Japan International Cooperation Agency
Ministry of Power
NTPC LTD

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

Final Report

Summary

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Tokyo, Japan,
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SUMMARY

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ABBREVIATIONS

Abbreviation	Description
AH	Air Heater
AM	Approved Methodology
AMS	Approved Methodology of Small Scale CDM
C/P	Counterpart
CDM	Clean Development Mechanism
CenPEEP	Center for Power Efficiency and Environmental Protection
CER	Certified Emission Reduction
COP	Conference of the Parties to the UNFCCC
DNA	Designated National Authority
DOE	Designated Operational Entity
EB	CDM Executive Board
ERPA	Emission Reduction Purchase Agreement
GHG	Greenhouse Gas
IET	International Emission Trading
JI	Joint Implementation
JICA	Japan International Cooperation Agency
MoM	Minutes of Meeting
MOP	Ministry of Power
NTPC	NTPC Limited
O&M	Operation & Maintenance
OJT	On the Job Training
P/S	Power Station
PDD	Project Design Document
RH	Re-Heater
SH	Super Heater
SoW	Scope of Work
SSC	Small Scale CDM
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
W/G	Working Group

CONCLUSION AND RECOMMENDATION

The Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India showed the economically viable measures for efficiency improvement and some of them were executed while the rest under consideration or being processes by NTPC. In addition, a lot of technologies, information and exercises were introduced and transferred to NTPC, state electricity as well through in-situ demonstration, counterpart trainings in Japan, Seminars/Workshops and materials such as Final Report and Guideline/Manual.

Conclusion

1. Background

Due to tight balance in the supply and demand of electricity caused by rapid economic growth, the existing power plants have recorded high availability as more than 90% which results in restrictions in proper maintenance work time. This has, on the other hand, caused electrical outages and a fall in power output and has aggravated the present tight supply and demand balance.

India has abundant coal resources and around 66% of its present installed capacity is coal-fired thermal power. As coal will remain the dominant fuel for electric power generation according to India's eleventh five-year electric development plan, it is vital to enhance its technical capability for the efficient operation of existing power plants, such as plant efficiency improvement and life-extension management, in addition to the normal plant operation and maintenance.

In recent years, the worldwide reduction of environmental impact has been called for. In India as the fourth-largest energy consumer, an awareness-raising on climate change issues and actual steps to introduce countermeasure technologies have become important issues.

Under such circumstances, the government of India has requested the government of Japan to conduct a study on improving the operation of the country's thermal power plants, titled "The Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India." In response to this request, the Japan International Cooperation Agency ("JICA") decided to conduct the Study, and subsequently selected a consortium comprised of Electric Power Development Co., Ltd., Kyushu Electric Power Co., Inc., and The Chugoku Electric Power Co., Inc. to serve as a consultant in implementing and operating the Study on December, 2008.

2. Objectives

There are two objectives of the Study as follows:

1) To improve the efficiency of coal-fired thermal power stations of NTPC in India on sustainable basis,
2) To transfer to the counterparts the technology that is necessary to achieve the above objective.

3. Chronological Steps

The Study was conducted through the following steps. Progress of the Study was reviewed and confirmation of the way to proceed was made at the opportunities of each Steering Committee.

1) Establishment of scope of work, policy, methodology and schedule
   #1 Steering Committee, 2nd Feb. 2009
2) Selection of three(3) target units out of five(5) candidate units through site visits
   #1 Field Work, 18th May - 5th June, 2009

   Considering unit overhaul timing, equipment configuration and other conditions, target units were adjusted item by item for assessment, contrary to the original selection criteria of commissioning year-wise, i.e. 1980s, around 1985 and 2000s. As a result, target units were spread over nine(9) units of five(5) power plants as seen in Table 0-1.
3) Detail investigation of target units
   #2 Field Work, 21st Jul. - 8th Aug. 2009
4) Implementation of field study, assessment, diagnosis and test, and report to Steering Committee
   #3 Field Work, 6th Oct. - 13th Nov. 2009
   #2 Steering Committee, 29th Oct. 2009
5) Report of findings and recommendation and decision of next course including NTPC's request for additional activities in FY 2010
   #4 Field Work, 16sh Feb. - 5th Mar. 2010
   #3 Steering Committee, 2nd Mar. 2010
6) Implementation of additional activities in FY 2010
   Turbine Assessment (RLA, SPA and PA) at Korba #4, May - Jun. 2010
   Supplemental Combustion Simulation and Training in Japan, May - Sep. 2010
7) Establishment of Guideline/ Manual methodology
   #5 Field Work, 13th Jun. - 19th Jun. 2010
8) Accomplishment of the Study through finalization of draft Final Report including Guideline/Manual and Report to Steering Committee
   #6 (final) Field Work, 5th Sep. - 18th Sep. 2010
   #4 Steering Committee, 14th Sep. 2010

4. Scope Matrix for Assessment

Although there were several changes in the scope of assessment in the course of assessment mainly due to changes in overhaul shut down timing of the target units, proper adjustments were conducted each time. Table 0-1 shows the final Scope Matrix for Assessment.

In order to introduce new technologies to Indian power sector, following service providers/consultant in respective discipline areas were invited as sub-contractors of the Study Team.

Condenser Leak Assessment:	Fuji Electric Systems Co., Ltd.
Pump Assessment:	Torishima Pump Mfg. Co., Ltd.
C&I Assessment:	Yokogawa Electric Corp.
Boiler RLA:	Kyuden Sangyo Co., Inc.
Turbine Assessment (RLA, SPA, PA):	Alstom K.K. (Japan) with assistance of NTPC-Alstom Power Service Pvt. Ltd.
Boiler Combustion Simulation:	Combustion & Flow Research Institute Co., Ltd.
CDM (draft PDD preparation):	Ernst & Young Pvt. Ltd.

5. Findings and Recommendation

Findings and Recommendation derived from various studies are summarized Table 0-2.

6. Implementation of Recommended Proposals

Most of the proposals for efficiency improvement need unit shut down for rehabilitation or retrofit works. Therefore, practical proposals were taken up among all the recommendation proposed by the Study Team considering necessary lead time to execution, including evaluation inside NTPC, discussion with OEMs / service providers and procurement process, vs. forecasted overhaul timing as on March 2010 when the proposal was made, and magnitude of improvement. These are summarized in Table 0-3.

With these proposals, detail economic and financial evaluation consisting of cost benefit analysis and discount cash analysis was conducted to assure viability of the proposals. The result is shown in Table 0-4. It shows some of them are not viable due to negative present value caused by high investment cost compared with returns. However, the remaining proposals are viable and actions for implementation are under way by NTPC.

In addition to Table 0-4, respective proposals were made as seen in Table 0-2 separately to each study item for efficiency improvement. While some of them such as rectification of suspected air ingress area around condenser and treatment of turbine seal fin burr were executed, the remaining is under study or consideration by NTPC with the projected timelines since some lead times are necessary to discuss internally inside NTPC, with OEMs / service providers.

Furthermore, proposals for improvement of O&M procedures were made in order to detect abnormalities easily and keep human being safety during field patrol. These are on going in phased manner.

7. CDM

In order to apply CDM to the proposals for efficiency improvement, specific measures of AH seal improvement and BFP improvement were studied at Korba #6 / Singrauli #4 and Rihand #2 respectively. Draft Project Design Document (PDD) was prepared for the said respective unit by applying Small Scale Methodology AMS II.B. At the same time, road map from submission up to registration at UNFCCC was indicated for future action taken by NTPC.

Recommendation

Implementation of the proposals, as much as possible, is highly recommended since they were derived from the Study through collaboration and discussion with NTPC. Before implementation, detail discussion inside NTPC and with OEMs / service providers, economic and financial evaluation same as JICA Study Team conducted are required in order to establish clear picture up to accomplishment.

For wider dissemination of the new and effective assessment methodologies and tools introduced by the Study, it is recommended that NTPC takes the lead role among Indian power sector including State Utilities, manufacturers and service providers.

As for the potential technical cooperation area after the Study, Study Team would like to recommend the followings.

1) Boiler RLA
2) Turbine modernization (3D design blade, new type of seal, etc.)
3) Combustion simulation

Table 0-1 Scope Matrix for Assessment

Study Item	Korba #6	Singrauli #4	Rihand #2	Unchahar	Vindhyachal #7
(Efficiency)					
AH	✓	✓			
Condenser		✓(#6)			
Pump	✓(BFP)	✓(CWP)	✓(BFP/CWP)		
BFP-T			✓(#3)		✓
BT Efficiency	✓	✓	✓		
C&I				✓(#3)	
(RLA)					
Boiler		✓(#6)		✓(#2)	
Turbine (incl. SPA, PA)	✓(#4)				
Gene./Trans.	✓	✓(#4/#6)	✓		
(O&M)					
Procedure	✓	✓	✓		
(Boiler)					
Diagnosis of problems					✓
Combustion Simulation					✓

Table 0-2 Recommendation Plan of Study Items (1/5)

Efficiency / Reliability / Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
1	Location (State)	Chattisgarh	UP	UP	MP	UP
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210
3	Turbine Make	KWU	#4 LMZ #6 KWU	#2 GEC	KWU	KWU
4	Boiler Make	BHEL	BHEL	#2 ICL	BHEL	BHEL
5	Overhaul Scope	B+IP+LP	#4: B+HP+(IP)+LP #6: B+LP	#2 B+IP+LP	B	#3 B+HP+IP #2 B+LP
6	Age	#4 1987, #6 1989	#4 1983, #6 1986	#2 1989, #3 2004	1999	#3 1999, #2 1989
7	Shut down period	#4 9 Mar – 12 June 2010	#4: 27 May - 10 July 2010 #6: 18 Oct - 11 Nov 2009	#2: 10 July - 18 Aug 2010	18July - 16Aug 2009	#3: 1 Sep - 5 Oct 2009 #2: 18 Oct - 11 Nov 2009
8	Diagnosis of boiler problem	—	—	—	**RESULT** - Current heat absorption in furnace is still high after addition of wall SH. - Exhaust gas flow at outlet of radiant superheater is expected to be not uniform. **RECOMMENDATION** - Add Wall SH left and right sides of furnace. - Apply the cross-connecting pipes between Division SH and Platen SH.	—
9	Combustion simulation	—	—	—	**RESULT** - The combination of lower levels mill (ABCDEFGH) operation and minus 10 degree burner tilt is the best condition for mitigation of flue gas right/left temperature imbalance without modification of pressure parts. - It was found that heat absorption at furnace is high compared to design value. When the burner tilt turns up, heat absorption in the furnace will be reduced. This may improve low MS and RH steam temperature matters. **RECOMMENDATION** - Carry out trial operation by applying the best parameters written above to the current boiler. For further mitigation of temperature imbalance, modify the boiler by applying the cross-connecting pipes between Division SH and Platen SH. - To increase SH and RH steam temperature, remove front Division SH, and add the same heating surface to rear Division SH by modification of rear Division SH. In addition, apply wall SH at left and right sides of furnace where Division SH is located. Removal of front Division SH is also effective for mitigation of temperature imbalance.	—

Table 0-2 Recommendation Plan of Study Items (2/5)

Efficiency Reliability Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
10	Boiler RLA	—	**#6** **RESULT** - As a whole, creep damage was not remarkable with no creep void and creep strain observed in each evaluated component. - Residual life of desuperheater was estimated to be 100,000, which was minimum among tested boiler pressure parts and headers. - Residual life of main steam pipe was estimated to be 21,000 hours. - Thickness decrease by erosion and attrition were observed in water wall tubes and SH tubes respectively. **RECOMMENDATION** - Implement RLA including outer diameter measurement and replica for main steam pipe again before reaching 21,000 hours, and preferably periodically later on. - Alternative standard criteria for tube replacement such as tsr (Thickness Shell Required) can be considered. In Japan boiler tube replacement is based on calculations of tsr which is a function of allowable stress, design pressure & design OD. NTPC can also consider the use of such criteria in consultation with OEM rather than the method of thickness decrease ratio from design thickness. - Conduct RLA focusing or emphasizing on critical parts after identification of critical ones by considering creep life instead of all high temperature & pressure parts, which NTPC focuses on currently. - For implementation of new RLA technology, training in Japan is recommended such as SUS scale detection, TOFD inspection and evaluation of metallurgical deterioration using SEM &TEM.	—	—	**#2** **RESULT** - As a whole, creep damage was not remarkable with no creep void and creep strain observed in each evaluated component. - Residual life of final superheater tube was estimated to be 35,000 hours, which was minimum among tested boiler pressure parts and headers. - Residual life of main steam pipe was estimated to be 69,000 hours in coarse grain HAZ region. The estimated residual life in base metal varies from 8,000 to 130,000 hrs due to no OD measurements applied, while microstructure shows a little degradation. - Thickness decrease by erosion was observed in water wall tubes. **RECOMMENDATION** - For accurate estimation of residual life of main steam pipe, creep strain (OD) measurement along with microstructure is recommended to be carried out preferably within 8,000 hrs or practically at the earliest opportunity. - Alternative standard criteria for tube replacement such as tsr (Thickness Shell Required) can be considered. In Japan boiler tube replacement is based on calculations of tsr which is a function of allowable stress, design pressure & design OD. NTPC can also consider the use of such criteria in consultation with OEM rather than the method of thickness decrease ratio from design thickness. - Conduct RLA focusing or emphasizing on critical parts after identification of critical ones by considering creep life instead of all high temperature & pressure parts, which NTPC focuses on currently. - For implementation of new RLA technology, training in Japan is recommended such as SUS scale detection, TOFD inspection and evaluation of metallurgical deterioration using SEM &TEM.
11	AH performance improvement	**#6** **Primary AH** **RESULT** - Air leak of A-AH and B-AH is higher than the design value. Leakage air greatly affects AH outlet gas/air temperature. - Imbalance in outlet temperature between Primary AH and Secondary AH is observed and this is assumed to be caused by gas flow imbalance between them. - AH cold end metal temperature is lower than dew point temperature of 66 degree C. This seems to be caused by large air leak in PAH and low gas flow rate in Primary AH due to imbalance between Primary AH and Secondary AH. **RECOMMENDATION** - Improve seal performance applying SDU or Floating Radial Seals. - In addition to guide vane flow regulation, study the possibility of gas duct re-arrangement considering vacant space around AHs for substantial measure against imbalance gas flow between Primary and Secondary AHs. - Confirm AH cold end metal temperature after applying the above measures. - Furthermore, for better O&M, review the current field activities of periodic inspection for AH by utilizing supervisors from licenser of OEM.	**#4** **RESULT** - Air leakage of A-AH and B-AH is higher than the design value. Leakage air greatly affects AH outlet gas/air temperature. - Temperature efficiency is lower than design. This seems due to low heat exchange performance of AH element and/or insufficient soot blowing operation. **RECOMMENDATION** - Improve seal performance applying SDU or Floating Radial Seals. - Collect the historical data such as AH inlet/outlet air/gas temperature and soot blowing operation from just after periodical inspections in order to evaluate AH heating element heat transfer condition for improvement of low temperature efficiency of AH. - Furthermore, for better O&M, review the current field activities of periodic inspections for AH by utilizing supervisors from licenser of OEM.			

