-261-268	158	281-284-288
119	251-252-254	159	271-276-277
120	240-246-248	160	274-276-277
121	251-255-258	161	280-286-288
122	254-255-266	162	281-283-288
123	261-268-271	163	282-283-284
124	269-270-278	164	281-286-287
125	261-264-268	165	271-272-276
126	240-241-242	166	274-275-278
127	243-244-248	167	276-277-280
128	249-252-254	168	283-284-285
129	261-262-266	169	281-283-288
130	268-269-270	170	284-288-289

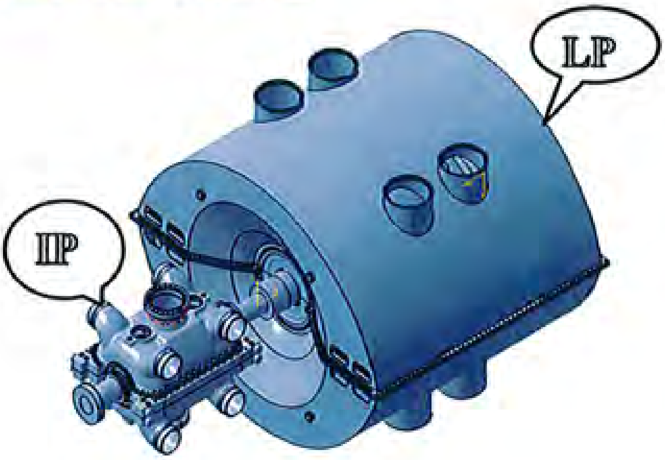
6.1.5 ANALYSIS OF FINDINGS

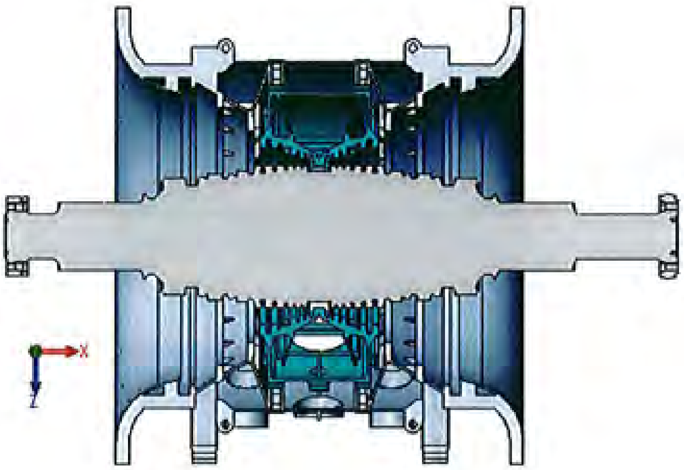
Visual Observations and NDT reveal that the IP Rotor, Casing and Diaphragms are intact. No abnormal deposits are there indicating good water chemistry. There is no Creep microstructural and hardness degradation of the Rotor material. Sealing strips in IP inner casing are found in damaged condition, which were rectified / repaired during the overhaul. Coupling holes and coupling bolts are also in good condition.

6.1.6 REMAINING LIFE ANALYSIS

- **For IP Rotor:** Based on the microstructural degradation and scope of analysis it is concluded that the reaming life of the IP rotor is beyond 20 years.
- **For IP Casing:** Based on the microstructural degradation and scope of analysis it is concluded that the reaming life of the IP casing is beyond 25 years.

6.2 LOW PRESSURE TURBINE





ROTOR, CASINGS & DIAPHRAGMS

- INTRODUCTION
- VISUAL INSPECTION
- NON DESTRUCTIVE TESTING
- INSITU METALLOGRAPHY & HARDNESS MEASUREMENT
- ANALYSIS OF FINDINGS

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6.2.1 Visual Inspection

- Erosion on the steam exit side of the last stages i.e. TS-6 & GS-6 of blades.
- Minor erosion observed on blades of second last stages i.e. TS-5 & GS-5.
- Minor pitting is also observed on the blades of stages TS-3 & GS-3.

- Deposits were observed and collected for analysis
- No rubbing marks were observed on rotor surfaces.
- All balancing weights are in position.
- Integral seals are intact.

Arrow indicates the location of erosion marks observed on trailing edge.

Erosion marks observed on trailing edge of blade.
NDT (LPI, MPI , UT & ET) of the casing, casing internals (guide blade stages, front sealing housing, rear sealing housing, LP rotor and moving blades of all stages was carried out. No significant defect was observed.

Refer Report 7.1 for LPI
Refer Report 7.2 for MPI
Refer Report 7.3 for UT
Refer Report 7.5 for ET.
Refer Report 7.6 for NFT.

Natural Frequency Test on free standing blades of last three stages of LP turbine blades was carried out. There is no significant drop observed in NFT measurements which respect to design value. Below table shows the max. difference observed. (for details pls. refer. Report 8.7)

LP Rotor Stage No. : 4 Turbine Side

Sr.No.	Blade no.	Previous Press (F_1)	Rotor (F_2)	Difference
2	2341	245.0	257.5	12.5
55	2332	247.0	257.5	10.5
56	2388	251.0	260.0	9
64	2414	237.0	252.5	15.5

LP Rotor Stage No. : 5 Generator Side.

Sr. No.	Blade no.	Previous Press (F_1)	Rotor (F_2)	Difference	Previous Press (F2)	Rotor (F_2)	Difference
41	1360	135.0	132.0	3	292.5	283.0	10.5
42	1361	135.0	135.0	0	287.5	296.0	8.5
LP Rotor Stage No. : 5 Turbine Side.							
36	1220	135.0	133.0	2	297.5	288.0	10.5
50	1169	137.5	133.0	4.5	297.5	288.0	10.5

LP Rotor Stage No : 6 Generator Side.

Sr. No.	Blade no.	Previous Press (F_1)	Rotor (F_1)	Difference	Previous Press (F_2)	Rotor (F_2)	Difference
17	566	43.0	43.0	0	100.0	114.0	14
19	574	42.5	41.0	1.5	102.5	128.0	25.5

6.2.2 IN SITU METALLOGRAPHY AND HARDNESS MEASUREMENT: (Refer Report 7.4)

In situ Metallography and Hardness Measurements were conducted at 02 locations in the LP Turbine Rotor one on steam entry area and other at the lower temperature (exhaust) regions.

The microstructure and hardness at the colder side are considered as the baseline since severity of temperature and pressure is least when compared to the casing internal pressure faces, which are exposed to steam flow. The base microstructure shows a microstructure of fine tempered Bainite having an average hardness 261 to 278 BHN as per table given below.

Sr. No	Component ID & Location	Hardness	Observations	Degradation Level	Remarks
1	**LP Rotor Shaft** Inlet Zone	**268-278 BHN**	Microstructure shows fine tempered bainite.	No significant microstructural degradation is observed.	**(Fig on Report 8.5)**
2	**LP Rotor Shaft** To IP Side shaft surface i.e. colder region.	**261-271 BHN**	Microstructure shows fine tempered bainite.	No significant microstructural degradation is observed.	**(Fig on Report 8.5)**

6.2.3 ANALYSIS OF FINDINGS

Visual Observations and NDT reveal that the LP Rotor, Casing and Diaphragms are intact.

No abnormal deposits are found there, thus indicating good water chemistry. There is no creep microstructural and hardness degradation of the Rotor material. Sealing strips are found in good condition. Coupling holes and coupling bolts are also in good condition.

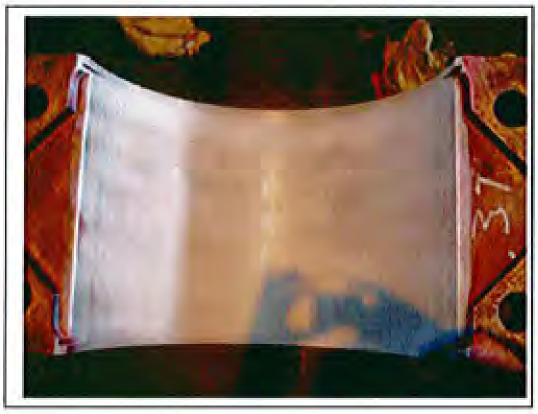
6.2.4 REMAINING LIFE ANALYSIS

- **For LP Rotor:** Based on the microstructural analysis along with NDT testings, it is concluded that the reaming life of the LP rotor is beyond 25 years. However the NFT testing on the last 03 stages of the free standing blades shows higher frequency levels, which is accepted and there is no significant drop in frequency observed.

  Based on the erosion observed in the blades of the last three stages it is recommended to replace the same by new ones at the earliest, to improve reliability & performance.

6.3 BEARINGS AND HOUSING PEDESTAL

- Visual Observations
- Liquid Penetrant Inspection
- Ultrasonic Inspection



6.3.1 Introduction

- There are totally two bearings, one set of thrust pads.
- Visual observations and NDT (UT & LPI) was performed to access condition of the babbit metal bond with the steel backing.

6.3.2 VISUAL OBSERVATIONS

- Minor scattered porosity observed on B/H of Brg.3#4.

6.3.3 LIQUID PENETRANT INSPECTION

Liquid Penetrant inspection was performed on babbit metal lining to detect the surface defects on all bearings, thrust pads.

- Minor Scattered porosity observed on B/H of Brg.3#4.
- All thrust pads are also having no significant defects

6.3.4 ULTRASONIC INSPECTION

Ultrasonic inspection was performed on babbit metal lining to detect the bond quality between the babbit metal and the backing on all the bearings and thrust pads.

De-bond was not observed in bearings.

6.3.5 HOUSING PEDESTAL:

Visual observations and NDT (MPI) was performed to access condition of the housing pedestal.

There is no significant abnormality observed in visual examination.

Magnetic particle inspection was performed on parting plane area of housing pedestal. There is no significant abnormality on MPI examination.

6.3.6 Conclusion:

Based on the above testings, the bearings condition is found healthy and it is fit for next five years of operation.

6.4 VALVES

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6.4.1 TURBINE VALVES AND INTEGRAL STEAM PIPES

- INTRODUCTION
- VISUAL OBSERVATION
- LIQUID PENETRANT INSPECTION
- MICROSTRUCTURE (IN-SITU REPLICA) & HARDNESS MEASUREMENT
- ANALYSIS OF FINDINGS

The Twenty two **valves** in the steam circuit for this turbine are as:

- 4 Numbers of Main Steam Stop Valves: They control the steam flow from the main steam line to the control valves of the HP Turbine.
- 4 Numbers of Main Steam Control Valves: They control the main steam flow entering in to the HP Turbine.
- 4 Numbers of RH stop valves: They control the steam flow from the re-heater pipeline to the control valves of the IP Turbine.
- 4 Numbers of RH Control valves: They control the Re heat steam flow entering in to the IP turbine.
- 2 Numbers of LP Bypass stop valves , They dump the steam to the condenser which was not entering in to the turbine.
- 2 Numbers of LP Bypass control valves; they dump the steam to the condenser which was not entering in to the turbine.
- 2 Numbers of HP Bypass valves: They prevent the steam entering in to the turbine before rolling.