Table 0-2 Recommendation Plan of Study Items (3/5)

Efficiency Reliability Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
12	Turbine RLA	**#4** **RESULT** - The unit is generally in good conditions. - No significant defect is observed in turbine and piping. - Remaining life of IP rotor is estimated to be 16 years. Remaining life of IP casing, LP rotor, LP casing is estimated to be more than 20 years. - Remaining life of MS piping is estimated to be more than 20 years, and HRH piping to be 13.6 years. - According to Steam Path Audit, 90% of losses of turbine (output & heat rate) are come from surface roughness. **RECOMMENDATION** **Turbine** - Carry out inspection and microstructure analysis of stressed location at next overhaul. - Carry out cleaning of blade surface at next overhaul. - For IP turbine, carry out RLA in 5 years. - LP last stage rotating blades need to be replaced. **Piping** - For MS piping, carry out micro structure analysis, thickness measurement, strain mequrement EMAT for stressed location at next overhaul. - For other piping, carry out inspection in 5 years. - Indicated hangers need to be corrected.				
13	Condenser assessment	—	**#6** **RESULT** - Air ingress from gland seal packing of both A-BFPT and B-BFPT were 44% and 21% of total ingress measured respectively. **RECOMMENDATION** - Inspect these area and conduct necessary repair.	—	—	—
14	Pump assessment	**#6** **BFP-6B** **RESULT** - Pump efficiency is decreased from the design value. **RECOMMENDATION** - Refurbish inner parts of the pump after economic evaluation. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	**CWP Stage-I 09** **RESULT** - Pump efficiency is decreased from the design value. **RECOMMENDATION** - Refurbish inner parts of the pump after economic evaluation. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	**#2** **BFP-2B** **RESULT** - Pump efficiency is decreased from the design value. **RECOMMENDATION** - Refurbish inner parts of the pump. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps. **CWP-2B** **RESULT** - Pump is considered to be in acceptable condition. **RECOMMENDATION** - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	—	—

Table 0-2 Recommendation Plan of Study Items (4/5)

Efficiency | Reliability | Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
15	Control system assessment	—	—	—	—	#3 RESULT - No problems were observed including load ramp test while part of the operation mode was not in automatic but in manual mode. - Instruments were operating normally and no particular problems were observed, including their operating conditions, calibration method and spare part management in the C&I laboratory. - Extremely high level has been achieved in the fields of control and instrumentation (C&I) RECOMMENDATION - For further improvement in plant efficiency and reliability, introduction of latest technologies may be required. - To reduce frequent boiler tube leakage incidents, optimization of combustion and soot blow operation is recommendable in addition to refurbishment of boiler pressure parts and verification of operation parameters which may be recommended by observation in each sector.
16	Generator assessment	#6 RESULT - Insulation diagnosis could not be evaluated because appropriate data was not available. RECOMMENDATION - Carry out the tests in the condition that the stator cooling water is properly drained and dried out.	#4 RESULT - Current stator insulation of the generator is in good condition considering PI data of more than 2.0 - B phase PI data fluctuates without trend of deterioration while R and Y phase PI data decreases along with operation time - Tanδ of Y phase becomes smaller when the test voltage increases contrary to the theoretical behavior. RECOMMENDATION - Conduct insulation diagnosis test for each phase periodically in the future and monitor trend of deterioration. - For Tanδ test, review test data enough in order to get proper data.	#2 RESULT - Current stator insulation of the generator is in good condition with preferable Average PI data of 3.7 being in the normal range of over 2.0. RECOMMENDATION - Conduct the insulation diagnosis periodically in the future and grasp the deterioration trend because Rihand#2 generator is 20 years old and Japanese technical book reports that stator coil insulation strength of generator might accelerate its deterioration faster after 20-25 years operation.	—	—
17	Transformer assessment	#6 RESULT - Estimated total lifetime is 39 to 54 years, and 38 to 56 years based on $CO+CO_2$ analysis and furfural analysis respectively. RECOMMENDATION - Review test data enough and get proper test data because some data are inconsistent from technical point of view. - Conduct furfural test periodically so that Korba#6 can grasp furfural generation trend and improve the accuracy of the RLA because the test was conducted only once.	#6 RESULT - It is estimated that the GT condition had already reached to Average lifetime point in 2005 (18 years operation) and will reach to Dangerous level in 2019 (33 years operation) according to RLA by $CO+ CO_2$ analysis. - There is big difference in furfural data between 2006 and 2008 while no big difference in DGA during the period. RECOMMENDATION - For confirmation of actual GT condition, sample the insulation paper and measure DP. If sampling the insulation paper is difficult, options such as conducting DGA with shorter interval to monitor trend and evaluating furfural analysis with proper test data may be taken. - As for furfural, check theoretical consistency of the data and get proper test results. RESULT - Insulation oil treatment is often conducted due to moisture increase in oil. RECOMMENDATION - Conduct cooler leak check and take the countermeasures if there is a leak.	#2 RESULT - Estimated total lifetime is 24 to 26 years. RECOMMENDATION - For confirmation of actual GT condition, sample the insulation paper and measure DP. If sampling the insulation paper is difficult, options such as conducting DGA with shorter interval to monitor trend and evaluation of furfural analysis with proper test data may be taken. - As for furfural, check theoretical consistency of the data and get proper test results. RESULT - Insulation oil treatment is often conducted due to moisture increase in oil. RECOMMENDATION - Conduct cooler leak check and take the countermeasures if there is a leak.	—	—

Table 0-2 Recommendation Plan of Study Items (5/5)

Efficiency Reliability Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
18	Analysis of present performance and performance decrease	**#6** **1.Boiler efficiency** **RESULT** - Boiler efficiency is decreased from design value. - Average gas temperature (after gas flow correction) of Primary AH and Secondary AH outlets is higher than design outlet gas temperature. It is estimated that exhaust gas amount of flow is imbalanced. - Air leak in Primary AH is higher than design value. **RECOMMENDATION** - Improve exhaust gas flow imbalance between Primary AH and Secondary AH (refer to AH performance improvement). - Improve Primary AH seal performance (refer to AH performance improvement). **2.Turbine heat rate** **RESULT** - Turbine heat rate is increased from design value. - HP turbine efficiency is decreased from design value. **RECOMMENDATION** - Replace HP turbine seal fin in order to increase efficiency. - Review inconsistency in data for heat rate calculation, if any, and carry out calibration of required instruments before performance test. - Measure extraction steam pressure and temperature at turbine end. - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	**#4** **1.Boiler efficiency** **RESULT** - Boiler efficiency is decreased from design value. - AH outlet gas temperature is lower than design value. - AH outlet air temperature of Primary AH and Secondary AH outlets are lower than design value. It is estimated that heat exchange performance is decreased. - Air leakage is higher than design value **RECOMMENDATION** - Improve temperature efficiency (refer to AH performance improvement). - Improve AH seal performance (refer to AH performance improvement). **2.Turbine heat rate** **RESULT** - Turbine heat rate is increased from design value. - HP turbine efficiency is decreased from design value. **RECOMMENDATION** - Replace HP turbine seal fin in order to increase efficiency. - Review inconsistency in data for heat rate calculation, if any, and carry out calibration of required instruments before performance test. - Measure extraction steam pressure and temperature at turbine end. - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	**#2** **1.Boiler efficiency** **RESULT** - Boiler efficiency is decreased from design value. - Average gas temperature (after gas flow correction) of Primary AH and Secondary AH outlets is higher than design outlet gas temperature. The average secondary air preheaters inlet exhaust gas temperature is higher than design value. - Air leak is higher than design value (assumption). - Unit is operated under slightly higher O2 concentration at economiser outlet **RECOMMENDATION** - Observe and adjust at economizer outlet gas temperature during operation. - Improve AH seal performance through consultation with OEM. - Observe and adjust O2 value at economizer outlet during operation to realize better boiler efficiency. **2.Turbine heat rate** **RESULT** - Turbine heat rate is increased from design value. - HP turbine efficiency is decrease from design value. - IP turbine efficiency is decreased from design value. **RECOMMENDATION** - Replace IP turbine seal fin in order to increase efficiency. - Review inconsistency in data for heat rate calculation, if any, and carry out calibration of required instruments before performance test. - Review historical trends of heat rate and HP/IP turbine efficiency whether they have been gradually decreased or were originally lower than design values. - Measure extraction steam pressure and temperature at turbine end. - Investigate seal welding of partition plate - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	—	—
19	Review and improvement of past and present O & M procedure	**RESULT** - Picked-up five O&M procedures are properly edited as manuals. - Some recommendations were found through monitoring of operation including field patrol activities in order to improve technical and safety performance further. **RECOMMENDATION** **Safety Aspect** - Wear suitable safety gear (working clothes, helmet, gloves, safety shoes, flash light). - Encourage safety mind further through safety education. - Implement safety monitoring patrol and hold KY (Kiken-Yochi, danger prediction) meeting. - Indicate dangerous condition clearly to persons around intricate works in the same area. - Manage the entry and exit status into and from closed space by applying "In and Out Status Board". - Carry out field housecleaning by vacuum cleaner instead of air blow. - Enhance application of 5S(Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization), and Shitsuke (discipline)) especially in local field. **Improvement of Patrol** - Use suitable detection gear （flash light, listening rod）. - Use listening rod to detect abnormal noise of rotating machines. - Put marks to local gauges to show normal working values. - Put thermo label to effectively detect steam leak from safety valve seat.			—	—

Table 0-3 Practical Proposals for Efficiency Improvement

	Korba #6 500MW	**Singrauli #4 200MW**	**Rihand #2 500MW**	**Unchahar #3 210MW**
OH Shut Down (as on Mar. 2010)	1 Apr. - 4 May, 2010/11	27 May - 10 Jul., 2010/11	1 Apr. - 7 May, 2010/11	??? 2011/12
Turbine Seal Fin	✓	✓	✓	
AH Seal				
SDU	✓	✓		
FRS	✓	✓		
C&I Optimization				✓

Table 0-4 Results of Economic/Financial Evaluation of Practical Proposals

	Korba #6 500MW	**Singrauli #4 200MW**	**Rihand #2 500MW**	**Unchahar #3 210MW**
OH Shut Down (as on Mar. 2010)	1 Apr. - 4 May, 2010/11	27 May - 10 Jul., 2010/11	1 Apr. - 7 May, 2010/11	??? 2011/12
Turbine Seal Fin	NOT viable	Viable with a certain Increment of Unit Efficiency (Small Investment.)	Viable with a certain Increment of Unit Efficiency (Small Investment.)	
AH Seal				
SDU	Viable with a certain Increment of Unit Efficiency (Large Investment.)	Viable with a certain Increment of Unit Efficiency (Large Investment.)		
FRS	Viable with a certain Increment of Unit Efficiency (Large Investment.)	NOT viable		
C&I Optimization				NOT viable

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

India's power demand is dramatically increasing under rapid economic growth. Due to tight balance in the supply and demand of electricity, the existing power plants have overused without appropriate maintenance. This has caused electrical outages and a fall in power output and has aggravated the present tight supply and demand balance. India has abundant coal resources and around 66% of its present installed capacity is based on coal-fired thermal power plants. As coal will remain the dominant fuel resource for electric power generation according to India's eleventh five-year electric development plan, it is vital to enhance its technical capability for the efficient operation of existing power plants, such as plant efficiency improvements and life-extension managements, in addition to the normal plant operation and maintenance.

In recent years, the worldwide reduction of environmental burdens has been called for. In India as the fourth-largest energy consumer, an awareness-raising on climate change issues and actual steps to introduce countermeasure technologies have become important issues.

The government of India has requested the government of Japan to conduct a study on improving the operation of the country's thermal power plants, titled "The Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India." In response to this request, the Japan International Cooperation Agency ("JICA") decided to conduct the study, and subsequently selected a consortium comprised of Electric Power Development Co., Ltd., Kyushu Electric Power Co., Inc., and The Chugoku Electric Power Co., Inc. to serve as a consultant in implementing and operating the study on December, 2008.

1.2 Purpose of the Study

The following are the two objectives of this study:

(1) To improve the efficiency of coal-fired thermal power stations of NTPC in India on sustainable basis.

(2) To transfer to our counterpart the technology that is necessary to achieve the above objective.

1.3 Schedule of the Study

The study schedule consists following three (3) phases base on the JICA instruction. The total implementation period is from December 2008 to October 2010.

First Year (from December 2008 to February 2009)
Second Year (from May 2009 to February 2010)
Third Year (from May 2010 to October 2010)

1.4 Outline of the Study

The following indicates the scope of our service based on the Inception Report:

(1) Investigation of Indian power policy, law and organization

(2) Review of past and present efforts for energy efficiency improvement

(3) Presentation for efficiency enhancement, O&M and condition assessment of coal fired power plant in Japan

(4) Selection of candidate power plants (units)

(5) Analysis of present performance and performance decrease of candidate power plants (units)

(6) Work schedule

(7) Establishment of counter part team

(8) Plant performance diagnosis

(9) Condition assessment (life, damage, defect)

(10) Review and improvement of past and present O&M procedure

(11) Financial analysis

(12) Improvement of plant performance and application

(13) Preparation of CDM application

(14) Development of guide line and manual

(15) Holding of seminars for technology transfer and workshops

(16) Preparation of program for training of counterpart members in Japan

(17) Holding of steering committee meetings

Selected Units

Selected coal-fired thermal power stations owned by the NTPC are five power stations which included 9 units taking into consideration the above study items, periodical inspection schedule and Study team schedule. The name of selected units is as follows.

- Korba Power Station Unit 4 and Unit 6
- Singrauli Power Station Unit 4 and Unit 6
- Rihand Power Station Unit 2 and Unit 3
- Vindhyachal Power Station Unit 7
- Unchahar Power Station Unit 2 and Unit 3

Detail scope matrix is attached in Clause 5.

Counterpart Agency

The C/P Team will be composed of persons who take overall responsibility for this project, those in charge of power stations that have units which will be applicable for this study, and members from CenPEEP.

- C/P Team Leader: Mr. D.K Agrawal (NTPC CenPEEP)
- C/P Team Member: Mr. Pankaj Bhartiya
  Mr. S.Bandyopadhyay,
  Mr. M.K.S Kutty
  Mr. A.K Mittal
  Mr. A K Arora
  Mr. Surendra Prasad
  Mr. Subodh Kumar
  Mr. R.K. Kurana
- C/P Team Member (Power Station):

- Korba Power Station:	Boiler:	Mr. Ramesh Babu
		Mr. P. Jetha
		Mr. P. Upadhyay
	Turbine:	Mr. S.K. Ghosh
		Mr. H.P. Dewangan
		Mr. B.R. Das
	Electrical:	Mr. B.K. Urmliya
		Mr. J.S. Pandey
		Mr. S. Vyas
	C&I:	Mr. S. Das
		Mr. R.B. Dwivedi
		Mr. S.K. Choukikar
	EMMG:	Mr. A.A. Prasad
		Mr. M.K. Malviya
- Singrauli Power Station:	Boiler:	Mr. P. Khare
		Mr. A. Kumar (APH)
		Mr. B. Bhattacharya
	Electrical:	Mr. B.K. Singh
		Mr. H.S. Sahu
	C&I:	Mr. K. Ganguly
	EMMG:	Mr. K.N. Chaudhary
		Mr. B.K. Saha
		Mr. S.K. Thakele

		Mr. A. Kumar
	Maintenance Procedure:	Mr. J.S. Thakur
		Mr. B.K. Singh
		Mr. B. Bhattacharya
		Mr. S. Patra
	Pump Performance:	Mr. V.C. Shukla,
	Condenser Performance:	Mr. Sadhukhan
		Mr. S. Upadhayay
		Mr. S. Kumar Singh
- Rihand Power Station:	Boiler:	Mr. A.K. Sharma
		Mr. A.K. Dutta
		Mr. P. Kashyap
	Turbine:	Mr. L.K. Behera
	Electrical:	Mr. V.S. Georpe
		Mr. S.K. Parida
	C&I:	Mr. T.K. Naroi
	EMMG:	Mr. C.K. Samanta
	Planning:	Mr. F. Rahman
- Vindhyachal Power Station:	Operation:	Mr. V. Thangapandiyan
	EMMG:	Mr. D. Varadarajan
		Mr. S. Banerjee
- Unchahar Power Station:	C&I:	Mr. P.K. Gupta
	EMMG:	Mr. D. Paul

Study Team Member

Study Team is consisted of the 11 members and 1 coordinator as shown in Table 1.4-1 below:

Table 1.4-1 Member of Study Team

Name	Position	Organization
1. Noriyuki SHIMIZU	Team Leader / Thermal Power	Electric Power Development Co., Ltd.
2. Morikuni MIYAGI	Sub-Team Leader / Thermal Power (Boiler)	Electric Power Development Co., Ltd.
3. Nobuchika KOIZUMI	Thermal Power (Turbine / Life assessment B)	Electric Power Development Co., Ltd.
4. Takashi FUJIMORI	Thermal Power (Electric)	The Chugoku Electric Power Co., Inc.
5. Hiroshi OKAME (Dec. 2008 – Aug. 2009) Kyoichi NAKANISHI (Aug. 2009 -)	Thermal Power (Control)	The Chugoku Electric Power Co., Inc.
6. Hiroyuki HAYAKAWA	Thermal Power (Life assessment A)	Kyushu Electric Power Co., Inc.
7. Tatsuya MOROOKA	Thermal Power (Efficiency assessment)	Electric Power Development Co., Ltd.
8. Makoto YOTSUMOTO	CDM Application Support	Electric Power Development Co., Ltd.
9. Takashi YAMAGUCHI (Dec. 2008 – June 2009) Katsumi YOSHIDA (July 2009 -)	Economy / Financial Analysis	Kyushu Electric Power Co., Inc.
10. Shinji KUBA (Dec. 2008 – Aug. 2009)	Coordinator	Kyushu Electric Power Co., Inc.
11. Seiji TAMURA (Dec. 2008 – Feb.2009) Futoshi MASUDA (April 2010 -)	Preparation for Training Program in Japan	The Chugoku Electric Power Co., Inc.
12. Toshihiko FURUE (April 2010 -)	Preparation for Training Program in Japan (Boiler RLA)	Kyushu Electric Power Co., Inc.

CHAPTER 2 POWER SECTOR IN INDIA

2.1 Government Policy

2.1.1 Law/Regulation

Electricity utility industry in India have been established by three major acts such as Indian Electricity Act in 1910 under the governed by U.K., Electricity (Supply) Act in 1948 and Electricity Regulatory Commissions Act in 1988 and was operating. In year 2003, the above three laws were integrated by Government to the Electricity Act 2003 in order to reformation of framework for the Electricity. The Government issued National Electricity Policy in 2005 and Tariff Policy in 2006 on the basis of Electricity Act 2003. The Tariff Policy showed concrete policy about tariff reformation. Under this circumstance, the reformation of electricity has been carried out such as the promotion of private investment, the liberalization of electricity trading, elimination of licensed power generation (without hydro-power), separation of SEB, the open access to the transmission/distribution line and rationalization of electricity tariff.

2.1.2 Power Sector Structure

Electricity (Supply) Act provides power supply system. The power supply system is broadly divided into national level (central government) and state level (state government). Ministry of Power has direct control to electricity producers and electric transmission companies. On the other hand state government has State Electricity Board (SEB) which controls power distribution system and power stations. The power sector structure is shown below.

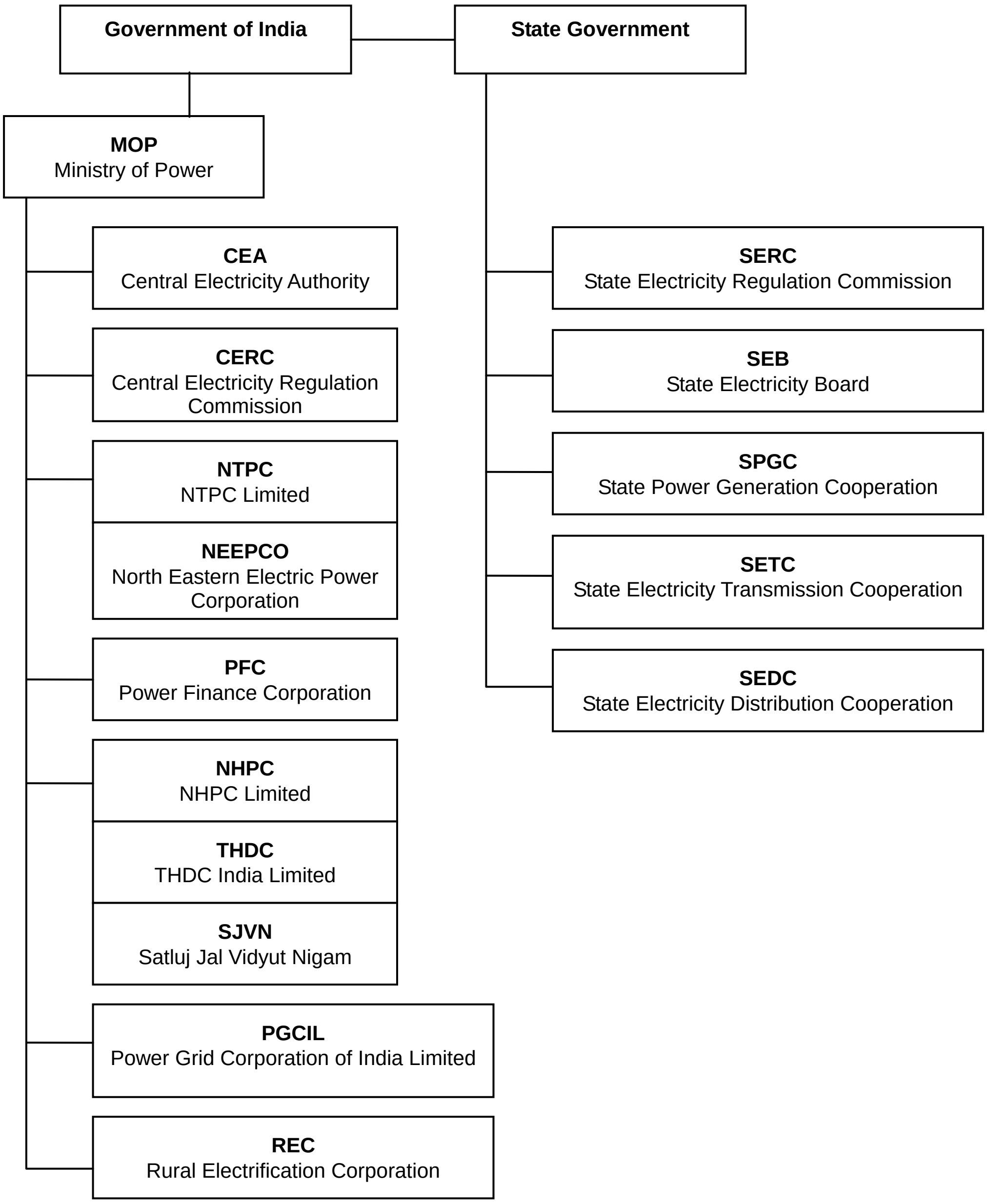


Fig. 2.1-1 Structure of Power Sector

2.1.3 Power Demand and Supply

(1) Power Demand

The annual growth rate and peak demand rate from 2001 to 2008 are 7 to 11% and over 11% respectively that indicates obvious chronic power shortage. The major reason of this situation is that the past electricity power development could not catch up with actual power demand.

(2) Power Consumption

Power consumption increased constantly. The annual growth trend was going up especially in the 1980's. The total average power consumption growth ratio from 2001 to 2004 is about 6.2% per annum which should be required further building up of power plants. Each sector's annual growth ratio of power consumption is 6.3% for domestic, 9.2% for commercial, 8.7% for industrial, 5.4% for traction, 2.7% for agriculture and 2.9% for others. It is found that growth ratios of domestic, commercial and industrial are higher than agriculture which have many working population compared to those sectors.

(3) Forecast of Power Demand

India power consumption ratio increased about 6% average per annum from 2001 to 2004. It is easy to expect that this ratio increases continuously year after year.

MOP assumed that 1,029~1,077×10^3 GWh amount of energy requirement and 206,000~215,000 MW of power supply capacity are required at the end of 11^{th} 5 years power development plan.

(4) Power Supply (Power Generation Capacity)

Power generation capacity was increased about 4.8% average per annum form 1996 to 2007.

The growth rate of this period by fuel basis is as follows.

- Hydro power plant capacity increased from 21,658 MW to 35,909 MW which added generation capacity 14,251 MW (about 65.8% up)
- Thermal power plant capacity increased from 61,010 MW to 90,907 MW which added generation capacity 29,897 MW (about 49% up)
- Nuclear power plant capacity increased from 2,225 MW to 4,120 MW which added generation capacity 1,895 MW (about 85.2% up)
- Renewable energy power (REP) plant capacity increased from 902 MW to 11,125 MW which added generation capacity 10,223 MW (about 1133.4% up)

According to the 11^{th} 5-year power development plan, additional 80,609.9 MW is required by the end of 2012. Therefore new power plant development is carried out continuously.

(5) Plant Load Factor (PLF)

The PLF was high rate after 2001 which maintained over 60%. The trend of PLF of thermal power in India has increased recently because the thermal power stations (coal fired) are operated as a base load power source. However, thermal power stations in India are relatively aged facilities therefore structure of power source has to be considered in order to avoid further power shortage than present.

2.1.4 Policy and Development Plan and MEGA Project

(1) Policy

Indian government established policy of power sector in 2005 February and they will achieve stable power supply to each house within 2012. The government prepared 5 years power development plan on the base of this target.

- Access to Electricity - Available for all households in next five years.
- Availability of Power - Demand to be fully met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve to be available.
- Supply of Reliable and Quality Power of specified standards in an efficient manner and at reasonable rates.
- Per capita availability of electricity to be increased to over 1000 units by 2012.
- Minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012.
- Financial Turnaround and Commercial Viability of Electricity Sector.
- Protection of consumers' interests.

(2) Power Development Plan

1) 10th Power Development Plan

At the beginning of the 10th five-year development plan (2002-2007), the shortages for the peak capacity and the energy were 12.6% and 7.5%, respectively. The original power plant strengthening plan was to add 41,110 MW in total.

The achievements of the generation capacity expansion during the 10th five-year plan were only 51% compared with the original plan. The concerned officers including CEA analyze the reasons as follows.

- The delay in thermal power plants is due to the delay in construction and supply of equipment.
- In terms of hydro power plants, the factors for the delay are (i) delay in construction, (ii) slow decision making during the planning phase, (iii) delay in land acquisition and forest clearance, (iv) natural calamity, and (v) geological condition.
- The delay in super critical thermal is due to the contract closing delay with the contractor.
- Gas-fired plants are delayed due to the delay and lack of supply of gas.
- The trouble with the private sector development is the delay in escrow account provision by state governments. The investors also show less interest in power projects.

2) 11th Power Development Plan

It has been identified that the capacity increase of 82,500 MW is necessary to meet the expected peak demand of 152,746 MW and the energy demand of 1,038 bil kWh at the end of the 11th plan in 2012.

To cope with the situation, the supply expansion plan of 80,609.9 MW has been reviewed recently. Among the power plant development, hydro accounts for approximately 19% of the total development with 15,507 MW, the thermal power is about 77%, which has been significantly increased from the 10th plan. The 11th power development plan will be reviewed at an appropriate timing.

From the actual result of 10th power development plan, MOP, CEA and CII (Confederation of Indian Industry) take necessary action in order to ensure timely implementation of projects during 11th Plan and beyond.

3) 12th Power Development Plan

The 12th plan aims to develop power plants during the five years from 2012 to 2017. There are several development scenarios in the plan. At the time of planning study, an estimate targets the increase of generation capacity of 82,200 MW in the 12th plan.

The 12th plan comprises of 30,000 MW of hydro, 11,000-13,000 MW of nuclear and 40,000 MW of thermal. The sum of hydro and nuclear is larger than thermal because of the stabilization of energy supply and the global warming.

(2) MEGA Project

The Ministry of Power, Government of India has launched an initiative for development of coal-based Ultra Mega Power Projects (UMPPs) in India. Each project has a capacity of 4,000 MW (800 MW × 5 units) or above. The development company undertakes necessary works like preparation of feasibility reports, detail design, power plant construction, operation/maintenance of plant and power selling (Build, Own and operate: BOO system). The capacity of power plant was decided by Indian government taking into consideration economical point of view. Indian government is expected to reduce CO_2 emission by ultra super critical technology which applied to UMPPs.

2.1.5 Tariff

(1) Tariff Policy

Tariff Policy has been notified by the Government of India on January, 2006 under the provisions of section 3 of the Electricity Act, 2003.

The objectives of the tariff policy are to:

a) Ensure availability of electricity to consumers at reasonable and competitive rates;

b) Ensure financial viability of the sector and attract investments;

c) Promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks;

d) Promote competition, efficiency in operations and improvement in quality of supply.

2.1.6 Assistance Policy and Present Situation of Project Formation Proposed by Other Donors

(1) World Bank

The World Bank has financed more than US$3,220 mil to the power sector in India after 2000.

(2) ADB

ADB has also supported the sector reform programs in the states of Gujarat, Madhya Pradesh, Kerala and Assam. On the investment side, ADB has been financing the programs such as transmission/distribution system, energy efficiency improvement, rural electrification and hydro power development. The amount of finances after 2000 is approximately US$4,820 mil.

(3) USAID

USAID supported the priority areas of power sector by the Greenhouse Pollution Prevention Project. USAID and CENPEEP (NTPC) together with carry out performance improvement for operating thermal power plants of NTPC. They will support SEB by their experience of the projects.

CHAPTER 3 PERFORMANCE IMPROVEMENT IN NTPC POWER PLANTS

3.1 NTPC Limited Power Plant

NTPC was founded in 1975, as a central sector generating company to plan, promote and develop thermal power in India. The Company has acquired a new identity, "NTPC Limited" in November, 2005. This new identity signifies that the Company has diversified its operations beyond thermal power segment and has added new business activities.

The NTPC has grown rapidly to become the largest thermal generating company in India. The commissioned capacity of NTPC owned coal fired power Plants, as of 2009 August is 24,395 MW at 15 locations and they also own gas fired power Plants of which total capacity is 5,435 MW at 8 locations. NTPC has total 814 MW capacity of Joint venture power Plants in the 3 deferent states. Their total capacity excluding JV power Plant is 20% of the total commissioned capacity in India as of 2008 March. The details of power Plant is as indicated below.

They will develop 50,000 MW capacity of new power Plants by 2012. The breakdown is, 40,000 MW coal fired, 8,000 MW gas fired and 2,000 MW hydro.