Visual Observation

Visual Observation was conducted at the valve internals and externals after removal of insulation. All valves were observed visually to be in good condition.

Liquid Penetrant Inspection

Liquid Penetrant Inspection was performed at various valve components and results are as listed below.

(Refer Report 7.1 for details).

Magnetic Particle Inspection

Magnetic Particle Inspection was performed for accessible valve fasteners. No significant indication observed.

(Refer Report 7.2 for details).

In situ Metallography and Hardness Measurement (refer report 7.4 for details)

In situ Metallography and Hardness Measurement was conducted at external and internal surface of all the valves. The observations are summarized below:

SR NO	NAME OF VALVE	Location	Observation			REMARKS
			Hardness, BHN	Microstructure	Fig. No.	
1	**HP CV-1**	Valve Body	184-186 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.90	Expended Creep life fraction is 0.10
		Cone	171-178 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.113	Expended Creep life fraction is 0.10
		Bush	165-168 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.114/115	Expended Creep life fraction is 0.10
2	**HP CV-2**	Valve Body	171-187 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation level-IV L.	Fig.91	Expended Creep life fraction is 0.20

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		Cone	160-163 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.116	Expended Creep life fraction is 0.10
		Bush	158-163 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.117/118	Expended Creep life fraction is 0.20
3	HP CV-3	Valve Body	186-188 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation level-IV L.	Fig. 100	Expended Creep life fraction is 0.20
		Cone	161-162 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.119	Expended Creep life fraction is 0.10
		Bush	160-162 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.120	Expended Creep life fraction is 0.10
4	HP CV-4	Cone	163-165 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.121	Expended Creep life fraction is 0.20
		Bush	155-158 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level II L.	Fig.122/123	Expended Creep life fraction is 0.10

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5	IP CV -1	Valve Body	175-178 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.92	Expended Creep life fraction is 0.20
		Cone	135-139 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.112	Expended Creep life fraction is 0.20
		Bush	136-138 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 124/125	Expended Creep life fraction is 0.20
6	IP CV -2	Valve Body	171-179 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.93	Expended Creep life fraction is 0.20
		Cone	155-156 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.126	Expended Creep life fraction is 0.20
		Bush	155-157 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 109/127	Expended Creep life fraction is 0.20

7	IP CV -3	Valve Body	181-187 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 98	Expended Creep life fraction is 0.20
		Cone	168-171 BHN	Microstructure shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusional degradation Level-II L.	Fig. 111	Expended Creep life fraction is 0.10
		Bush	160-164 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.128	Expended Creep life fraction is 0.20
8	IP CV -4	Valve Body	171-178 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 99	Expended Creep life fraction is 0.20
		Cone	130-35 BHN	Microstructure shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusional degradation Level-II L.	Fig.130	Expended Creep life fraction is 0.10
		Bush	158-161 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 110/131	Expended Creep life fraction is 0.20

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9	HP SV-1	Cone	155-156 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.132	Expended Creep life fraction is 0.20
		Bush	150-164 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 101/133	Expended Creep life fraction is 0.20
10	HP SV-2	Cone	180-192 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 102/134	Expended Creep life fraction is 0.20
		Bush	151-158 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.135/136	Expended Creep life fraction is 0.20
11	HP SV-3	Cone	151-161 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.138/139	Expended Creep life fraction is 0.20
		Bush	191-200 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig. 103/137	Expended Creep life fraction is 0.20

12	HP SV-4	Cone	199-201 BHN	Microstructure shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusional degradation Level-II L.	Fig. 104/141	Expended Creep life fraction is 0.10
		Bonnet	130-135 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level IV L.	Fig.142/143	Expended Creep life fraction is 0.20
13	IP -SV-1	Bush	156-161 BHN	Microstructure shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusional degradation Level-II L.	Fig. 105	Expended Creep life fraction is 0.10
14	IP SV-2	Cone	140-148 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level-IV L.	Fig. 107	Expended Creep life fraction is 0.20
15	IPSV-3	Bush	157-164 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level-IV L.	Fig. 106	Expended Creep life fraction is 0.20
16	IP SV-4	Cone	148-151 BHN	Microstructure shows decomposed Bainite with ferrite and with carbides at the grain boundary. Diffusional degradation Level-IV L.	Fig. 108	Expended Creep life fraction is 0.20

17	LPBP	Valve Body	185-196 BHN	Microstructure shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusional degradation Level-II L.	Fig.96	Expended Creep life fraction is 0.10
21	HPBP -1	Valve Body	122-138 BHN	Microstructure shows fine tempered Bainite and ferrite with spherodisation of carbides. Diffusional degradation level IIL.	Fig. 97	Expended Creep life fraction is 0.10

6.4.2 ANALYSIS OF FINDINGS

There is no significant change in the hardness of any of the component.

Visual examination also shows no significant physical damage like erosion, cut marks etc.

LP testing shows no significant observation.

Conclusion: Microstructural Observations on optical suggest that the expended creep life fraction is only 0.1 to 0.2 and no abnormal Creep damage for HPSV and HPCVs and IPSV and IPCVs and other valves. Also the microstructures are without the presence of any cavities or micro cracking. It can be continued for further operation.

ALSTOM

Volume- I-B

Chapter – 7

Field Measurement Data

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7.1 LIQUID PENTRANT INSPECTION

LIQUID PENETRANT INSPECTION REPORT

Order no.	**CGP10028C**		**Period ; 19/05/2010 To 29/10/2010**
REPORT NO	NASL/KK ALSTOM/LPT/01		
JOB	Ref. Table No 1		
AREAS EXAMINED	Ref. Table No.1 – STRAINERS		
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.		
TECHNIQUE	VISIBLE LIQUID PENETRANT TESTING		
	MAKE	**CODE NO**	**EXPIRY DATE**
PENETRANT	Magnaflux	09L62	23/11/2011
CLEANER	Magnaflux	10C02	26/03/2012
DEVELOPER	Magnaflux	10B11	11/02/2012
DWELL TIME PENETRANT	10 Minutes for Penetrant		
REMARKS	No surface indication observed.		

Table 1: LPT Observations

Sr. No.	Job	Qty	Areas examined	Observations
1	HRH Strainer	04	Internal & External surface of Body	No surface indication observed
2	MS Strainer	04	Internal & External surface of Body	No surface indication observed

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LIQUID PENETRANT INSPECTION REPORT

Order no.	**CGP10028C**	**Period ; 19/05/2010 To 29/10/2010**	
REPORT NO	NASL/KK ALSTOM/LPT/02		
JOB	Ref. Table No 2		
AREAS EXAMINED	Ref. Table No.2 – HP/LP Bypass main valve HP/IP GOVERNING VALVES. HP/IP STOP VALVES		
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.		
TECHNIQUE	VISIBLE LIQUID PENETRANT TESTING		
	MAKE	**CODE NO**	**EXPIRY DATE**
PENETRANT	Magnaflux	09L62	23/11/2011
CLEANER	Magnaflux	10C02	26/03/2012
DEVELOPER	Magnaflux	10B11	11/02/2012
DWELL TIME PENETRANT	10 Minutes for Penetrant		
REMARKS	No surface indication observed.		

Table 2: LPT Observations – HP/IP CONTROL Valve

Sr. No.	Job	Qty	Areas examined	Observations
1	HP Bypass main valve	02	Internal surface External surface	No surface indication observed
2	LP Bypass main valve	02	Internal surface External surface	No surface indication observed
3.	HP Control valve Seat ,spindle, cone & chamber	04	Internal surface External surface	No surface indication observed
4.	IP Control Valve Seat ,spindle, cone & chamber	04	Internal surface External surface	No surface indication observed
5.	HP stop valve Seat ,spindle, cone & chamber	04	Internal surface External surface	No surface indication observed
6.	IP stop valve Seat ,spindle, cone & chamber	04	Internal surface External surface	No surface indication observed

LIQUID PENETRANT INSPECTION REPORT

Order no.	CGP10028C		Period ; 19/05/2010 To 29/10/2010
REPORT NO	NASL/KK ALSTOM/LPT/03		
JOB	Ref. Table No 3		
COMPONENT EXAMINED	BEARING # 3 & 4.		
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.		
TECHNIQUE	VISIBLE LIQUID PENETRANT TESTING		
	MAKE	CODE NO	EXPIRY DATE
PENETRANT	Magnaflux	09L62	23/11/2011
CLEANER	Magnaflux	10C02	26/03/2012
DEVELOPER	Magnaflux	10B11	11/02/2012
DWELL TIME PENETRANT	10 Minutes for Penetrant		
REMARKS	No surface indication observed.		

Table 3: LPT Observations

Sr.No.	Job	Qty	Areas examined	Observations
1.	Bearing No. # 3	01	Top & Bottom half	Minor scattered porosity observed.
2.	Bearing No. # 4	01	Top & Bottom half	Minor scattered porosity observed.

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LIQUID PENETRANT INSPECTION REPORT

Order no.	**CGP10028C**	**Period ; 19/05/2010 To 29/10/2010**	
REPORT NO	NASL/KKALSTOM/LPT/04		
JOB	Ref. Table No.4		
COMPONENT EXAMINED	IP ROTOR & LP ROTOR		
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.		
TECHNIQUE	VISIBLE LIQUID PENETRANT TESTING		
	MAKE	**CODE NO**	**EXPIRY DATE**
PENETRANT	Magnaflux	09L62	23/11/2011
CLEANER	Magnaflux	10C02	26/03/2012
DEVELOPER	Magnaflux	10B11	11/02/2012
DWELL TIME PENETRANT	10 Minutes for Penetrant		
REMARKS	No surface indication observed.		

Table 4: LPT Observations

Sr.No.	Job	Qty	Areas examined	Observations
1.	IP Rotor	01	Journal area	No surface indication observed.
		01	Coupling face	No surface indication observed.
2.	LP Rotor	01	Journal area	No surface indication observed.
		01	Coupling Face	No surface indication observed.

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LIQUID PENETRANT INSPECTION REPORT

Order no.	CGP10028C		Period ; 19/05/2010 To 29/10/2010
REPORT NO	NASL/KK ALSTOM/LPT/05		
JOB	Ref. Table No.5		
COMPONENT EXAMINED	Coupling bolt & HP/IP Integral piping at weld joint near casing		
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.		
TECHNIQUE	VISIBLE LIQUID PENETRANT TESTING		
	MAKE	CODE NO	EXPIRY DATE
PENETRANT	Magnaflux	09L62	23/11/2011
CLEANER	Magnaflux	10C02	26/03/2012
DEVELOPER	Magnaflux	10B11	11/02/2012
DWELL TIME PENETRANT	10 Minutes for Penetrant		
REMARKS	No surface indication observed.		