Table 3.1-1 List of NTPC Coal Fired Thermal Power Plants

Name of Power Plant	Location	Total Capacity (MW)	Capacity (MW) and Commissioned Day			Boiler Manufacturer	Turbine Manufacturer
			Unit	MW	Date		
Singrauli	Uttar Pradesh	2,000	I	200	Feb 1982	BHEL	BHEL(LMZ)
			II	200	Nov 1982	BHEL	BHEL(LMZ)
			III	200	Mar 1983	BHEL	BHEL(LMZ)
			IV	200	Nov 1983	BHEL	BHEL(LMZ)
			V	200	Feb 1984	BHEL	BHEL(LMZ)
			VI	500	Dec 1986	BHEL	BHEL
			VII	500	Nov 1987	BHEL	BHEL
Korba	Chattisgarh	2,100	I	200	Mar 1983	BHEL	BHEL
			II	200	Oct 1983	BHEL	BHEL
			III	200	Mar 1984	BHEL	BHEL
			IV	500	May 1987	BHEL	BHEL
			V	500	Mar 1988	BHEL	BHEL
			VI	500	Mar 1989	BHEL	BHEL
Ramagundam	Andhra Pradesh	2,600	I	200	Nov 1983	Ansaldo	Ansaldo
			II	200	May 1984	Ansaldo	Ansaldo
			III	200	Dec 1984	Ansaldo	Ansaldo
			IV	500	Jun 1988	BHEL	BHEL
			V	500	Mar 1989	BHEL	BHEL
			VI	500	Oct 1989	BHEL	BHEL
			VII	500	2005	BHEL	BHEL
Farakka	West Bengal	1,600	I	200	Jan 1986	BHEL	BHEL
			II	200	Dec 1986	BHEL	BHEL
			III	200	Aug 1987	BHEL	BHEL
			IV	500	Sep 1992	BHEL	BHEL
			V	500	Feb 1994	BHEL	BHEL

Name of Power Plant	Location	Total Capacity (MW)	Capacity (MW) and Commissioned Day			Boiler Manufacturer	Turbine Manufacturer
			Unit	MW	Date		
Vindhyachal	Madhya Pradesh	3,260	I	210	Oct 1987	USSR	USSR
			II	210	Jul 1988	USSR	USSR
			III	210	Feb 1989	USSR	USSR
			IV	210	Dec 1989	USSR	USSR
			V	210	Mar 1990	USSR	USSR
			VI	210	Feb 1991	USSR	USSR
			VII	500	Mar 1999	BHEL	BHEL
			VIII	500	Feb 2000	BHEL	BHEL
			IX	500	Jul 2006	BHEL	BHEL
			X	500	Mar 2007	BHEL	BHEL
Rihand	Uttar Pradesh	2,000	I	500	Mar 1988	BHEL	BHEL
			II	500	Jul 1989	BHEL	BHEL
			III	500	Jan 2005	BHEL	BHEL
			IV	500	Sep 2005	BHEL	BHEL
Kahalgaon	Bihar	2,340	I	210	Mar 1992	BHEL	BHEL
			II	210	Mar 1994	BHEL	BHEL
			III	210	Mar 1995	BHEL	BHEL
			IV	210	Mar 1996	BHEL	BHEL
			V	500	Mar 2007	BHEL	BHEL
			VI	500	Jul 2007	BHEL	BHEL
			VII	500	Sep 2007	BHEL	BHEL
Dadri	Uttar Pradesh	840	I	210	Oct 1991	BHEL	BHEL
			II	210	Dec 1992	BHEL	BHEL
			III	210	Mar 1993	BHEL	BHEL
			IV	210	Mar 1994	BHEL	BHEL
Talcher Kaniha	Orissa	3,000	I	500	Feb 1995	BHEL	BHEL
			II	500	Mar 1996	BHEL	BHEL
			III	500	Jan 2003	BHEL	BHEL
			IV	500	Oct 2003	BHEL	BHEL
			V	500	May 2004	BHEL	BHEL
			VI	500	Feb 2005	BHEL	BHEL
Unchahar	Uttar Pradesh	1,050	I	210	Nov 1988	BHEL	BHEL
			II	210	Mar 1989	BHEL	BHEL
			III	210	Jan 1999	BHEL	BHEL
			IV	210	Oct 1999	BHEL	BHEL
			V	210	Sep 2006	BHEL	BHEL
Talcher Thermal	Orissa	460	I	60		BHEL	BHEL
			II	60		BHEL	BHEL
			III	60		BHEL	BHEL
			IV	60		BHEL	BHEL
			I	110		BHEL	BHEL
			II	110		BHEL	BHEL
Simhadri	Andhra Pradesh	1,000	I	500	Feb 2002	BHEL	BHEL
			I	500	Aug 2003	BHEL	BHEL
Tanda	Uttar Pradesh	440	I	110		BHEL	BHEL
			II	110		BHEL	BHEL
			III	110		BHEL	BHEL
			IV	110		BHEL	BHEL
Badarpur	New Delhi	705	I	95	Jul 1973	BHEL	BHEL
			II	95	Aug 1974	BHEL	BHEL
			III	95	Mar 1975	BHEL	BHEL
			IV	210	Dec 1978	BHEL	BHEL(LZM)
			V	210	Dec 1981	BHEL	BHEL(LZM)

Name of Power Plant	Location	Total Capacity (MW)	Capacity (MW) and Commissioned Day			Boiler Manufacturer	Turbine Manufacturer
			Unit	MW	Date		
Sipat	Chattisgarh	1,000	I	660	UC*	Dusan	Power Machines
			II	660	UC*	Dusan	Power Machines
			III	660	UC*	Dusan	Power Machines
			IV	500	Nov 2008	BHEL	BHEL
			V	500	Aug 2009	BHEL	BHEL

*UC: Under Construction

Coal Based Joint Ventures

Durgapur	West Bengal	120
Rourkela	Orissa	120
Bhilai	Chhattisgarh	574

NTPC started to construct 200 MW sub-critical thermal power plants in 1982 and developed 500 MW class in1986. They are constructing 660 MW super-critical thermal power plants at present. Their adoption plan of high efficiency power plant is indicated below.

NTPC took over Badarpur power plant, Unchahar power plant, Talcher power plant and Tanda power plant operation and maintenance from SEB and applied necessary modification or replacement of equipment for each power plant in order to improve their Plant load factor (PLF). They achieved improvement of their PLF from 15-30% to 90%. This result shows us their excellent operating capability of power plant.

Table 3.1-2 Adoption Plan of High Efficiency Power Plant

	Sub-critical units		Super-critical units	
Efficiency(HHV base)	Rihand II: 38%	Simhadri II: 38.26%	Sipat-I: 39.14%	Barh: 39.96%
Unit Size (MW)	500	500	660	660
MS Pressure (kg/cm^2)	170	170	247	247
MS Steam Temp (°C)	537	537	537	566
RH Steam Temp (°C)	537	565	565	593
Commissioned year	2005	(Under Construction)	(Under Construction)	(Under Construction)

NTPC's thermal power plants are located near coal mines and coal is transferred from coal mines to power plants by train. Presently, imported coals (Indonesian coal) around 5-8% of total coal consumption are in use at some of their plants, mainly Simhadri, Ramagundam, Talcher Kaniha and Kahalgaon power plants.

3.2 Statues of Operation

(1) Plant Load Factor (PLF)

Each thermal power plant of NTPC is requested to operate more than rated output due to high power demand. Generally, almost all units are operated approximates 105% of rated output at peak power demand period, as a result PLF becomes over 100% in case of 24 hours period.

PLF of coal fired power plant from 2005 to 2008 is 85.9%, 83.7%, 82.4% and 87.2% respectively, which achieved high PLF value especially in Dadri and Rihand power plants. In addition six (6) power plants maintained over 90% of PLF for two years period. It is easy to understand by these PLF values that NTPC has good operation and maintenance capability.

However, some power stations are operating continuously despite of leakage from main steam pipe until next planned shutdown due to strong power demand. In such a case in Japan, power plant must be shutdown and take a repair work for safety and steady operation. This situation affects the high PLF values. Reserve margin of power supply is required for urgent development from the proper maintenance point of view.

(2) Procedure of Application and Notification for Availability Power Output

Generated power by the each power plant is delivered to designated state customers after confirmation of load dispatch center (LDC) in Power Grid Corporation. Procedure of application and notification for availability of power output is as follows.

- Each power plant is to make advance declaration of its capacity for generation in terms of MWh (divided into 96 time blocks of 15 minutes each) to load dispatch center by fax in every 10 a.m.
- Each power plant will confirmed notified MWh which is indicated in the Load Dispatch Center web site and informed relative department.
- Notified MWh is countied every 15 minutes.
- In case of any forced outage of a unit, or in case of any transmission bottleneck, power plant will inform expected next the 4th time block availability to LDC.
- Amount of shortage MWh will be beard by power plant.

3.3 Former Performance Improvement in NTPC

In 1994, NTPC established the Centre for Efficiency & Environmental Protection (CenPEEP), which aims at the efficiency improvement of coal-fired thermal power stations and the reduction of greenhouse gases through operability improvements, based on an agreement between the Government of India and USAID. CenPEEP plays a central role in the collection, implementation, and dissemination of advanced technology for the efficiency improvement of coal-fired thermal power stations. With two branch offices in the northern and eastern parts of India, CenPEEP has been also conducting similar activities for coal-fired thermal power stations in India, those are not NTPC's power stations.

Originally, USAID support was to be finished in 2002, however USAID agreed to extend their support by 2010 in line with NTPC's request.

CenPEEP works for the purpose of (a) Reduction of GHG emission from coal fired thermal power Plant by performance optimization in terms of efficiency, availability and reliability, (b) Technology acquisition for performance optimization, (c) Institutionalization of cooperation for technology transfer under the supporting from USAID.

CHAPTER 4 WORK IN INDIA

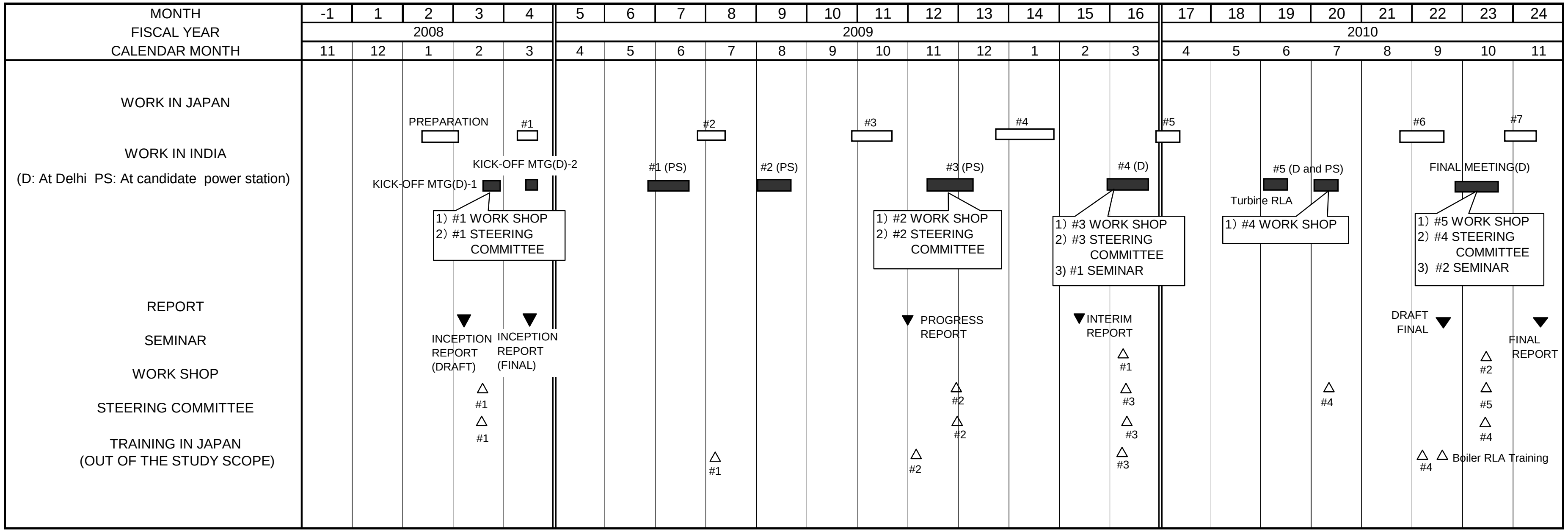
4.1 #1 Kick off Meeting

#1 Kick off meeting, consists of #1 work shop and #1 steering committee, was held from January 29, 2009 to February 5, 2009 in New Delhi and Noida.

4.2 #2 Kick off Meeting

#2 Kick off meeting was held from February 24, 2009 to February 26, 2009 in Noida. NTPC and Study Team discussed and finalized the content of inception report. Work schedule is as follows.

WORK SCHEDULE



Electric Power Development Co., Ltd.
Kyusyu Electric Power Co., Inc.
The Chugoku Electric Power Co., Inc.

4.3 #1 Field Work

Before #1 Field work, Study team prepared survey sheets in order to collect necessary information about candidate 5 units, and sent them to NTPC in advance, and NTPC sent them back after filled in. #1 Field work was carried out from May 18, 2009 to June 5, 2009, by visiting 5 units, two days per each unit, in order to select the candidate three units. At each power station, following activities were implemented.

(1) Presentation of Japanese activities (By Study team. Extraction from #1 Work shop slides)
(2) Presentation of Study (By Study team)
(3) Brief presentation of present problem of the unit (By NTPC)
(4) Confirmation of availability of necessary document (By Study team)
(5) Site investigation

After investigating 5 units, discussing with CenPPEP at Noida, the candidate units and the scope of study for each unit were decided. The locations of five units are shown in the attached map. In this course, although number of main target units was remained to be three, candidate units were spread over nine units finally depending on respective investigation theme by reflecting applicability of each investigation theme to nominated units. The detail is mentioned in Clause 5.