Table 5: LPT Observations

Sr.No.	Job	Areas examined	Observations
1.	Coupling bolts	Thread area	No surface indication observed
2.	HP/IP Integral piping at weld joint near casing	Circumferential weld Joints	No surface indication observed.

LIQUID PENETRANT INSPECTION REPORT

Order no.	CGP10028C	Period ; 19/05/2010 To 29/10/2010	
REPORT NO	NASL/K K ALSTOM/LPT/06		
JOB	Ref. Table No.6		
COMPONENT EXAMINED	IP Casing Halves(Key & Key ways) LP casing halves (Key & Key ways)		
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.		
TECHNIQUE	VISIBLE LIQUID PENETRANT TESTING		
	MAKE	CODE NO	EXPIRY DATE
PENETRANT	Magnaflux	09L62	23/11/2011
CLEANER	Magnaflux	10C02	26/03/2012
DEVELOPER	Magnaflux	10B11	11/02/2012
DWELL TIME PENETRANT	10 Minutes for Penetrant		
REMARKS	No surface indication observed.		

Table 6: LPT Observations

Sr. No.	Job	Areas examined	Observations
1.	IP Casing Halves	Key & Key ways	No surface indication observed.
2.	LP casing halves	Key & Key ways	No surface indication observed.

7.2 MAGNETIC PARTICLE TESTING

MAGNETIC PARTICLE INSPECTION REPORT

Order no.	CGP10028C	Period ; 19/05/2010 To 29/10/2010
REPORT NO	NASL/KK ALSTOM/MPT/01	
JOB	Ref. Table No.1	
AREAS EXAMINED	Ref. Table No.1	
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.	
TECHNIQUE	A.C Wet Fluorescent Continuous Technique	
MACHINE	Y-7 Magnaflux yoke / K-Electronics make coil type	
POLE SPACING	AS PER REQUIREMENT	
NON FLUORESCENCE POWDER CONCENTRATION	Make: Magna flux 14AM 1.2-2.4 gm/100ml of kerosene	
RESULTS	No surface/sub surface indication observed.	

Table 1: MPT Observations – IP TURBINE

Sr. No.	Job	Areas examined	Observations
1	IP Rotor	Integral disc, shaft surface, blades, shrouds, sealing grooves	No surface/sub surface indication observed.
2	IP Casing (Inner & Outer)	Casing halves, parting plane stud & fasteners	No surface/sub surface indication observed.
2.1	IP stationary blades & liners	stationary blades	No surface/sub surface indication observed.

MAGNETIC PARTICLE INSPECTION REPORT

Order no.	**CGP10028C**	**Period ; 19/05/2010 To 29/10/2010**
REPORT NO	NASL/KK ALSTOM/MPT/02	
JOB	Ref. Table No.2	
AREAS EXAMINED	Ref. Table No.2	
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.	
TECHNIQUE	A.C Wet Fluorescent Continuous Technique	
MACHINE	Y-7 Magnaflux yoke	
POLE SPACING	AS PER REQUIREMENT	
NON FLUORESCENCE POWDER CONCENTRATION	Make: Magna flux 14AM 1.2-2.4 gm/100ml of kerosene	
RESULTS	No surface/sub surface indication observed.	

Sr. No.	Name of pipe	Location	Qty of weld joint	Area of Examine	Observation
1	CRH pipe	9th floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
2	CRH stub joint	8th floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
3	Feed water pipe	Turbine floor	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
4	HP By pass pipe	1st floor	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
5	HRH pipe	12th floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
6	HRH pipe	Y joint 6th floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
7	IP integral pipe	Turbine floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
8	HP integral pipe	Turbine floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
9	LP By pass pipe	1st floor	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
10	MS pipe	12th floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
11	MS pipe	Y joint 6th floor	2 nos	Circumferential Weld Joints	No surface/sub surface indication observed.
12	MS pipe 1	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
13	MS pipe 2	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
14	MS pipe 3	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
15	MS pipe 4	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.

16	HRH pipe 1	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
17	HRH pipe 2	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
18	HRH pipe 3	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
19	HRH pipe 4	Near strainer	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
20	Eco outlet	7^{th} floor	1 no	Circumferential Weld Joints	No surface/sub surface indication observed.
21	T-pipe	Turbine floor	2 no	Circumferential Weld Joints	No surface/sub surface indication observed.

MAGNETIC PARTICLE INSPECTION REPORT

Order no.	CGP10028C	Period ; 19/05/2010 To 29/10/2010
REPORT NO	NASL/KK ALSTOM/MPT/03	
JOB	Ref. Table No.3	
AREAS EXAMINED	Ref. Table No.3	
REFERENCE STANDARDS & PROCEDURE	ASTM Spécification.	
TECHNIQUE	A.C Wet Fluorescent Continuous Technique	
MACHINE	Y-7 Magnaflux yoke / K-Electronics make coil type	
POLE SPACING	AS PER REQUIREMENT	
NON FLUORESCENCE POWDER CONCENTRATION	Make: Magna flux 14AM 1.2-2.4 gm/100ml of kerosene	
RESULTS	No surface/sub surface indication observed..	

Table 1: MPT Observations – LP TURBINE

Sr.No.	Job	Areas examined	Observations
1.0	LP Rotor	Blades, shrouds, sealing grooves	No surface/sub surface indication observed.
2.0	LP Casing (Inner & Outer)	Casing halves, parting plane stud & fasteners	No surface/sub surface indication observed.
3.0	LP stationary blades & liners	stationary blades	No surface/sub surface indication observed.

7.3 ULTRASONIC TESTING INSPCTION

ULTRASONIC TESTING INSPECTION REPORT.

Order no.	**CGP10028C**		**Period ; 19/05/2010 To 29/10/2010**		
Report No	NASL/KK ALSTOM/UT/ 04				
JOB	Ref. Table No.1				
AREAS EXAMINED	Ref. Table No.1				
Reference Standards & Procedure	ASTM Spécification.				
Technique	Pulse Echo, A - Scan.				
Machine	Ultrasonic Flaw Detector, Model: DS322, Make: EECI				
Couplant	Grease/Oil				
	Normal Beam Examination				
Location	**Probe**	**Probe Frequency**	**Probe Size**	**Range**	**Reference Level**
IP Turbine Parting plane area of casing.	Normal	4 MHz	10 mm	0 – 200 mm	46 + 6 dB
Calibration	Reference Level Was Adjusted when First Back Wall Echo From The Sound Region Was At 80 % FSH.				
Indications	No recordable indications were observed.				

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Table 1: UT Observations – IP Turbine

Sr.No.	Job	Qty	Areas examined	Observations
1.0	**OUTER CASING**			
1.1	SURFACE (U/H)	01	Parting plane surface	No recordable indications were observed.
1.2	SURFACE (L/H)	01	Parting plane surface	No recordable indications were observed.
	INNER CASING			
1.3	SURFACE	01	Parting plane surface	No recordable indications were observed.
1.4	SURFACE	01	Parting plane surface	No recordable indications were observed.

ULTRASONIC TESTING INSPECTION REPORT

Order no.	**CGP10028C**		**Period ; 19/05/2010 To 29/10/2010**		
Report No	NASL/KK ALSTOM/UT/ 02				
JOB	Ref. Table No.2				
AREAS EXAMINED	Ref. Table No.2				
Reference Standards & Procedure	ASTM Spécification.				
Technique	Pulse Echo, A - Scan.				
Machine	Ultrasonic Flaw Detector, Model: DS322, Make: ECCI				
Couplant	Grease/Oil				
	Normal Beam Examination				
Location	**Probe**	**Probe Frequency**	**Probe Size**	**Range**	**Reference Level**
Shaft & all accessible area	Normal	4 MHz	10 mm	0 – 500 mm	42+6 dB
Calibration	Reference Level Was Adjusted when First Back Wall Echo From The Sound Region Was At 80 % FSH.				
Indications	No recordable indications were observed.				

Table 2: UT Observations – IP ROTOR

Sl.No.	Job	Qty	Areas examined	Observations
1	**LP Rotor**			
1.1	Rotor Shaft	01	Journal and Coupling face area	No recordable indications were observed.

ULTRASONIC TESTING INSPECTION REPORT.

Order no.	**CGP10028C**		**Period ; 19/05/2010 To 29/10/2010**		
Report No	NASL/KK ALSTOM/UT/ 04				
JOB	Ref. Table No.1				
AREAS EXAMINED	Ref. Table No.1				
Reference Standards & Procedure	ASTM Spécification.				
Technique	Pulse Echo, A - Scan.				
Machine	Ultrasonic Flaw Detector, Model: DS322, Make: EECI				
Couplant	Grease/Oil				
	Normal Beam Examination				
Location	**Probe**	**Probe Frequency**	**Probe Size**	**Range**	**Reference Level**
LP Turbine Parting plane & all accessible area of casing.	Normal	4 MHz	10 mm	0 – 200 mm	46 + 6 dB
Calibration	Reference Level Was Adjusted when First Back Wall Echo From The Sound Region Was At 80 % FSH.				
Indications	No recordable indications were observed.				

Table 1: UT Observations – LP Turbine

Sr.No.	Job	Qty	Areas examined	Observations
1	**OUTER CASING(only on accessible area)**			
1.1	SURFACE (U/H)	01	Parting plane surface	No recordable indications were observed.
1.2	SURFACE (L/H)	01	Parting plane surface	No recordable indications were observed.
	INNER CASING LOWER nly on accessible area)			
1.3	SURFACE	01	Parting plane surface	No recordable indications were observed.
	INNER CASING UPPER HALF(only on accessible area)			
1.4	SURFACE	01	Parting plane surface	No recordable indications were observed.

ULTRASONIC TESTING INSPECTION REPORT

Order no.	**CGP10028C**		**Period ; 19/05/2010 To 29/10/2010**		
Report No	NASL/KK ALSTOM/UT/ 02				
JOB	Ref. Table No.2				
AREAS EXAMINED	Ref. Table No.2				
Reference Standards & Procedure	ASTM Spécification.				
Technique	Pulse Echo, A - Scan.				
Machine	Ultrasonic Flaw Detector, Model: DS322, Make: ECCI				
Couplant	Grease/Oil				
	Normal Beam Examination				
Location	**Probe**	**Probe Frequency**	**Probe Size**	**Range**	**Reference Level**
Shaft & all accessible area	Normal	4 MHz	10 mm	0 – 600 mm	38 + 6 dB
Calibration	Reference Level Was Adjusted when First Back Wall Echo From The Sound Region Was At 80 % FSH.				
Indications	No recordable indications were observed.				

Table 2: UT Observations – LP ROTOR

Sl.No.	Job	Qty	Areas examined	Observations
1	**LP Rotor**			
1.1	Rotor Shaft	01	Journal area and all accessible area	No recordable indications were observed.