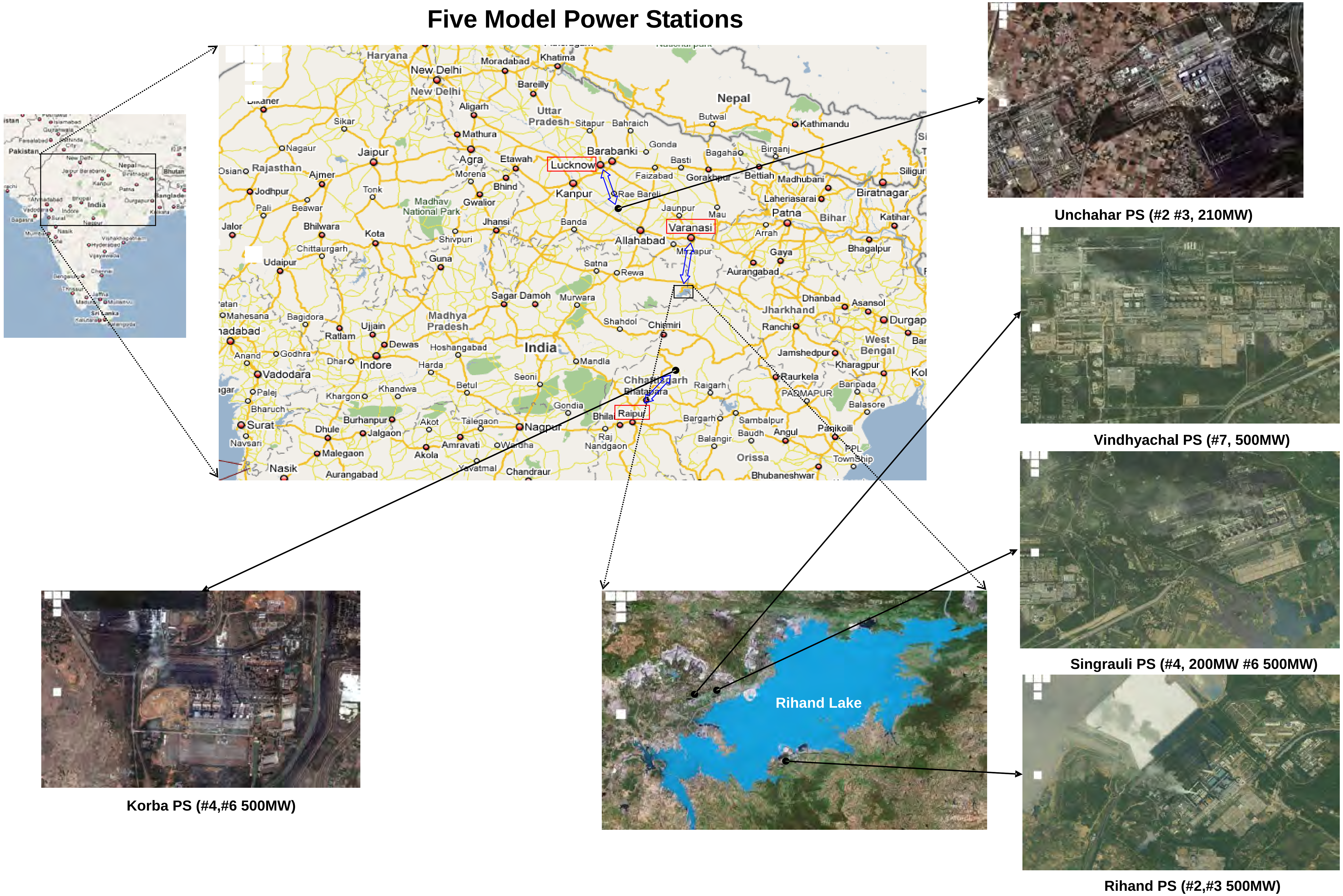


Fig. 4.3-1 Five Candidate Power Station

4.4 #2 Field Work

#2 Field work was carried out from July 21, 2009 to August 8, 2009. Study team visited 5 candidate units, and collected necessary drawings and documents for the study.

4.5 #3 Field Work

#3 Field work was carried out from October 6, 2009 to November 13, 2009. Study team carried out following actions for the candidate units based on the scope matrix and attended to #2 steering committee.

1) Performance test
2) Pump test
3) Boiler RLA
4) I&C assessment
5) Generator and transformer assessment (data collection)
6) Financial pre-investigation

4.6 #4 Field Work

#4 Field work was carried out from February 16, 2010 to March 4, 2010. Study team held #3 workshop and #1 seminar about various test and assessment, and attended #3 steering committee.

4.7 #5 Field Work

#5 Field work consisted of two parts. First part was turbine assessment of Korba #4, which contained turbine RLA, steam path audit and piping assessment, and carried out from May 18, 2010 to May 29, 2010. The second part was carried out from June 13, 2010 to June 19, 2010. Study team discussed with NTPC about structure and sample documents of Guideline & Manual and held #4 workshop.

4.8 #6 Field Work

#6 Field work was carried out from September 5, 2010 to September 18, 2010. Study team discussed with NTPC about draft Guideline & Manual and draft Final report, held #5 workshop and #2 seminar, and attended the last #4 steering committee.

CHAPTER 5 SELECTION OF CANDIDATE UNITS AND STUDY SCOPE

5.1 Selected Units and Study Scope

It was planned that NTPC will nominate five candidate units first, and after investigation NTPC and Study team will select three units out of five units. Before #1 Field work, Study team prepared survey sheets in order to collect necessary information about candidate 5 units, and sent them to NTPC in advance, and NTPC sent them back after filled in. During the #1 field work, Study team and NTPC visited all five units, taking various circumstances, such as shut down period, problem of the unit, OEM of turbine, renovation of Control and Instrument system, etc. into consideration, according to NTPC's intention, the candidate units and the scope of the study were finalized as shown in Table 5.1-1. Although number of main target units was remained to be three, candidate units were spread over nine units finally depending on respective investigation theme by reflecting applicability of each investigation theme to nominated units.

The brief circumstances of the selection reason are as follows.

1) Diagnosis of boiler problem
According to NTPC's request, in order to solve its own boiler problem mentioned later, it was decided to carry out this study for Vindhyachal #7.

2) Combustion simulation
This study was not included in the original scope of work, however, according to NTPC's strong demand, Study team agreed to do the simulation for Vindhyachal #7.

3) Boiler RLA
Taking the age of the unit and shut down schedule into consideration, three units were selected.

4) Turbine RLA
Taking shut down schedule and OEM into consideration, two units were selected. As for Rihand #2, only the potential service provider Alstom in UK was not in the position to carry out the assessment.

5) Condenser assessment
According to NTPC's request, Singrauli #6 was selected, because in this unit two vacuum pumps are in operation due to air ingress to vacuum section.

6) Pump assessment
According to NTPC's request, three units were selected.

7) Control system assessment
Since the unit for which future renovation was not planned was only Unchahar #3, this unit was selected.

8) BFPT parameter assessment

Three units where turbine driven BFPs are installed were selected.

9) Other scope

Taking relation to other study items into consideration, and also according to NTPC's request, Korba #6, Singrauli #4 (Singrauli #6 for Transformer assessment) and Rihand #2 were selected.

Table 5.1-1 Scope Matrix

July 6, 2009

No	Plant name	Korba #6	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3	Required Condition	In charge *0	Remarks
1	Location (State)	Chatisgar	UP	UP	MP	UP			
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210			
3	Turbine Make	KWU	#4 LMZ #6 KWU	GEC	KWU	KWU			
4	Boiler Make	BHEL	BHEL	ICL	BHEL	BHEL			
5	Overhaul Scope *1	B+IP+LP	B+HP+(IP)+LP #6: B+LP	B+IP+LP	B	B+HP+IP			
6	Age	1989	1983	1989	1999	1999			
7	Shut down period *2	1 Oct – 30 Oct	#4 : Feb 2010 (?) #6: 10 Sep – 4 Oct 2009	15Oct – 23Nov	18July – 16Aug	11 Oct – 14 Nov			
8	Diagnosis of boiler problem	–	–	–	○	–	At operation	JST(Miyagi,Morooka)	
9	Combustion simulation	–	–	–	○	–	–	JSC	
10	Boiler re-engineering	–	–	–	–	–	–	–	Alstom in USA and Indonesia are not in the position to carry out this work.
11*5	Boiler RLA	○	○	○	– *3	○	At shut down	JSC	three of four
12*5	AH performance improvement	○	○	○	○	○	–	JST(Miyagi,Morooka)	two of five
13*5	Turbine RLA	○	○	–*4	–	○	At shut down	Alstom	three of four
14	Turbine steam path audit	○	○	–	–	○	At shut down	Alstom	one of three
15	MS/HTR/LTR piping assessment	○	– (–)	○	–	○	At shut down	Alstom	one of four
16	Seal fin replacement	○	○	○	–	○	At shut down	JST	one of four Advice to site work Site work done by NTPC
17	Turbine blade honing	–	–	–	–	–	–	–	Honing is blasting. Procedure and specification to be provided by JICA ST.
18	Condenser assessment	– (no trouble)	○ (#6)	– (no trouble)	–	– (no trouble)	At operation	JSC	one of four
19	Pump assessment	○ BFP	○ CWP	○ BFP, CWP	–	–	At operation	JSC	two of four
20	Control system assessment	– (Future renovation at next overhaul after 2009 is approved) all system	– (renovation ABB 2006) except for BMS, Governor	– (renovation Yokogawa 2009) except for BMS, Governor	–	○	At operation	JSC	one of four
21*5	BFPT parameter assessment	○	– (no BFPT)	○ (#3)	○	– (no BFPT)	–	JST(Koizumi,Morooka)	three of four
22*5	Generator assessment		○	○	–	○	–	JST(Fujimori)	three of four
23*5	Transformer assessment				–		–	JST(Fujimori)	three of four
24*5	Analysis of present performance and performance decrease				–		–	JST(Miyagi, Koizumi, Morooka)	TOR5, three of four
25*5	Plant performance test				–		At operation	JST(Miyagi, Koizumi, Morooka, Fujimori, Okame)	TOR8, three of four
26*5	Review and improvement of past and present O & M procedure				–		–	JST(Miyagi, Koizumi, Fujimori, Okame, Hayakawa, Morooka)	TOR10, three of four
27	Financial analysis				–		–	JST(Yamaguchi)	TOR11, three of four
28*5	Improvement of plant performance and application				–		–	JST(Miyagi, Koizumi, Morooka, Fujimori, Okame)	TOR12, three of four
29	Preparation of CDM application				–		–	JST(Yotsumoto)	TOR13, three of four

*0: JST: JICA Study Team, JSC: Japanese Service Company, A: Alstom (Alstom Japan and NASL)
*1: B-Boiler, HP-HP turbine, IP-IP turbine, LP-LP turbine
*2: Shut down period: As per current plan; some changes may be required to be made after unit selection
*3: In spite of our reply as per e-mail dated 7th April, it was found through confirmation with a potential service company that we could not implement boiler RLA of Vindhyachal #7 due to the short period for contract and preparation work until unit shut down.
*4: Alstom UK, witch is an only remaining company who can carry out NO.13 for GEC turbine, is not in the position of carrying out this work.
*5: Inorder to carry out Financial analysis(NO.27) and CDM application(NO.29), all relating study should be carried out for the identical unit.

○: applied, –: not applicable
colored cell : selected (NO.8 to 29)
In order to carry out Financial analysis(NO.27) and CDM application(NO.29),

However, NTPC informed the change of shut down schedule on August 27, 2009, as follows.

Table 5.1-2 Shut-down Schedule and Scope of Boiler RLA and Turbine RLA

No.	Plant name	Planned			Modified		
		Shut down	B	T	Shut down	B	T
1	Korba #6	1 Oct – 30 Oct 2009	✓	✓	After Dec 2009		
2	Singrauli #6	10 Sep – 4 Oct 2009	✓		4 Oct – 28 Oct 2009	✓	
3	Rihand #2	15 Oct – 23 Nov 2009	✓		29 Oct – 7 Dec 2009	✓	✓
4	Unchahar #3	11 Oct – 14 Nov 2009		✓	1 Sep – 5 Oct 2009		
5	Unchahar #2 *	N.A.			11 Oct – 14 Nov 2009	✓	

*: Newly proposed by NTPC.

By this change, following modification of the scope was done.

1) Boiler RLA and Turbine RLA planned at Korba was stopped, since it was not possible to complete these study within FY 2009, which is JICA's requirement.
2) Turbine RLA planned at Unchahar #3 was stopped, since there was no preparation period.
3) Boiler RLA of Unchahar #2 was added, after study by Study team, since its shut down schedule was within the time frame of the study.
4) According to NTPC's request, Turbine RLA of Rihand #2 was planned to add, after discussion with service provider.

The scope matrix based on above shut-down schedule is shown in Table 5.1-3.

Further, on October 8, 2009, during #3 field work, NTPC informed to Study team that due to shut down of Rihand #4 by generator trouble, shut down schedule of both Singrauli #6 and Unchahar #2 will be postponed. Additionally on October 12, NTPC informed to JICA-ST that due to Rihand #4 trouble, Rihand #2 shut down date will be postponed to November 10. JICA-ST studied possible schedule of boiler RLA for three units, and decided that boiler RLA will carry out only for Singrauli #6 and Unchahar #2, and will give up that for Rihand #2 because of shortage of sample test period in Japan. As a fact, Singrauli #6 and Unchahar #2 shut down on October 18, JICA-ST managed to carry out boiler RLA for both units.

Though the postponement of Rihand #2 shut down date to November 10 did not affect turbine RLA schedule, on November 5, just 5 days before scheduled starting date of Rihand #2 shut down, NTPC informed to JICA-ST that due to Rihand #4 trouble and trouble of one unit of Singrauli, they cannot shut down Rihand #2 and the overhaul will be planed in April to May of 2010. Receiving this notice, JICA-ST was forced to give up turbine RLA of Rihand #2, since JICA-ST cannot meet JICA's requirement, which the RLA study has to be completed within 2009 fiscal year.

The Scope matrix at this time is shown in Table 5.1-4.

At #3 steering committee, NTPC requested Study team to carry out turbine RLA and additional combustion simulation in 2010 fiscal year. Further, NTPC requested JICA to carry out Boiler RLA training in Japan, according to Study team recommendation at #3 steering committee. In response to these requests from NTPC, JICA accepted NTPC's request, and Study team carried out following additional items in 2010 fiscal year.

1) Boiler RLA training
2) Turbine RLA, steam path audit and main piping assessment of Korba #6
3) Additional combustion simulation and training

As for Turbine RLA, steam path audit and main piping assessment of Korba #6, its shut down was scheduled on June 1, 2010, and test was scheduled to start on June 6. However, since Korba #4 unexpectedly shut down on May 8, 2010, because of HP turbine high vibration, #6 had to continue to operate, overhaul was postponed, and instead #4 overhaul was started. NTPC requested Study team to switch the target unit from #6 to #4. Study team and service provider managed their schedule, they started tests from May 18 even under critical lead time for preparation and they finally completed all the tests within #4 overhaul period.

The final Scope matrix is shown in Table 5.1-5.

Table 5.1-3 Scope Matrix

September 17, 2009

No	Plant name	Korba #6	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)	Required Condition	In charge *0	Remarks
1	Location (State)	Chatisgar	UP	UP	MP	UP			
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210			
3	Turbine Make	KWU	#4 LMZ #6 KWU	#2 GEC	KWU	KWU			
4	Boiler Make	BHEL	BHEL	#2 ICL	BHEL	BHEL			
5	Overhaul Scope *1	B+IP+LP	#4: B+HP+(IP)+LP #6: B+LP	#2 B+IP+LP	B	#3 B+HP+IP #2 B+LP			
6	Age	1989	#4 1983, #6 1986	#2 1989	1999	#3 1999, #2 1989			
7	Shut down period *2	Dec. 2009 – June 2010 (??)	#4 : Feb 2010 (?) #6: 4 Oct – 28 Oct 2009	#2 29Oct – 7 Dec	18July – 16Aug	#3 1 Sep – 5 Oct #2 11 Oct – 14 Nov			
8	Diagnosis of boiler problem	–	–	–	○	–	At operation	JST(Miyagi,Morooka)	
9	Combustion simulation	–	–	–	○	–	–	JSC	
10	Boiler re-engineering	–	–	–	–	–	–	–	Alstom in USA and Indonesia are not in the position to carry out this work.
11*5	Boiler RLA	⊖	○(#6)	○(#2)	– *3	○ (#2)	At shut down	JSC	three of four
12*5	AH performance improvement	○	○(#4)	○	○	○	–	JST(Miyagi,Morooka)	two of five
13*5	Turbine RLA	⊖	⊖	○(#2)	–	⊖	At shut down	Alstom	three of four
14	Turbine steam path audit	⊖	○	○(#2)	–	○	At shut down	Alstom	one of three
15	MS/HTR/LTR piping assessment	⊖	– (–)	○(#2)	–	○	At shut down	Alstom	one of four
16	Seal fin replacement	○	○ (#4)	○	–	○	At shut down	JST	one of four Advice to site work Site work done by NTPC
17	Turbine blade honing	–	–	–	–	–	–	–	Honing is blasting. Procedure and specification to be provided by JICA ST.
18	Condenser assessment	– (no trouble)	○ (#6)	– (no trouble)	–	– (no trouble)	At operation	JSC	one of four
19	Pump assessment	○ TBFP	○ CWP (Stage I)	○ MBFP(2A), CWP(2A)	–	–	At operation	JSC	two of four
20	Control system assessment	– (Future renovation at next overhaul after 2009 is approved) all system	– (renovation ABB 2006) except for BMS, Governor	– (renovation Yokogawa 2009) except for BMS, Governor	–	○(#3)	At operation	JSC	one of four
21*5	BFPT parameter assessment	○	– (no BFPT)	○ (#3)	○	– (no BFPT)	–	JST(Koizumi)	three of four
22*5	Generator assessment		○(#4)	○(#2)	–	○	–	JST(Fujimori)	three of four
23*5	Transformer assessment		○(#6)		–		–	JST(Fujimori)	three of four
24*5	Analysis of present performance and performance decrease		○(#4)		–		–	JST(Miyagi, Koizumi, Morooka)	TOR5, three of four
25*5	Plant performance test				–		At operation	JST(Miyagi, Koizumi, Morooka)	TOR8, three of four
26*5	Review and improvement of past and present O & M procedure				–		–	JST(Miyagi, Koizumi, Fujimori, Nakanishi, Hayakawa, Morooka)	TOR10, three of four
27	Financial analysis				–		–	JST(Yoshida)	TOR11, three of four
28*5	Improvement of plant performance and application				–		–	JST(Miyagi, Koizumi, Morooka)	TOR12, three of four
29	Preparation of CDM application				–		–	JST(Yotsumoto)	TOR13, three of four

*0: JST : JICA Study Team, JSC : Japanese Service Company, A : Alstom (Alstom Japan and NASL)
*1: B-Boiler, HP-HP turbine, IP-IP turbine, LP-LP turbine
*2: Shut down period: As per current plan; some changes may be required to be made after unit selection
*3: In spite of our reply as per e-mail dated 7th April, it was found through confirmation with a potential service company that we could not implement boiler RLA of Vindhyachal #7 due to the short period for contract and preparation work until unit
~~*4: Alstom UK, witch is an only remaining company who can carry out NO.13 for GEC turbine, is not in the position of carrying out this work.~~
*5: Inorder to carry out Financial analysis(NO.27) and CDM application(NO.29), all relating study should be carried out for the identical unit.

○: applied, –: not applicable
yellow cell : selected (NO.8 to 29)
gray cell : stopped the action
In order to carry out Financial analysis(NO.27) and CDM application(NO.29),

Table 5.1-4 Scope Matrix

No	Plant name	Korba #6	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)	Required Condition	In charge *0	Remarks
1	Location (State)	Chatisgar	UP	UP	MP	UP			
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210			
3	Turbine Make	KWU	#4 LMZ #6 KWU	#2 GEC	KWU	KWU			
4	Boiler Make	BHEL	BHEL	#2 ICL	BHEL	BHEL			
5	Overhaul Scope *1	B+IP+LP	#4: B+HP+(IP)+LP #6: B+LP	#2 B+IP+LP	B	#3 B+HP+IP #2 B+LP			
6	Age	1989	#4 1983, #6 1986	#2 1989	1999	#3 1999, #2 1989			
7	Shut down period *2	Dec. 2009 – June 2010 (??)	#4 : Feb 2010 (?) #6: 18 Oct – 11 Nov 2009	#2 April – May 2010	18July – 16Aug	#3 1 Sep – 5 Oct #2 18 Oct – 11 Nov 2009			
8	Diagnosis of boiler problem	–	–	–	○	–	At operation	JST(Miyagi,Morooka)	
9	Combustion simulation	–	–	–	○	–	–	JSC	
10	Boiler re-engineering	–	–	–	–	–	–	–	Alstom in USA and Indonesia are not in the position to carry out this work.
11*5	Boiler RLA	~~○~~	○(#6)	~~○(#2)~~	– *3	○ (#2)	At shut down	JSC	three of four
12*5	AH performance improvement	○	○(#4)	○	○	○	–	JST(Miyagi,Morooka)	two of five
13*5	Turbine RLA	~~○~~	~~○~~	~~○(#2)~~	–	~~○~~	At shut down	Alstom	three of four
14	Turbine steam path audit	~~○~~	○	~~○(#2)~~	–	○	At shut down	Alstom	one of three
15	MS/HTR/LTR piping assessment	~~○~~	– (–)	~~○(#2)~~	–	○	At shut down	Alstom	one of four
16	Seal fin replacement	○	○ (#4)	○	–	○	At shut down	JST	one of four Advice to site work Site work done by NTPC
17	Turbine blade honing	–	–	–	–	–	–	–	Honing is blasting. Procedure and specification to be provided by JICA ST.
18	Condenser assessment	– (no trouble)	○ (#6)	– (no trouble)	–	– (no trouble)	At operation	JSC	one of four
19	Pump assessment	○ TDBFP(6B)	○ CWP (Stage I)	○ MDBFP(2B), CWP(2B)	–	–	At operation	JSC	two of four
20	Control system assessment	– (Future renovation at next overhaul after 2009 is approved) all system	– (renovation ABB 2006) except for BMS, Governor	– (renovation Yokogawa 2009) except for BMS, Governor	–	○(#3)	At operation	JSC	one of four
21*5	BFPT parameter assessment	○ (rows 21–29)	– (no BFPT)	○ (#3)	○	– (no BFPT)	–	JST(Koizumi)	three of four
22*5	Generator assessment		○(#4)	○(#2) (rows 22–29)	–	○ (rows 22–29)	–	JST(Fujimori)	three of four
23*5	Transformer assessment		○(#6)		–		–	JST(Fujimori)	three of four
24*5	Analysis of present performance and performance decrease		○(#4) (rows 24–29)		–		–	JST(Miyagi, Koizumi, Morooka)	TOR5, three of four
25*5	Plant performance test				–		At operation	JST(Miyagi, Koizumi, Morooka)	TOR8, three of four
26*5	Review and improvement of past and present O & M procedure				–		–	JST(Miyagi, Koizumi, Fujimori, Nakanishi, Hayakawa, Morooka)	TOR10, three of four
27	Financial analysis				–		–	JST(Yoshida)	TOR11, three of four
28*5	Improvement of plant performance and application				–		–	JST(Miyagi, Koizumi, Morooka)	TOR12, three of four
29	Preparation of CDM application				–		–	JST(Yotsumoto)	TOR13, three of four

○:applied, –:not applicable yellow cell : selected (NO.8 to 29 gray cell : stopped the action

In order to carry out Financial analysis(NO.27) and CDM application(NO.29),

*0: JST : JICA Study Team, JSC : Japanese Service Company, A : Alstom (Alstom Japan and NASL)

*1: B-Boiler, HP-HP turbine, IP-IP turbine, LP-LP turbine

*2: Shut down period: As per current plan; some changes may be required to be made after unit selection

*3: In spite of our reply as per e-mail dated 7th April, it was found through confirmation with a potential service company that we could not implement boiler RLA of Vindhyachal #7 due to the short period for contract and preparation work until unit shut down.

~~*4: Alstom UK, witch is an only remaining company who can carry out NO.13 for GEC turbine, is not in the position of carrying out this work.~~

*5: Inorder to carry out Financial analysis(NO.27) and CDM application(NO.29), all relating study should be carried out for the identical unit.

Table 5.1-5 Scope Matrix

No	Plant name	Korba #6(#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)	Required Condition	In charge *0	Remarks
1	Location (State)	Chatisgar	UP	UP	MP	UP			
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210			
3	Turbine Make	KWU	#4 LMZ #6 KWU	#2 GEC	KWU	KWU			
4	Boiler Make	BHEL	BHEL	#2 ICL	BHEL	BHEL			
5	Overhaul Scope *1	B+IP+LP	#4: B+HP+(IP)+LP #6: B+LP	#2 B+IP+LP	B	#3 B+HP+IP #2 B+LP			
6	Age	#4:1987, #6:1989	#4 1983, #6 1986	#2 1989	1999	#3 1999, #2 1989			
7	Shut down period *2	#4: 8 May – 16 June 2010	#4 : Feb 2010 (?) #6: 18 Oct – 11 Nov 2009	#2: April – May 2010	18July – 16Aug	#3: 1 Sep – 5 Oct #2: 18 Oct – 11 Nov 2009			
8	Diagnosis of boiler problem	–	–	–	○	–	At operation	JST(Miyagi,Morooka)	
9	Combustion simulation	–	–	–	○	–	–	JSC	
10	Boiler re-engineering	–	–	–	–	–	–	–	Alstom in USA and Indonesia are not in the position to carry out this work.
11*5	Boiler RLA	~~○~~	○(#6)	~~○(#2)~~	– *3	○ (#2)	At shut down	JSC	three of four
12*5	AH performance improvement	○	○(#4)	~~○~~	~~○~~	~~○~~	–	JST(Miyagi,Morooka)	two of five
13*5	Turbine RLA	○(#4)	~~○~~	~~○(#2)~~	–	~~○~~	At shut down	Alstom	three of four
14	Turbine steam path audit	○(#4)	~~○~~	~~○(#2)~~	–	○	At shut down	Alstom	one of three
15	MS/HTR/LTR piping assessment	○(#4)	– (–)	~~○(#2)~~	–	○	At shut down	Alstom	one of four
16	Seal fin replacement	~~○~~	~~○~~ (#4)	~~○~~	–	~~○~~	At shut down	JST	Procedure to be provided by JICA ST.
17	Turbine blade honing	–	–	–	–	–	–	–	Honing is blasting. Procedure and specification to be provided by JICA ST.
18	Condenser assessment	– (no trouble)	○ (#6)	– (no trouble)	–	– (no trouble)	At operation	JSC	one of four
19	Pump assessment	○ TDBFP(6B)	○ CWP (Stage I)	○ MDBFP(2B), CWP(2B)	–	–	At operation	JSC	two of four
20	Control system assessment	– (Future renovation at next overhaul after 2009 is approved) all system	– (renovation ABB 2006) except for BMS, Governor	– (renovation Yokogawa 2009) except for BMS, Governor	–	○(#3)	At operation	JSC	one of four
21*5	BFPT parameter assessment		– (no BFPT)	○ (#3)	○	– (no BFPT)	–	JST(Koizumi)	three of four
22*5	Generator assessment		○(#4)		–		–	JST(Fujimori)	three of four
23*5	Transformer assessment		○(#6)		–		–	JST(Fujimori)	three of four
24*5	Analysis of present performance and performance decrease				–		–	JST(Miyagi, Koizumi, Morooka)	TOR5, three of four
25*5	Plant performance test	○(#6)			–		At operation	JST(Miyagi, Koizumi, Morooka)	TOR8, three of four
26*5	Review and improvement of past and present O & M procedure		○(#4)	○(#2)	–	~~○~~	–	JST(Miyagi, Koizumi, Fujimori, Nakanishi, Hayakawa, Morooka)	TOR10, three of four
27	Financial analysis				–		–	JST(Yoshida)	TOR11, three of four
28*5	Improvement of plant performance and application				–		–	JST(Miyagi, Koizumi, Morooka)	TOR12, three of four
29	Preparation of CDM application				–		–	JST(Yotsumoto)	TOR13, three of four

○:applied, –:not applicable

In order to carry out Financial analysis(NO.27) and CDM application(NO.29),

*0: JST : JICA Study Team, JSC : Japanese Service Company, A : Alstom (Alstom Japan and NASL)

*1: B-Boiler, HP-HP turbine, IP-IP turbine, LP-LP turbine

*2: Shut down period: As per current plan; some changes may be required to be made after unit selection

*3: In spite of our reply as per e-mail dated 7th April, it was found through confirmation with a potential service company that we could not implement boiler RLA of Vindhyachal #7 due to the short period for contract and preparation work until unit shut down.

~~*4: Alstom UK, witch is an only remaining company who can carry out NO.13 for GEC turbine, is not in the position of carrying out this work.~~

*5: Inorder to carry out Financial analysis(NO.27) and CDM application(NO.29), all relating study should be carried out for the identical unit.

CHAPTER 6 STUDY RESULT AND RECOMMENDATION

6.1 Diagnosis of Boiler Problem

Vindhyachal Unit 7 Boiler has the problem of lower Main Steam (MS)/High Reheter Steam (HRH) temperature than design value and Left/Right side unbalance in MS/HRH temperature since commissioning. The modification history of Boiler up to now is as follows;

Step I:

Original boiler supplier carried out thermal performance test, computational fluid dynamics from December 2000 to January 2001, modeling analysis was done at last and following modifications were done by them to solve the problems, in March 2002.

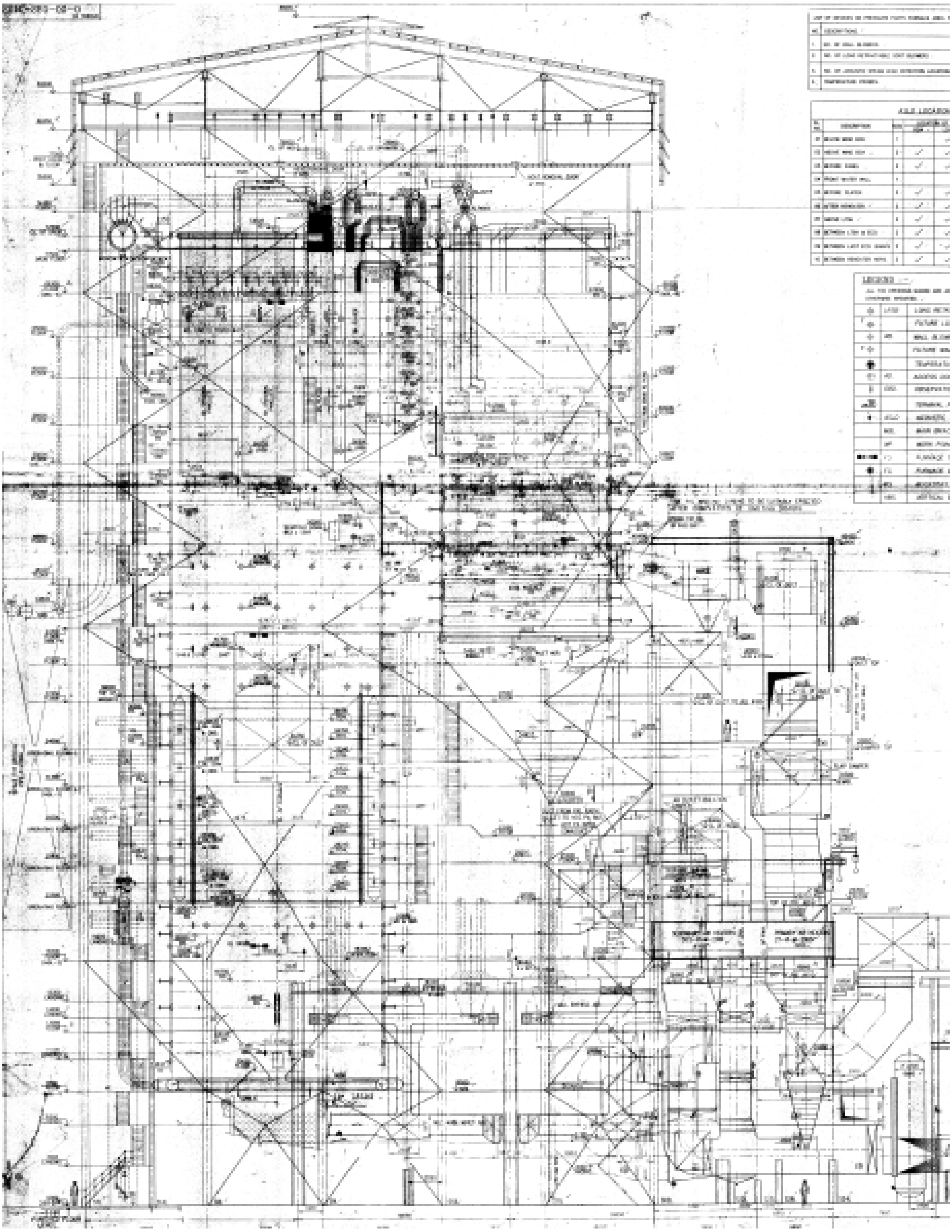
- Addition of wall superheater on the front wall (area: 922 m^2, consisting of 216 tubes)
- Removal of outer tube in each of the 74 reheater (area: 722 m^2)

Step II:

Additional modification was carried out by original boiler supplier in May 2005.