ULTRASONIC TESTING INSPECTION REPORT

Order no.	**CGP10028C**			**Period ; 19/05/2010 To 29/10/2010**	
Report No	NASL/KK ALSTOM/UT/ 03				
JOB	Ref. Table No.3				
AREAS EXAMINED	Ref. Table No.3				
Reference Standards & Procedure	ASTM Spécification.				
Technique	Pulse Echo, A - Scan.				
Machine	Ultrasonic Flaw Detector, Model: DS322, Make: ECCI				
Couplant	Grease/Oil				
	Normal Beam Examination				
Location	**Probe**	**Probe Frequency**	**Probe Size**	**Range**	**Reference Level**
Bearing Babbit material	T-R	4 MHz	10 mm	0 – 50 mm	32 + 6 dB
Calibration	Using Babbit material step block.				
Indications	No recordable indications were observed.				

Table 3: UT Observations – Bearings

Sr.No.	Job	Qty	Areas examined	Observations
1.	**Bearings**			
1.1	Bearings No. 3 Top & Bottom Half	01	Babbit Bonding	No recordable indications were observed.
1.2	Bearings No. 4 Top & Bottom Half	01	Babbit Bonding	No recordable indications were observed.

ULTRASONIC TESTING INSPECTION REPORT

Order no.	**CGP10028C**		**Period ; 19/05/2010 To 29/10/2010**		
Report No	NASL/KK ALSTOM/UT/ 04				
JOB	Ref. Table No.4				
AREAS EXAMINED	Ref. Table No.4				
Reference Standards & Procedure	ASTM Spécification .				
Technique	Pulse Echo, A - Scan.				
Machine	Ultrasonic Flaw Detector, Model: DS322, Make: ECCI				
Couplant	Grease/Oil				
	Normal/Angle Beam Examination				
Location	**Probe**	**Probe Frequency**	**Probe Size**	**Range**	**Reference Level**
Main piping at accessible weld joint	Angle0°	4 MHz	Dia 10 MM	0-200 mm	38+6 dB
	Angle 45°	4 MHz	8 x 9 mm	0 – 200 mm	36 + 6 dB
	Angle 60°	4 MHz	8 x 9 mm	0 – 300 mm	42 + 6 dB
Calibration	Reference Level Was Adjusted when First Back Wall Echo From The Sound Region Was At 80 % FSH.				
Indications	No recordable indications were observed.				

Table 4: UT Observations – Main Piping

Sr. No.	Name of pipe	Location	Qty of weld joint	Area of Examine	Observation
1	CRH pipe	9^{th} floor	2 nos	Weld Joints	No significant indications were observed.
2	CRH stub joint	8^{th} floor	2 nos	Weld Joints	No significant indications were observed.
3	Feed water pipe	Turbine floor	1 no	Weld Joints	No significant indications were observed.
4	HP By pass pipe	1^{st} floor	1 no	Weld Joints	No significant indications were observed.
5	HRH pipe(near Drum)	12^{th} floor	2 nos	Weld Joints	No significant indications were observed.
6	HRH pipe(near Drum)	Y joint 6^{th} floor	2 nos	Weld Joints	No significant indications were observed.
7	IP integral pipe	Turbine floor	2 nos	Weld Joints	No significant indications were observed.
8	HP integral pipe	Turbine floor	2 nos	Weld Joints	No significant indications were observed.
9	LP By pass pipe	1^{st} floor	1 no	Weld Joints	No significant indications were observed.
10	MS pipe(near Drum)	12^{th} floor	2 nos	Weld Joints	No significant indications were observed.
11	MS pipe(near Drum)	Y joint 6^{th} floor	2 nos	Weld Joints	No significant indications were observed.
12	MS pipe 1	Near strainer	1 no	Weld Joints	No significant indications were observed.
13	MS pipe 2	Near strainer	1 no	Weld Joints	No significant indications were observed.
14	MS pipe 3	Near strainer	1 no	Weld Joints	No significant indications were observed.
15	MS pipe 4	Near strainer	1 no	Weld Joints	No significant indications were observed.
16	HRH pipe 1	Near strainer	1 no	Weld Joints	No significant indications were observed.

Sr. No.	Name of pipe	Location	Qty of weld joint	Area of Examine	Observation
17	HRH pipe 2	Near strainer	1 no	Weld Joints	No significant indications were observed.
18	HRH pipe 3	Near strainer	1 no	Weld Joints	No significant indications were observed.
19	HRH pipe 4	Near strainer	1 no	Weld Joints	No significant indications were observed.
20	Eco outlet	7th floor	1 no	Weld Joints	No significant indications were observed.
21	T-pipe	Turbine floor	2 no	Weld Joints	No significant indications were observed.

7.4 In-Situ Metallography (Replica) Testing

1. 0 INTRODUCTION:

M/s K.K. Alstom. Japan had entrusted NASL New Delhi with the task of In-situ Metallography testing site at NTPC, Korba.

Details of the testing & analysis carried out are presented in the following sections.

2.0 METHODOLOGY ADOPTED:

For testing of the eroded runner, the following methodology was adopted.

(A) In-situ Metallography (Replica)

Following analytical tools / techniques were used for this purpose –

- Optical Microscopy – 'Olympus', Japan make

3. METHODOLOGY FOLLOWED:

3.1 Replica Test (In-situ Metallography Work)

The in-situ metallography was conducted using standard metallographic techniques i.e. by polishing & etching (manual as well as electrolytic) followed by microscopic examination & replication of microstructures. All the replicas were taken to the laboratory (ERDA, Vadodara) and microphotographs were taken. The details of equipment used are as follows:

a) **Electrolytic Polishing & Etching Machine (used at site)**

b) **Portable Grinder (used at site), Make: "Bosch", India**

For rough grinding

c) **Small Hand Grinder (used at site), Make: "Bosch", India**

For polishing up to mirror finish

d) **Portable Optical Microscope (used at site), Make: "APOLLO".**

e) **Laboratory Optical Microscope, Make: "Olympus", Japan**

Various methods of classifying the boiler steel microstructures are followed. A widely accepted classification is described below.

Designated Level **Description of microstructure**

For Diffusion degradation level:

I L : Minimal tendency to break up of bainite / pearlite.

II L : Incipient break of bainite & isolated precipitated carbides in ferrite.

III L : Distinct break up of bainite/pearlite. Ferrite grows darker due to carbide precipitation

IV L : Bainite/pearlite structure visible. Distinct grain boundary carbides & dot like precipitates in ferrite.

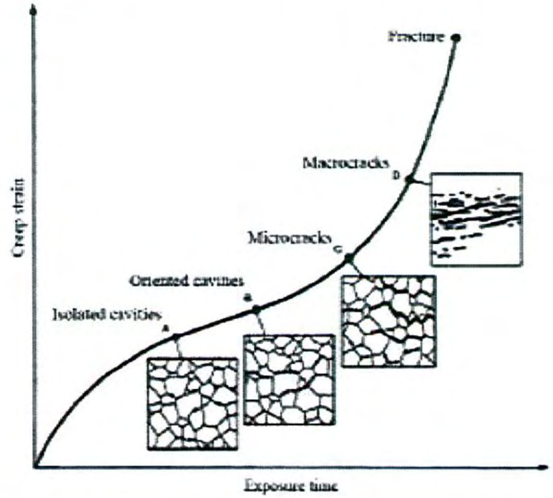
For Creep degradation level:

C I L : Isolated creep cavities

C II L : Oriented creep cavities

C III L : Micro-cracks

C IV L : Macro-cracks

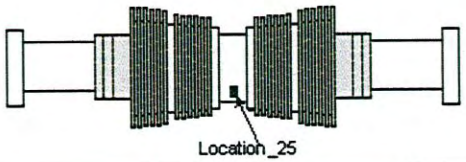


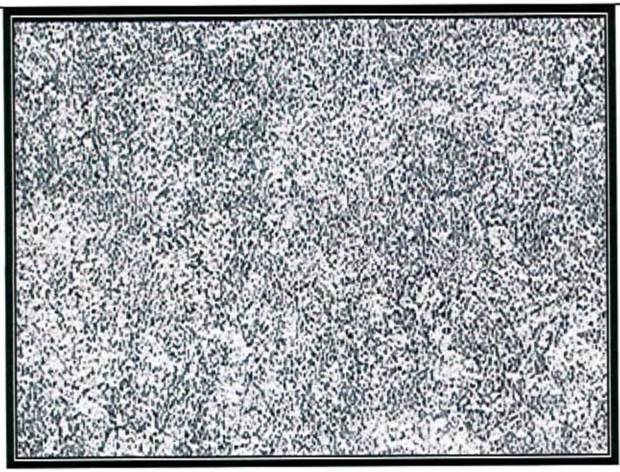
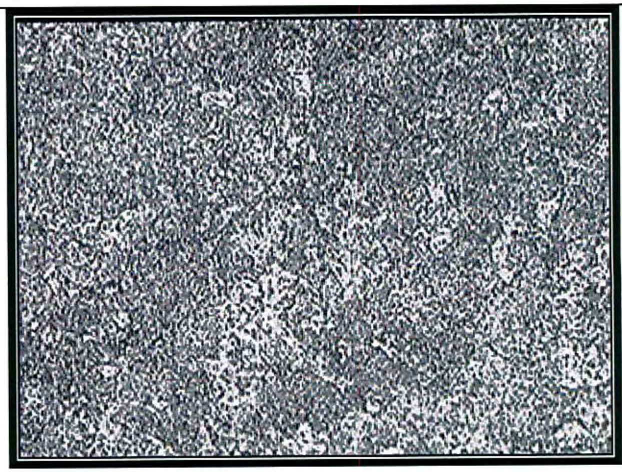
Creep life assessment based on cavity classification

. **DETAILS OF TEST CARRIED OUT**

In-situ Metallography test was carried out. The microstructures were observed at site & were replicated on plastic films for further observation & analysis at higher magnifications at laboratory as well as for taking microphotographs for permanent record.

Name of Component: IP Rotor
Location: IP Rotor steam inlet_ Replica No. 25
Hardness: 204-210HB



	
200X	400X
Observation: Microstructure shows fine tempered bainite with spherodisation of the carbides.	Degradation level-IIL.
Fig: 1	

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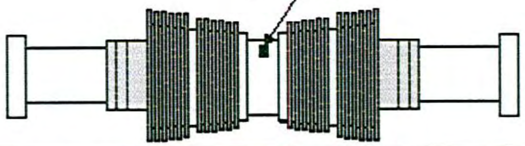
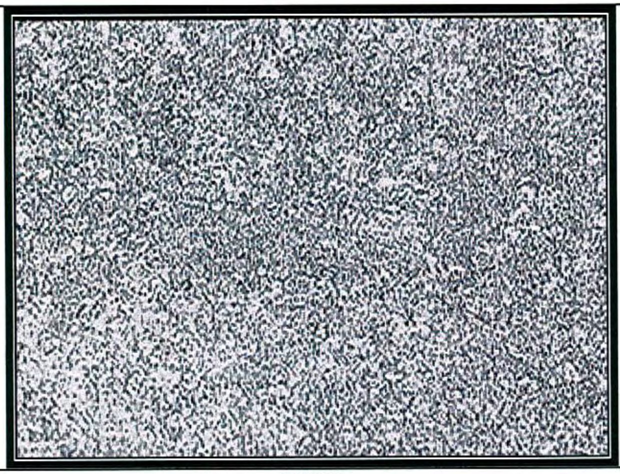
Name of Component: IP Rotor
Location: IP Rotor steam inlet at HP side_ Replica No. 26
Hardness: 211-212HB





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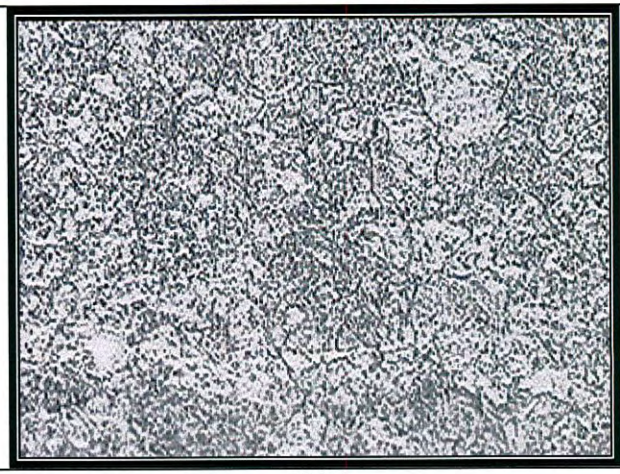


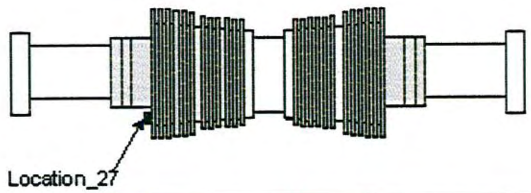
400X

Observation: Microstructure shows fine tempered bainite with spherodisation of the carbides.

Degradation level-IIL

Fig: 2

Name of Component: IP Rotor
Location: IP Rotor steam outlet at LP side_ Replica No. 27
Hardness: 210-218HB



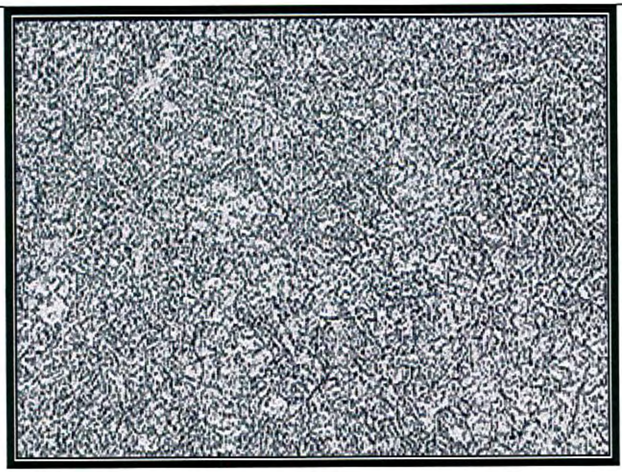
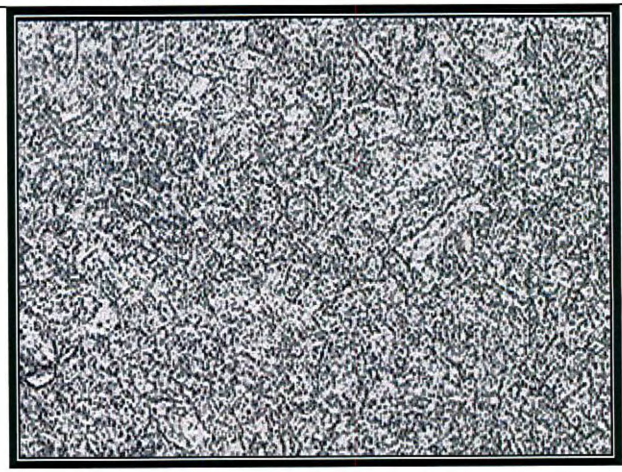
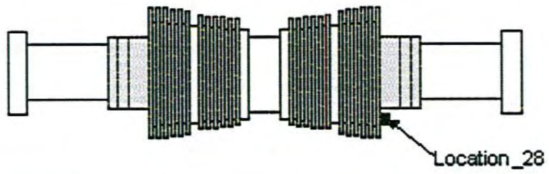
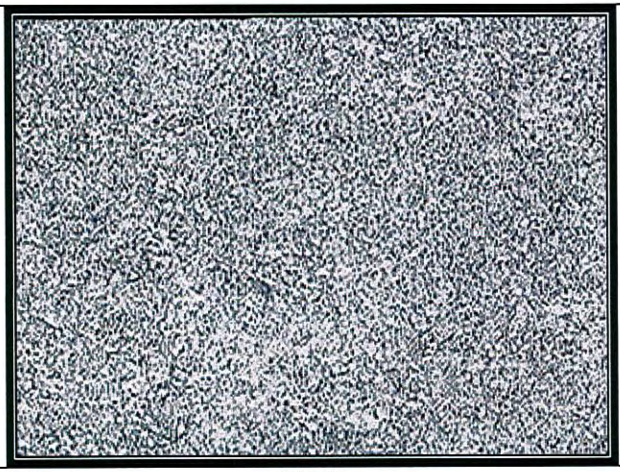
	
200X	400X
Observation: Microstructure shows fine tempered bainite with spherodisation of the carbides.	Degradation level-IIL

Fig: 3

	Client	J-Power (Electric Power Development Co. Ltd.,)
ALSTOM	Project	Turbine and System Assessment for NTPC-Korba Unit #4
	Order No.	CGP10028C
	Contractor	ALSTOM K.K. NASL Ltd. (Nominated subcontractor in India)
NTPC ALSTOM Power Services Pvt. Ltd.	**Document**	**FINAL REPORT VOL. I B(RLA OF TURBINE)**

Name of Component: IP Rotor
Location: IP Rotor steam outlet _ Replica No. 28
Hardness: 221-223HB





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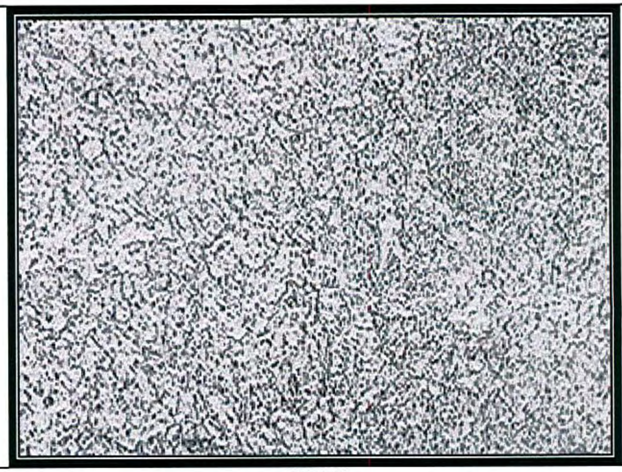


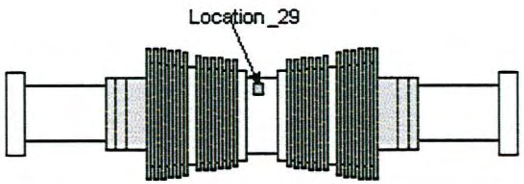
400X

Observation: Microstructure shows fine tempered bainite with spherodisation of the carbides.

Degradation level-IIL

Fig: 4

Name of Component: IP Rotor
Location: IP Rotor steam Inlet _ Replica No. 29
Hardness: 204-208HB



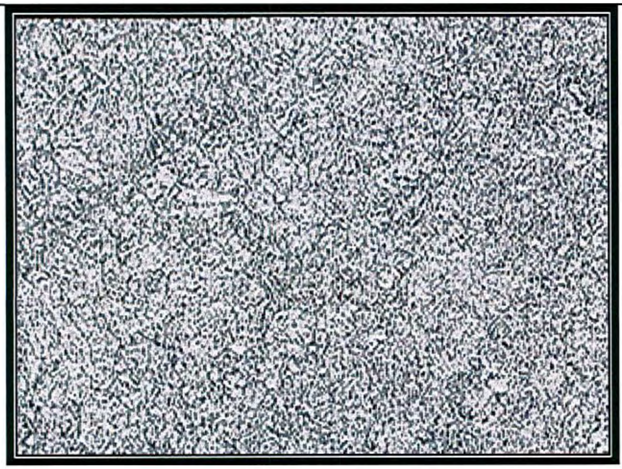
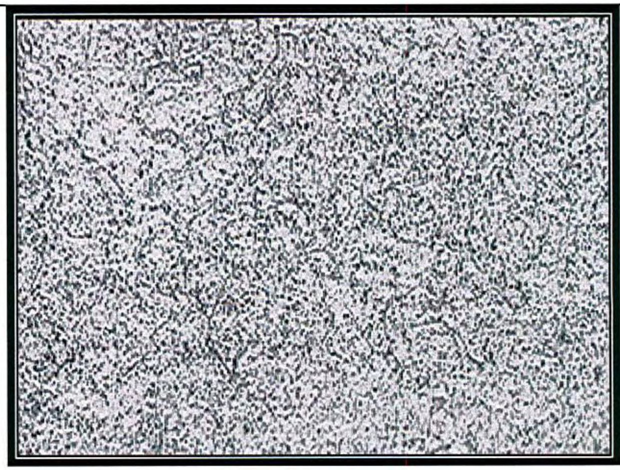
	
200X	400X
Observation: Microstructure shows fine tempered bainite with spherodisation of the carbides.	Degradation level-IIL