- To reduce the high metal temp of front reheater, out of 74 nos, 44 nos. of off-set bend piping (54 mm) in pent house was replaced by 44.5.mm piping to avoid the Reheater tube overheating.
- 75% size orifices were installed at reheater outlet header (LHS) to reduce the Left/right steam temp imbalance.

(1) Boiler Overview



(2) Furnace Comparison with Same/Capacity type of Boiler in Japan

The following table shows the furnace structure comparison table between Vindhayachal #7 and same capacity boiler in Japan. It is not easy to compare both boilers due to different coal characteristic, such as calorific value, ash contents and so on. However big different item is number of superheter panels (Division panels) such as 6 panels with 2.6m interval on same type of boiler in Japan and 48 panels with 0.4m interval on Vindhayachal #7 boiler. The design purpose of this area is to absorb radiant heat by Division SH and to maintain appropriate flue gas velocity and/or flow for convection heat transfer to Platen SH and reheter. Short interval of those panels is expected to disturb absorption of radiant heat and appropriate flue gas flow.

(3) Recommendation

Considering the current status of the boiler problems, Study team proposes the following improvement plans:

Increase in the superheater heat transfer area

The main steam temperature and reheat steam temperature are lower than the design values. This is presumably due to lots of furnace absorption although wall SH was added at the step I modification. In order to reduce furnace heat absorption and to increase heat absorption in superheter section, Study team recommend to add wall SH left and right sides of furnace. This modification is required to review and re-design of total heat balance of boiler by the original boiler supplier.

Cross connection of the left and right side of superheater header connecting pipes

The same type of boiler in Japan, the connecting pipes are cross-connected between Platen SH outlet header and Pendant SH inlet header as shown in Fig. 6.1-1 below, so as to achieve temperature balance between left and right side main steam temperature considering drift of flue gas flow. In Vindhyachal #7, however, the connecting pipes between Division SH outlet header and Platen SH inlet header are not cross-connected, that possibly results in expected to cause the steam temperature imbalance between the left and right side. Study team recommends that the connecting pipes between Division SH and Platen SH should be modify to cross-connecting the left and right side in order to achieve balance between the left and right steam temperatures. This modification is required to review and to re-design of total heat balance of boiler by the original boiler supplier

Considering the experience that some boiler case in Japan allies, the connecting pipes between the front RH outlet header and rear RH inlet header, this is also one of the countermeasures to balance left and right side of reheate steam temperature.

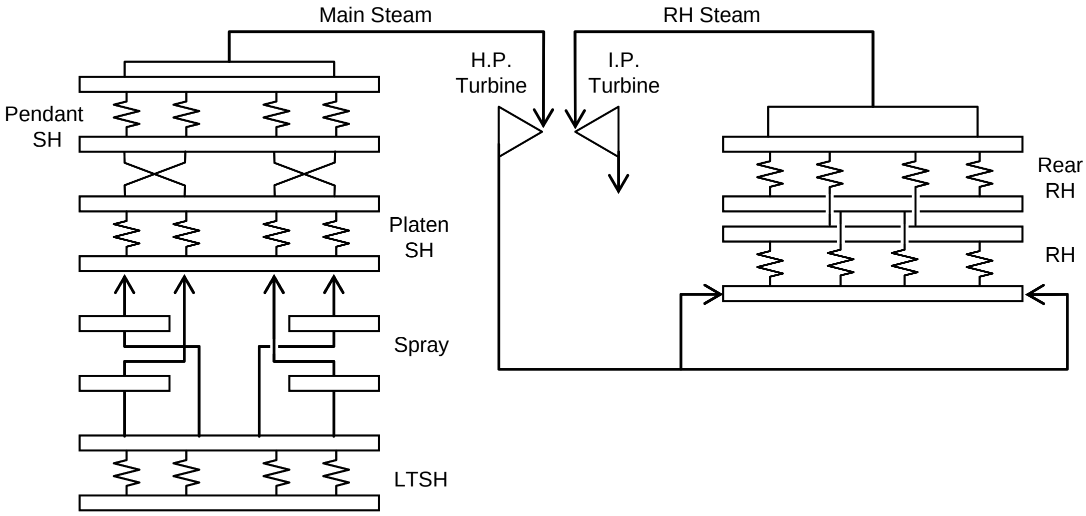


Fig. 6.1-1 Outline of Steam Flow Diagram (Same type of Boiler in Japan)

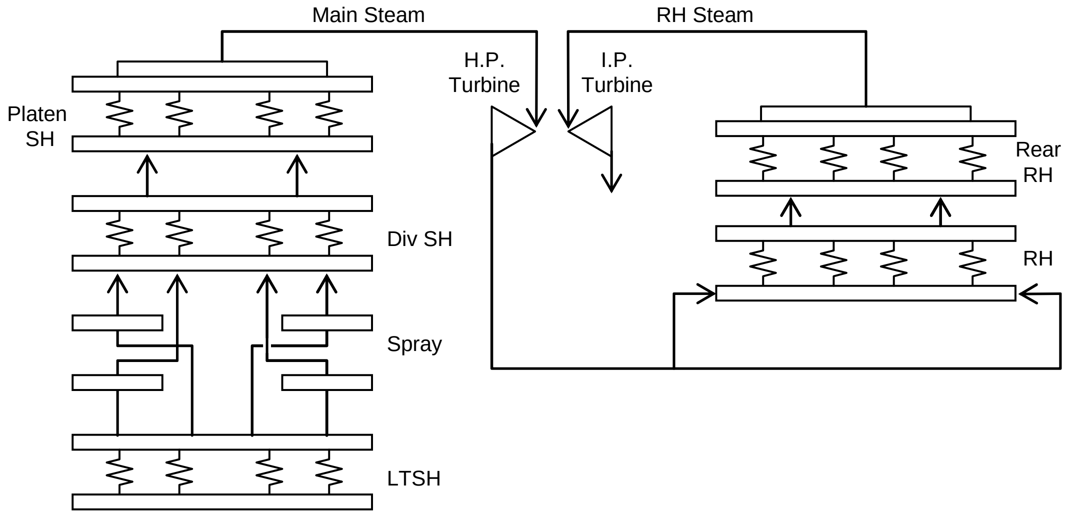


Fig. 6.1-2 Out line of Steam Flow Diagram (Vindhyachal Unit 7)

6.2 Combustion Simulation

6.2.1 Introduction

The combustion simulation can predict gas velocity, particle trajectories, temperature distribution, oxygen concentration and unburned carbon in consideration of shape of the boiler and an actual operating condition. Moreover, the operating condition can be also drastically changed in simulation. The diagnosis of the boiler by the combustion simulation evaluates the effectiveness of the operation or the design change from the calculation result, and the knowledge obtained from these simulations would minimize the risk of the actual test for improving the boiler performance.

In this project, the operation study on NTPC Vindhyachal Unit 7 & 8 Boiler was done by using a pulverized coal combustion simulator. As a result, several methods for improving the main & RH steam temperature and those right & left steam temperature differences were suggested.

6.2.2 Results

(1) General Matters of the Tangentially Fired Boiler

The big ±tilt angles disturb largely the flow pattern. The tilt angle is usually fixed by around -5 degrees. It is hoped that the tilt angle is kept around -5 degree as much as possible.

(2) Improvement within the Current Operation

It was found that the Bottom pattern and the Tilt=-10 degree was a better condition. Then, it is hoped that the actual test will be carried out under better conditions. However, there would not be the certainty that this condition keeps always the best condition because the other conditions of the load etc are always changing

(3) Improvement with a little modification

The cross combination of the SH heaters can considerably reduce the Right & Left deflection. If the improvement is only right and left deflection of the super heater, this method is very effective. However, to increase the main steam temperature and the re-heat steam temperature, it is necessary to employ another method.

(4) Improvement of the Heat Absorption Pattern by the Gas Volume Control such as the Oxygen Concentration and the Gas Recirculation

It was confirmed that the simultaneous reduction of the furnace (boiler) heat absorption amount and the nose temperature was led by the increment of the gas volume. In addition, it was also found that the GR has larger effect than that of the adjustment of the oxygen concentration in flue gas. It was found that the heat absorption percent of the re-heater was also improved largely by these operations. Thus, these methods have the possibility that the heat absorption pattern of the boiler can be improved. However, the prediction of the convection sections is not so accurate in this simulation. In addition, the first convection super heater is out of the analytical domain. Therefore, this evaluation is not perfect though this method has the possibility.

It is hoped that the effect of this method is confirmed by the actual test with increasing the oxygen concentration. This operation would be possible in the current boiler. When a good tendency in this test is obtained, the effectiveness of GR will be more certain.

(5) Improvement of the R&L Deflection by Using OFA and/or Additional Air (AA)

This simulation expected the improvement of right and left deflection by an excellent gas mixing. However, the improvement of the right & left deflection by changing AA and OFA was judged to be difficult in the range of the simulation cases at this time.

(6) Improvement of the Steam Temperature and its Deflection by Changing the Division Panel

The good effect as follows was able to be found in heater1 configuration as shown in Fig. 6.2-1.

- Right and Left deflection of Super heater is greatly improved.
- Further decrement of the deflection was found by using the cross heater combination

The temperature gradient in re-heater zone becomes small.

However, the heat absorption amount of the super heater was not increased. Therefore, the following modifications are also necessary to satisfy all improvements.

- Adjustment of the super heater surface area
- To add the Wall Super Heater to part of boiler side wall.

Adjustment of the oxygen concentration in flue gas or the gas re-circulation (GR)

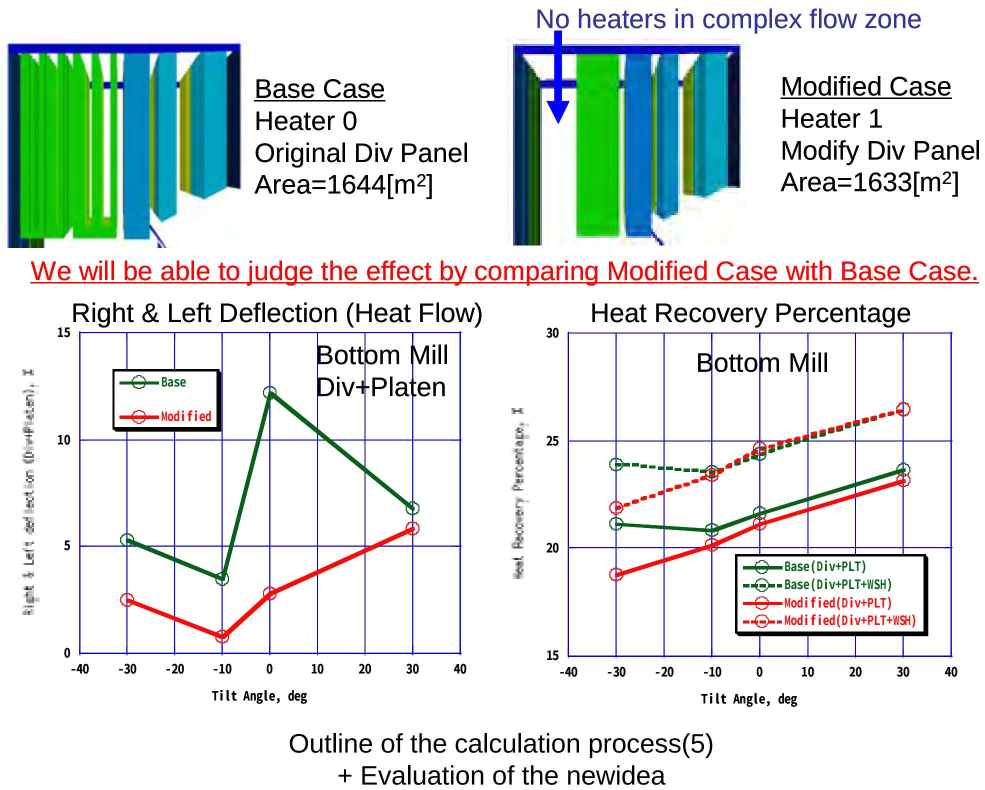


Fig. 6.2-1 Outline of the Calculation Process (5) + Evaluation of the New Idea

Several methods for improving the main & RH steam temperature and those right & left steam temperature differences were suggested. It is hoped that the final engineering judgment will be done about the possibility of how to realize the obtained good ideas.

6.2.3 Additional Case study for the Effect of the Air and Fuel Bias

(1) Results of the 2nd Air and/or Fuel Bias condition (Results of the additional cases)

Fig. 6.2-2 shows the effect of the right & left 2nd air bias on the gas flow and the temperature distribution. At the burner level, the swirl center shifts according to the air bias fraction. However, this influence did not appear to the right & left deflection in the SH zone well. The reason is that the combustion gas rises into the SH zone with the swirl. Fig. 6.2-3 shows the effect of the 2nd Air Bias to the 1,000°C isothermal surface in the SH zone. The temperature distribution is almost same when the condition is tilt=-10 and the bottom mill pattern, because this condition form a good swirl. On the other hand, the temperature distribution greatly changes right & left when the condition is tile=+30 and the Top mill pattern. In this condition, the weak swirl is formed. As a result, it was found that the effect of the 2nd bias to the right & left steam temperature difference was greatly different depending on the other conditions (Mill pattern and/or Tilt angle).