Fig: 5

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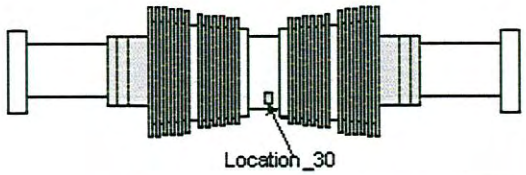
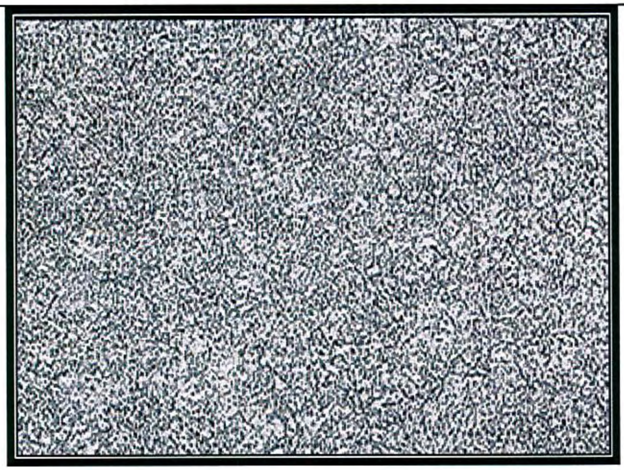
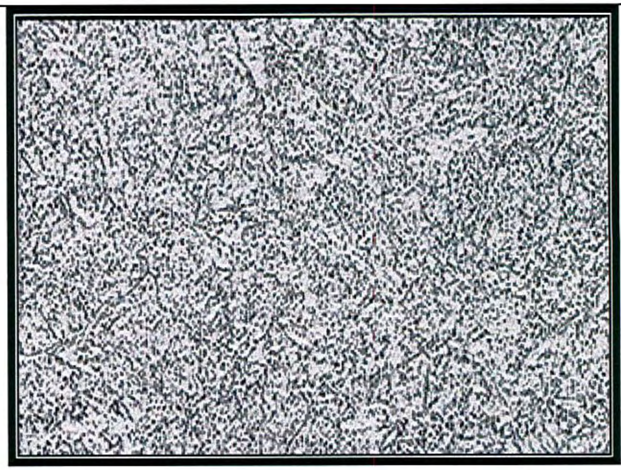
ALSTOM	Client	J-Power (Electric Power Development Co. Ltd.,)
	Project	Turbine and System Assessment for NTPC-Korba Unit #4
	Order No.	CGP10028C
	Contractor	ALSTOM K.K. NASL Ltd. (Nominated subcontractor in India)
NTPC ALSTOM Power Services Pvt. Ltd.	**Document**	**FINAL REPORT VOL. I B(RLA OF TURBINE)**

Name of Component: IP Rotor
Location: IP Rotor steam Inlet _ Replica No. 30
Hardness: 205-208HB



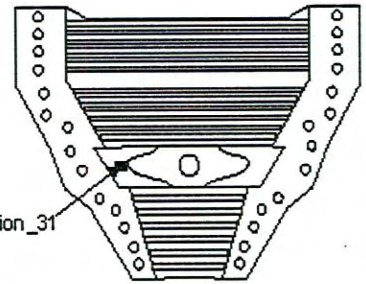




200X	400X
Observation: Microstructure shows fine tempered bainite with spherodisation of the carbides.	Degradation level-IIL

Fig: 6

Name of Component: IP Top Casing
Location: IP Top Inner Casing steam inlet Nozzle chamber _ Replica No. 31
Hardness: 168-172HB



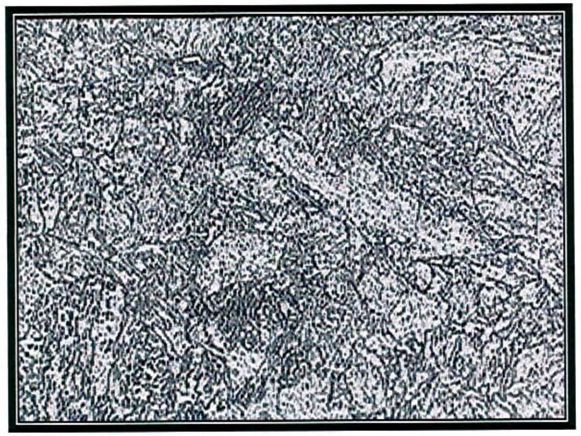
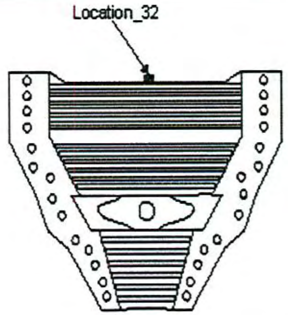
	
200X	400X
Observation: Microstructure shows tempered bainite with spherodisation of the carbides.	Degradation level-IIL

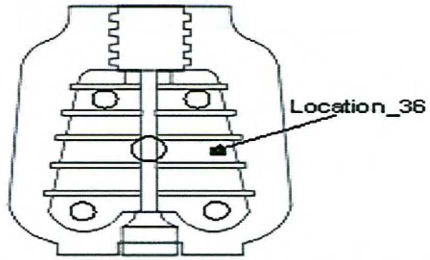
Fig: 7

Name of Component: IP Top Casing
Location: IP Top outlet Casing steam _ Replica No. 32
Hardness: 190-200HB.



	
200X	400X
Observation: Microstructure shows tempered bainite with spherodisation of the carbides.	Degradation level-IIL
Fig: 8	

Name of Component: IP Bottom Casing
Location: IP Bottom outlet Casing steam inlet _ Replica No. 36
Hardness: 168-171HB



200X

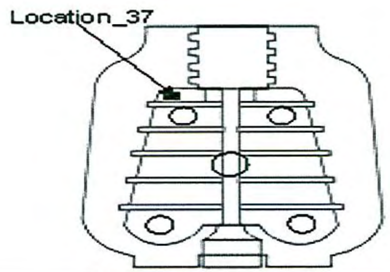
400X

Observation: Microstructure shows tempered bainite with spherodisation of the carbides.

Degradation level-IIL

Fig: 9

Name of Component: IP Bottom Casing
Location: IP Bottom outlet Casing steam Exit_ Replica No. 37
Hardness: 141-143HB



200X

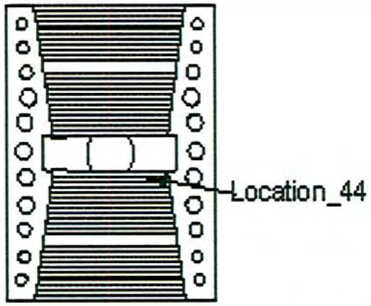
400X

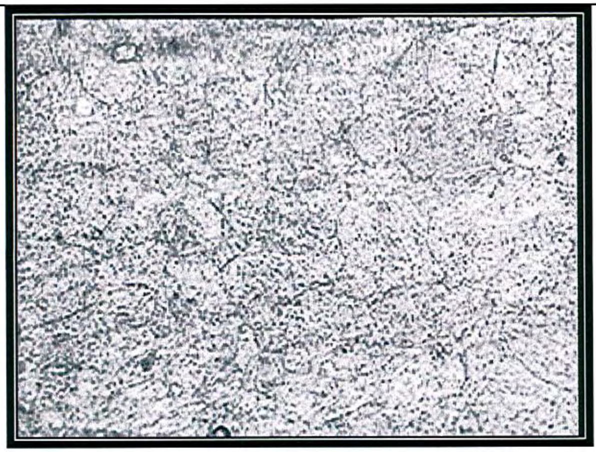
Observation: Microstructure shows tempered bainite with spherodisation of the carbides.

Degradation level-IIL

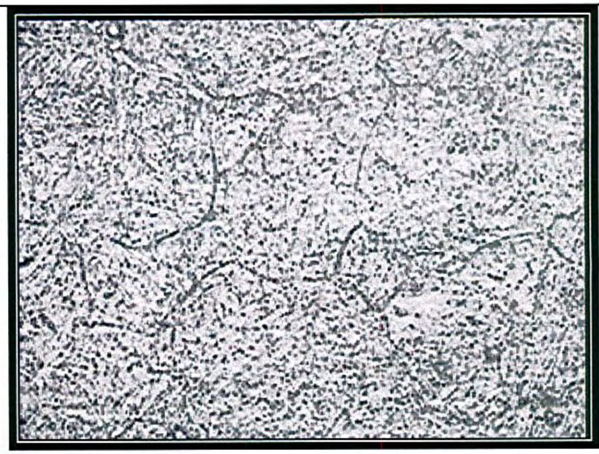
Fig: 10

Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-1 _ Replica No. 44
Hardness: -141-143HB





200X



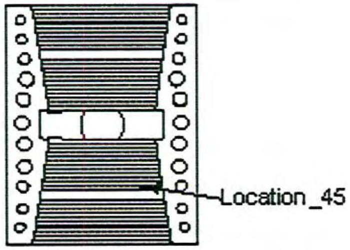
400X

Observation: Microstructure shows tempered martensite with spherodisation of the carbides.

Degradation level-IVL

Fig: 11

Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-2 _ Replica No. 45
Hardness: -142-144HB



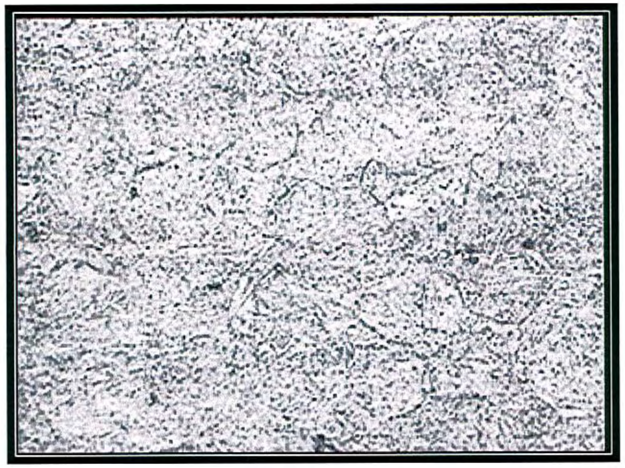
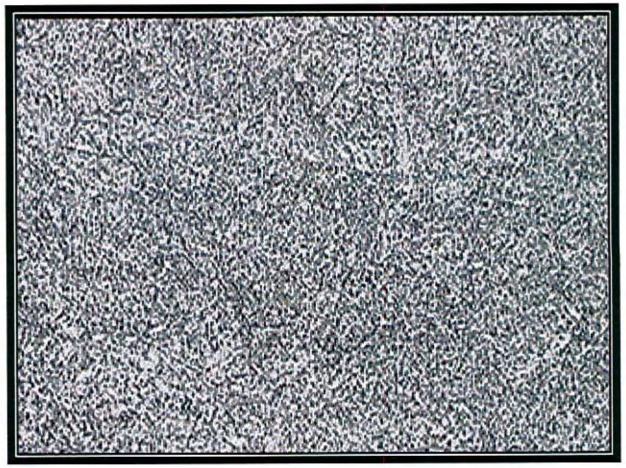
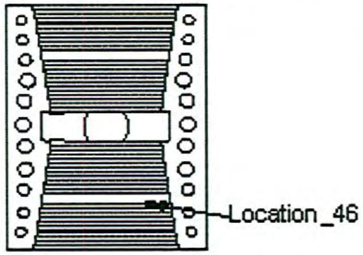
	
200X	400X
Observation: Microstructure shows tempered martensite with spherodisation of the carbides.	Degradation level-IVL

Fig: 12

Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-3 _ Replica No. 46
Hardness: -144-146HB



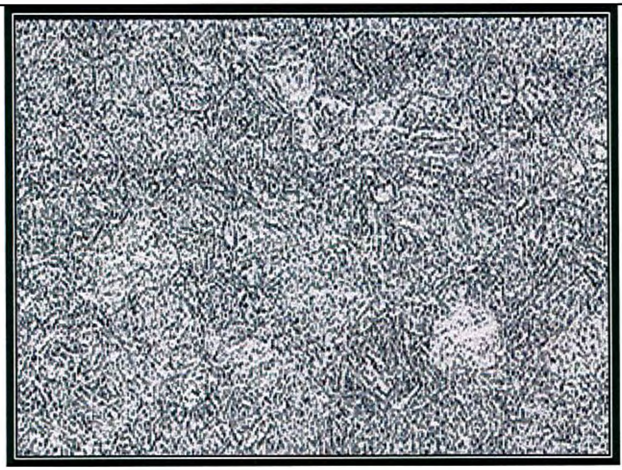
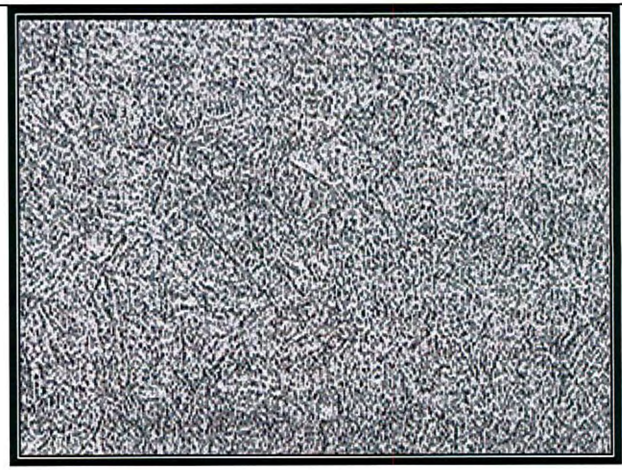
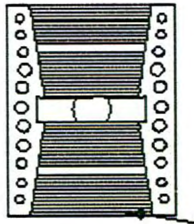
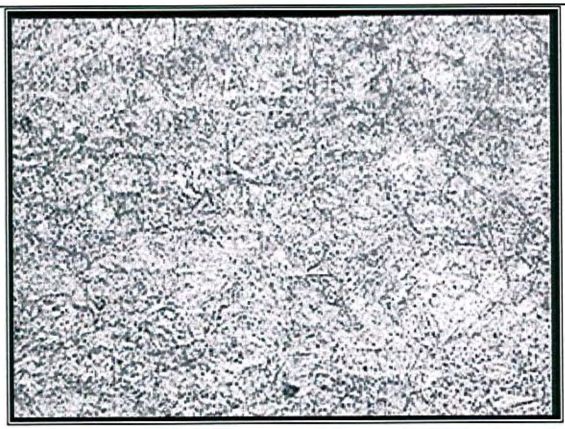
	
200X	400X
Observation: Microstructure shows tempered martensite with spherodisation of the carbides.	Degradation level-IIL

Fig: 13

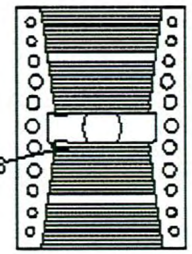
9ъ'

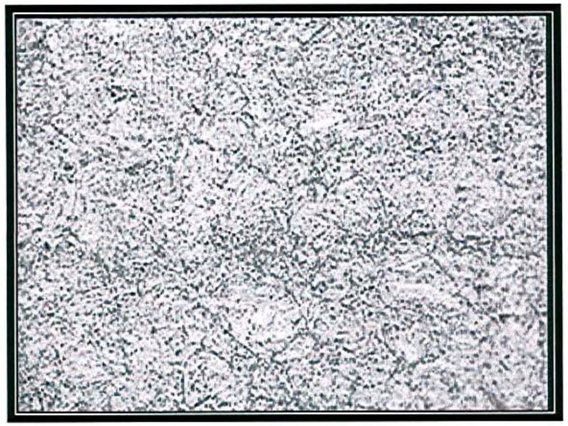
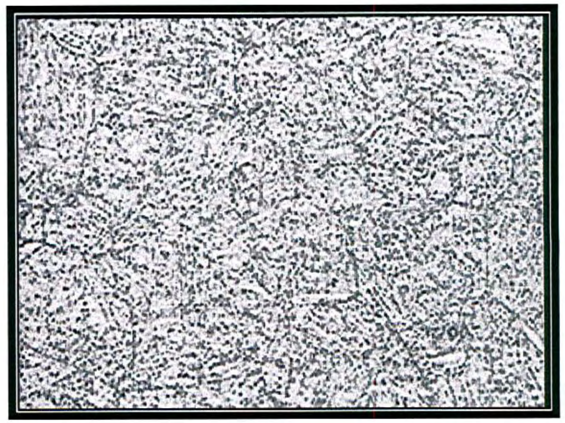
Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-4 _ Replica No. 47
Hardness: - 141-143HB



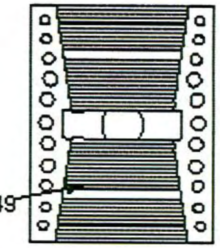
	
200X	400X
Observation: Microstructure shows tempered martensite with spherodisation of the carbides.	Degradation Level- IIL
Fig: 14	

Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-1 _ Replica No. 48
Hardness: -144-146HB



	
200X	400X
Observation: Microstructure shows tempered martensite with spherodisation of the carbides.	Degradation Level- IIL
Fig: 15	

Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-2 _ Replica No. 49
Hardness: -144-146HB



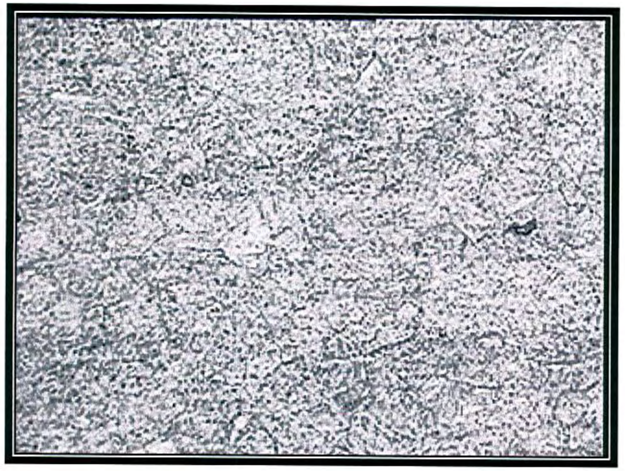
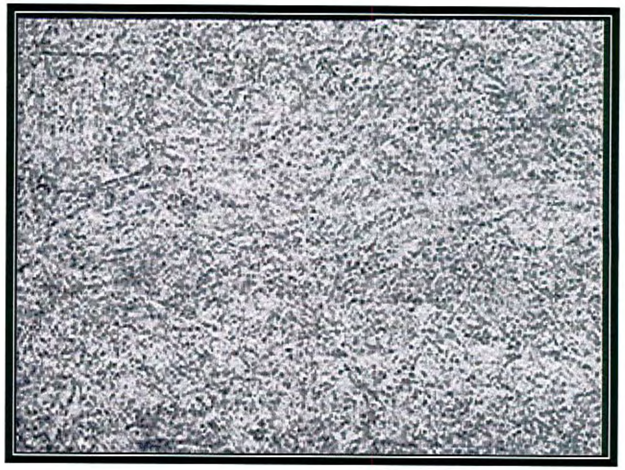
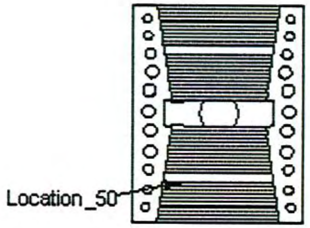
	
200X	400X
Observation: Microstructure shows tempered martensite with spherodisation of the carbides.	Degradation Level- IIL

Fig: 16

Name of Component: IP Bottom Casing
Location: IP Bottom inner Casing Blade stage-3 _ Replica No. 50
Hardness: -141-143HB



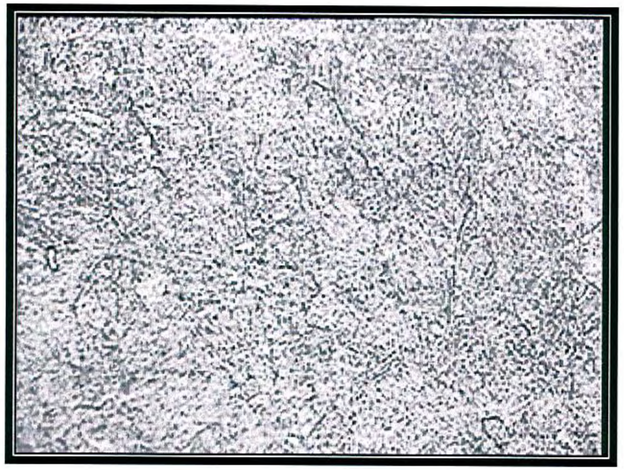
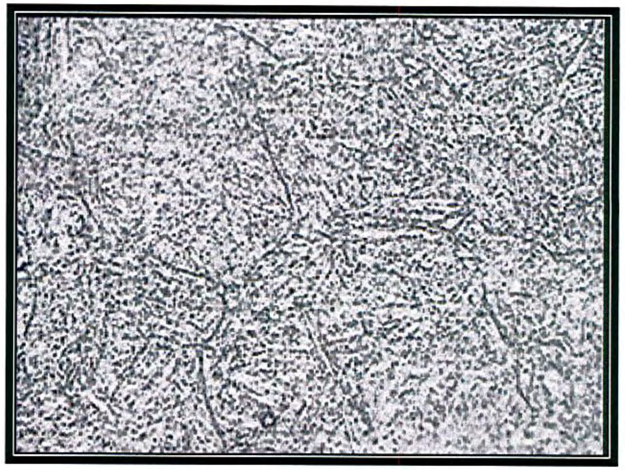
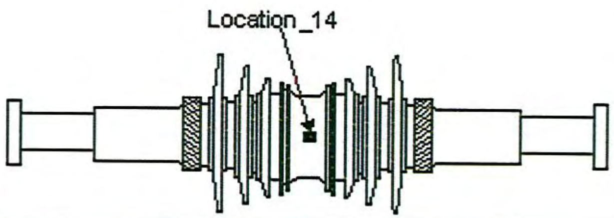
	
200X	400X
Observation: Microstructure shows tempered martensite with spherodisation of the carbides.	Degradation Level- IIL

Fig: 17

Name of Component: LP Rotor
Location: LP Rotor Steam Inlet _ Replica No. 14
Hardness: 268-278HB



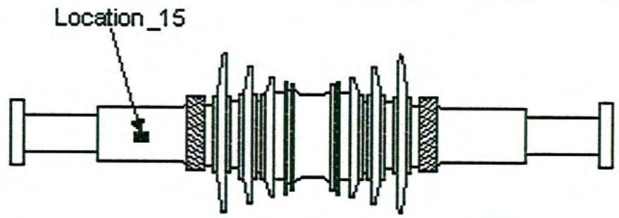
200X

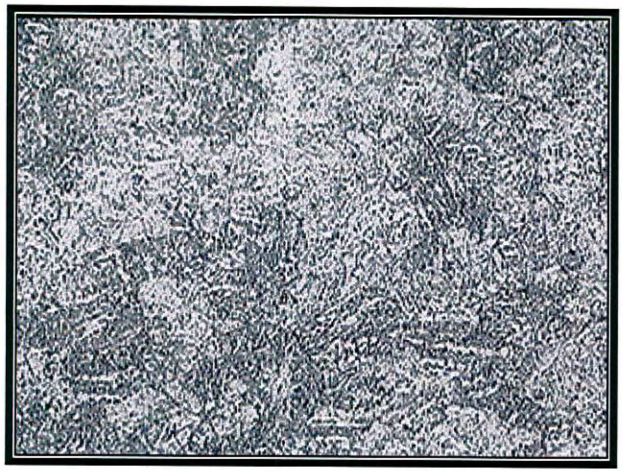
400X

Observation: Microstructure shows tempered bainite. No significant degradation.

Fig: 18

Name of Component: LP Rotor
Location: LP Rotor Steam Outlet _ Replica No. 15
Hardness: 261-271HB





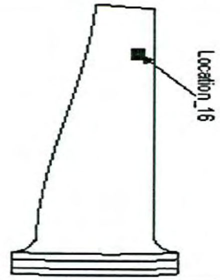
200X

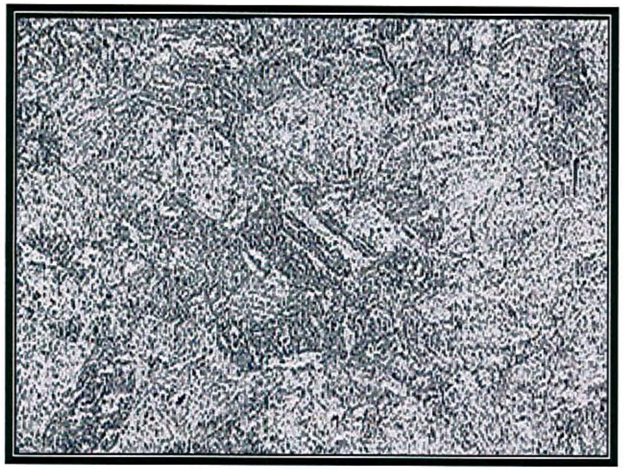
400X

Observation: Microstructure shows tempered bainite. No significant degradation observed

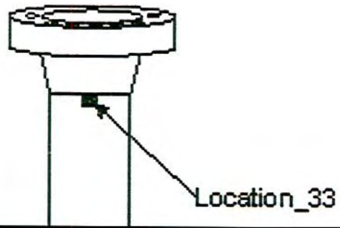
Fig: 19

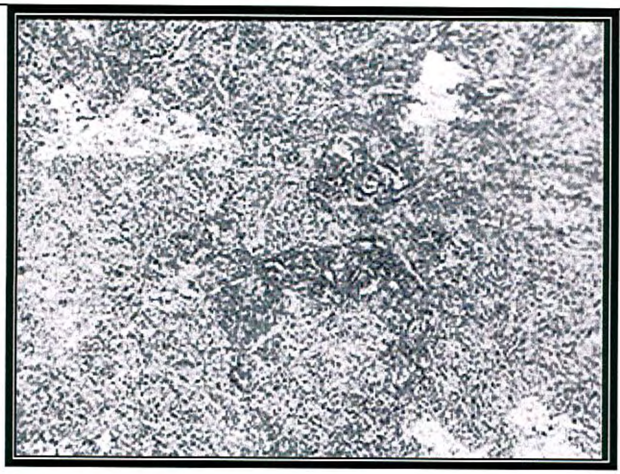
Name of Component: LP Rotor
Location: LP Rotor Blade No. 12 _ Replica No. 16
Hardness: -



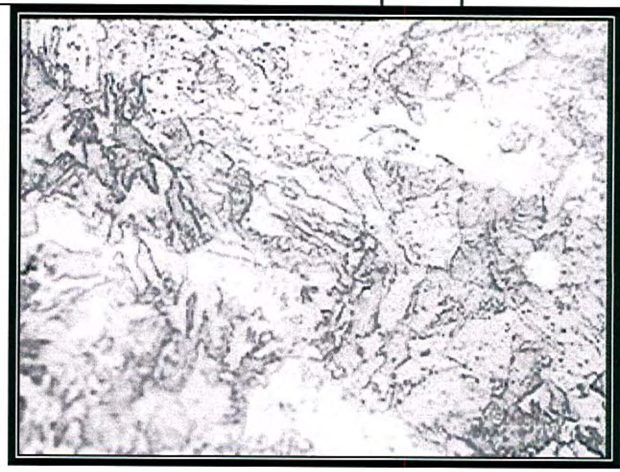
	
200X	400X
Observation: Microstructure shows tempered bainite.	No significant degradation observed
Fig: 20	

Name of Component: IP Integral pipe
Location: IP Integral pipe on weld joint _ Weld Metal _ Replica No. 33
Hardness: 190-200HB





200X

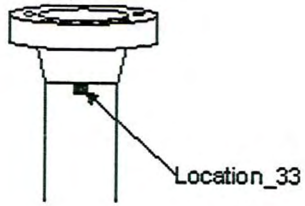


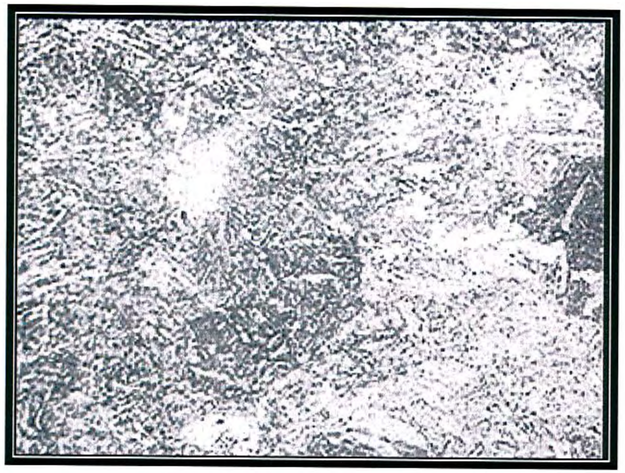
400X

Observation: Microstructure shows tempered bainite with spherodisation of the carbides.	Degradation Level- IIL

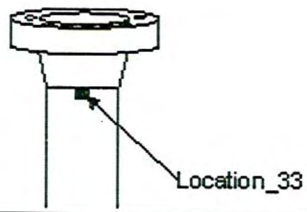
Fig: 21

Name of Component: IP Integral pipe
Location: IP Integral pipe on weld joint _ Heat affected zone _ Replica No. 33
Hardness: - 190-200HB



	
200X	400X
Observation: Microstructure shows tempered bainite with spherodisation of the carbides.	No significant degradation observed
Fig: 22	

Name of Component: IP Integral pipe
Location: IP Integral pipe on weld joint _ Parent Metal _ Replica No. 33
Hardness: 148-158HB



200X

400X

Observation: Microstructure shows tempered bainite with spherodisation of the carbides.

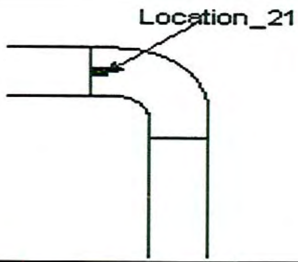
Degradation Level- IIL

Fig: 23

951

ALSTOM	Client	J-Power (Electric Power Development Co. Ltd.,)
	Project	Turbine and System Assessment for NTPC-Korba Unit #4
	Order No.	CGP10028C
	Contractor	ALSTOM K.K. NASL Ltd. (Nominated subcontractor in India)
NTPC ALSTOM Power Services Pvt. Ltd.	**Document**	**FINAL REPORT VOL. I B(RLA OF TURBINE)**

Name of Component: Main Steam line
Location: Main Steam line RHS _ Weld Metal _ Replica No. 21
Hardness: 161-169HB

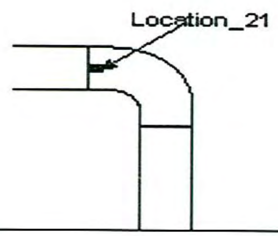


200X

400X

Observation: Microstructure shows tempered bainite with spherodisation of the carbides.	Degradation Level- IIL
Fig: 24	

Name of Component: Main Steam line
Location: Main Steam line RHS _ Heat affected zone_ Replica No. 21
Hardness: -164-172HB



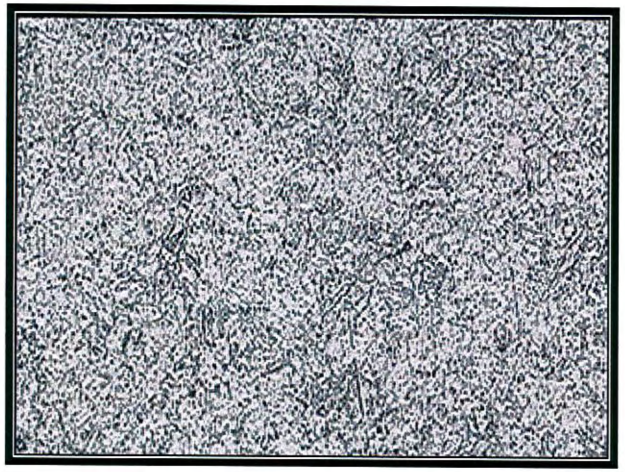
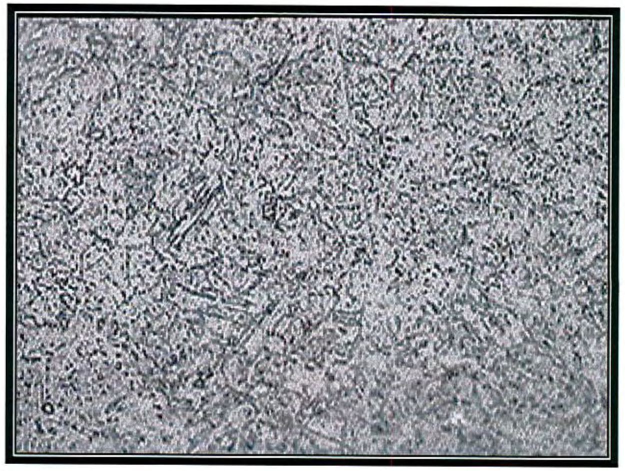
	
200X	400X
Observation: Microstructure shows tempered bainite with spherodisation of the carbides.	Degradation Level- IIL

Fig: 25