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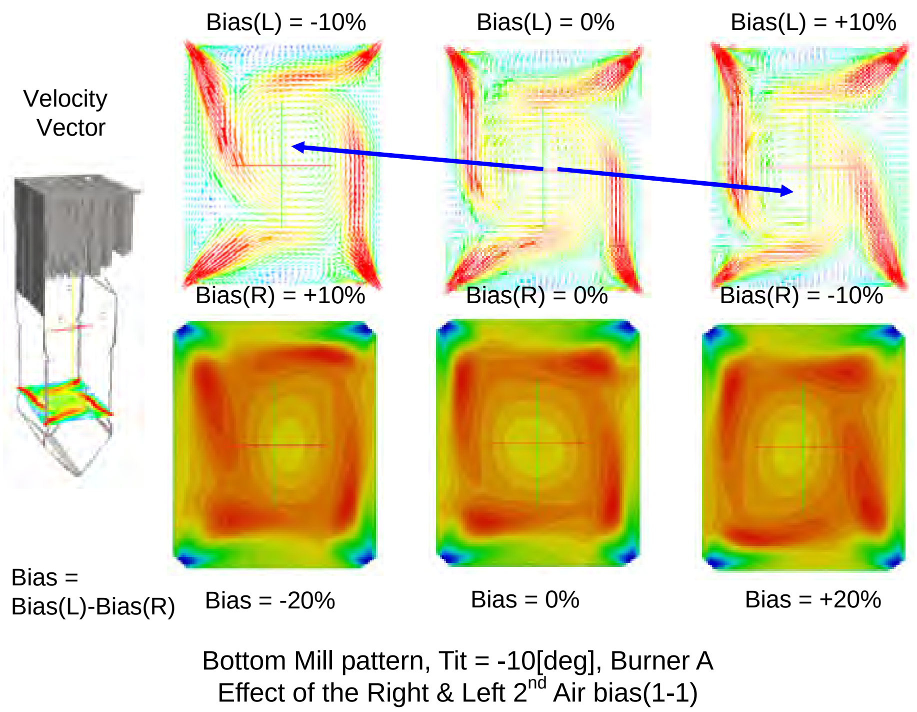


Fig. 6.2-2 Effect of the Right & Left 2nd Air Bias (1-1)

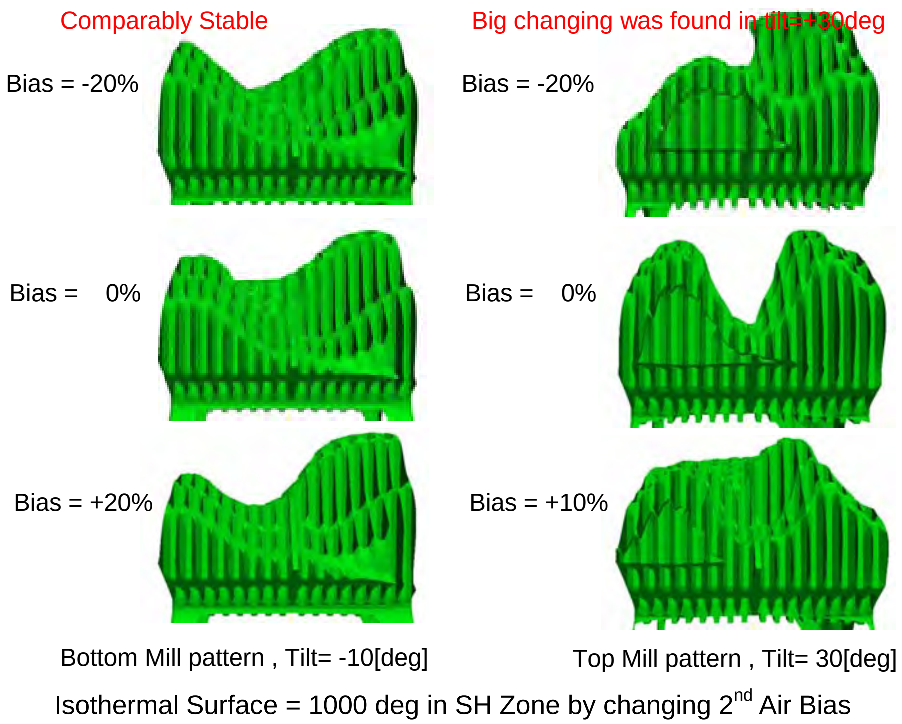


Fig. 6.2-3 Isothermal Surface = 1000 deg in SH Zine by Changing 2nd Air BiasResults of the 2nd Air and/or Fuel Bias

1) The effect of the 2nd Air bias to the Right & Left steam temperature deflection

The effect of the 2nd air bias to the right & left steam temperature deflection were summarized. It is an ideal that the right & left steam temperature deflection is decreased slowly by increasing the

2nd air bias. However, it is clearly found that the right & left deflection profiles are greatly different by the tilt angle and the mill pattern. Thus, it would be difficult to always keep the small right & left deflection by this bias operation.

Fig. 6.2-4 shows the super heater cross combination patterns, which are very effective to the reduction of the right & left deflection. As a result, it was found that the cross combinations have a big effect to reduce the right & left deflection in all conditions including 2nd air bias. Especially, it was found that the cross 2 and the cross 3 are very effective.

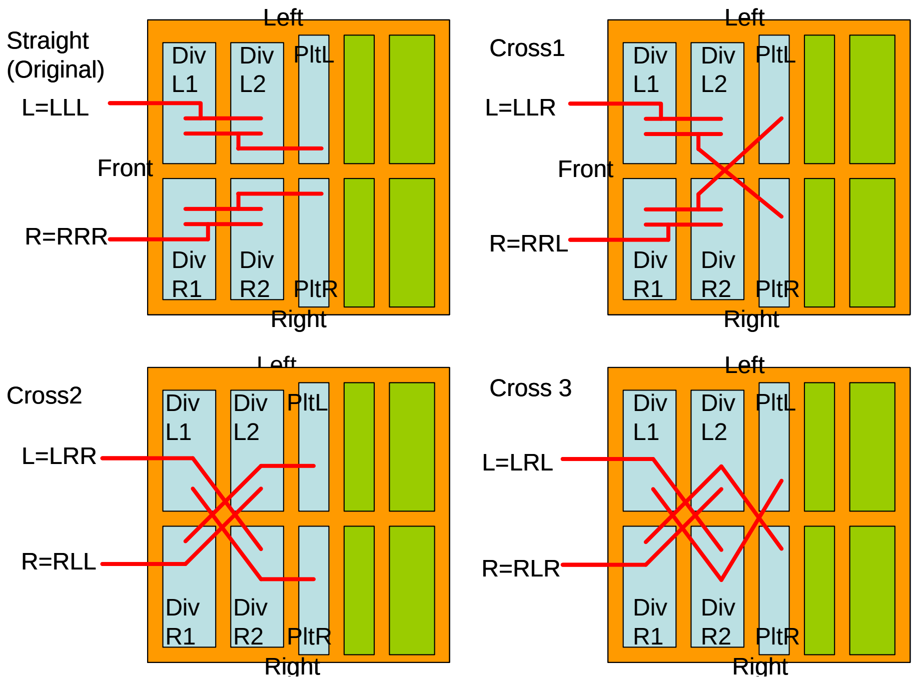
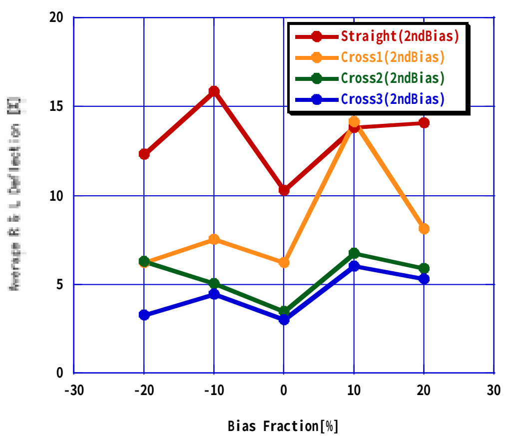


Fig. 6.2-4 Improvement of the R&L Deflection by Changing the Heater Combination (1)



Effect of the heater combination on the R & L Deflection
under the bias condition

Fig. 6.2-5 Effect of the Heater Combination on the R&L Deflection under the Bias Condition

2) The effect of the other operations

The other bias methods were also the almost same results as the 2nd air bias.

(2) Recommendation

From the above-mentioned results, it is thought that the following methods are the low-cost and the certain method.

From the above-mentioned results, it is thought that the following methods are the low-cost and the certain method.

(a) The super-heater is remodeled to the cross combinations.
+Cross 2 and Cross 3 is the best way of the three.

(b) The steam temperature is adjusted by turning up the tilt from the current angle to upper direction.
+Attention is paid to the RH metal temperature.

(c) It is better to select bottom2 mill pattern or middle mill pattern as a standard mill pattern.
+These mill patterns give a small gas temperature gradient in RH zone.

6.3 Boiler Remaining Life Assessment

6.3.1 Overview

Boiler RLA is not contributing to the efficiency improvement directly. However the assessment and implementation of appropriate counter measures are able to extend the boiler remaining life and prevent boiler tube leakage. That contributes significantly in terms of power generation (kWh).

As mentioned in Chapter 5, the candidate units were changed due to a change in the shutdown period of the model unit. The following two units were assessed by Kyuden Sangyo. Co., Inc., a Japanese research company, during the shutdown period for periodic inspection.

1) Singrauli Unit 6 (October 27 to November 1, 2009)
2) Unchahar Unit 2 (November 4 to November 9, 2009)

The parts to be inspected and inspection items for boiler remaining life assessment (Boiler RLA) were determined through discussions among Study team, the staff from Kyuden Sangyo and NTPC in the 2nd field work and before the start of the inspection. The Boiler RLA results for each unit are summarized in Table 6.3-1 and Table 6.3-2.

Among each technique demonstrated at sites, NTPC strongly desired to acquire the techniques to be able to conduct SUS scale deposition inspection, TOFD inspection and replica precise inspection. Therefore, Study team proposed providing training on Boiler RLA technique in Japan in 2010 fiscal year as a technology transfer. This training was planned and implemented in 2010 in Japan.

In the briefing session in India, the following opinions were exchanged:

- Boiler tube thickness control method
  Study team introduced the boiler tube thickness management method in Japan where the thickness shell required (tsr) calculated with the allowable stress of the material is used as a criterion.

- Difference of Boiler RLA between Japan and NTPC
  The Boiler RLA in NTPC covers every high temperature part for inspections which include items classified as precise inspections in Japan, while the Boiler RLA in Japan is limited to the parts that are subject to extremely severe conditions. Study team explained to NTPC that it was possible to prioritize the parts to be assessed according to the design life, calculated with the creep strength of the material.

Table 6.3-1 Summary of Boiler RLA in Singrauli Unit 6

Parts	Inspection item	Result
Water wall tube	Visual inspection	• Erosion of a number of tubes around short soot blower was observed. • No erosion at any other portions.
	Thickness measurement	• Thickness of tubes was measured at erosion area around soot blowers near each 4 corner (71 points in total). • Min. thickness was 3.7mm that is less than the designed value 5.6mm and the thickness shell required (tsr) 5.5mm.
Platen SH tube	Visual inspection	• Attrition of binding tube #4 and #5 with each other was found. (Min.2.8mm) • Attrition of a cooling spacer tube with the front tube of #14 panel (Min.5.0mm) was observed. • Disorder of panel arrangement with distortion and a number of disjointed slide spacers were observed. at lower part of panels
	Thickness measurement	• Thickness was measured mainly for outer tubes of rear side portion at soot blower level and outer bottom tubes (50 points in total). • No measured thickness value was found to be below the designed value.
	SUS scale deposition inspection	• SUS scale deposition was inspected mainly for bottom bend portions (50 points in total). • 4 portions were 15% fullness, 3 portions were 10% fullness and the others were less than 10% fullness of SUS scale deposition.
	Sample tube inspection	• The third tube of #12 panel from left was inspected for the oxide scale adhesion condition, etc.
	Creep rupture test	• Creep rupture test was conducted for the base metal portion and the weld portion of the sample tube mentioned above. • As a result, evaluated creep residual life was 290,000 hours for the base metal and 150,000 hours for the weld portion respectively.
RH tube	Visual inspection	• Disorder of panel arrangement with distortion was observed at lower part of panels. • No erosion was observed for the tubes around short soot blower.
	SUS scale deposition inspection	• SUS scale deposition was inspected mainly for bottom bend portions (50 points in total). • SUS scale deposition was not significant with 15% fullness for one portion and less than 10% fullness for the other portions.
	Sample tube inspection	• The first tube of #3 panel from left in penthouse and fifth tube from rear of #14 panel from left in furnace were inspected for the oxide scale adhesion condition, etc.
	Creep rupture test	• Creep rupture test was conducted for the base metal portion and the weld portion of the sample tube in furnace mentioned above. • As a result, evaluated creep residual life was 670,000 hours for the base metal and 610,000 hours for the weld portion respectively.
SH header	Visual inspection	• No appearance abnormality was observed in stubs and the other weld portions.
	Dye penetrant inspection	• 4 stub weld portions of #5 panel from left of Platen SH inlet header were inspected. • No penetrant indication by crack was detected.
	Replica inspection	• 2 replicas taken from 1 point of circumferential weld and 1 point of nearby base metal of left Platen SH outlet header were inspected. • As a result, min. evaluated creep residual life was 140,000 hours.
Desuper heater	Replica inspection	• 2 replicas taken from one each of circumferential weld of right and left Desuper heater were inspected. • As a result, min. evaluated creep residual life was 100,000 hours for each left and right Desuper heater.
RH header	Visual inspection	• No appearance abnormality was observed in stubs and the other weld portions.
	Ultrasonic testing	• 1 ring of circumferential weld of right RH outlet header was inspected. • No flaw echo judged as a crack was detected, although some echoes by subtle flaw were detected.
	TOFD inspection (Ultrasonic testing)	• 1 ring of circumferential weld of right RH outlet header was inspected. • No flaw echo judged as a crack was detected, although a number of flaw echoes from subtle blow holes and slag inclusions were detected
	Replica inspection	• 2 replicas taken from one each of circumferential weld of left and right RH outlet header were inspected. • As a result, min. evaluated creep residual life was 340,000 hours for left and 1,300,000 hours for right RH outlet header respectively.
Main steam pipe	Replica inspection	• 2 replicas taken from a circumferential weld of left Main steam pipe were inspected. • As a result, min. evaluated creep residual life was 21,000 hours.

Table 6.3-2 Summary of Boiler RLA in Unchahar Unit 2

Parts	Inspection item	Result
Water wall tube	Visual inspection	• Erosion of a number of tubes around short soot blower was observed. • Erosion and decrease in thickness of a number of tubes around burner and corner portions at short soot blower level were observed.
	Thickness measurement	• Thickness of tubes was measured at erosion area mentioned above (101 points in total). • Min. thickness was 4.2mm that is less than the designed value 6.3mm and the thickness shell required (tsr) 6.1mm.
SH tube	Visual inspection	• Disorder of panel arrangement with distortion and a number of disjointed slide spacers were observed at lower part of panels. • A slight erosion of the outer tubes was observed at the highest soot blower level.
	Thickness measurement	• Thickness of tubes was measured mainly for the outer tubes at the highest and the second highest soot blower level (71 points in total). • No measured thickness value was found to be below the designed value.
	SUS scale deposition inspection	• SUS scale deposition was inspected mainly at each 3 points for 29 bottom bend portions (87 points in total). • SUS scale deposition was not significant with 15% fullness for 4 points, 10% fullness for 2 points and less than 10% fullness for the other portions.
	Sample tube inspection	• The 8th tube from rear of #3 panel from left of Platen SH in furnace, the 3rd tubes from rear of #1 and #119 panel from left of Final SH in were inspected for the oxide scale adhesion condition, etc.
	Creep rupture test	• Creep rupture test was conducted for the base metal portion and the weld portion of the sample tubes of Platen SH and Final SH (#119 panel) mentioned above. • As a result, evaluated creep residual life was 7,800,000 hours for the base metal and 6,800,000 hours for the weld portion of Platen SH tube, 41,000 hours for the base metal and 35,000 hours for the weld portion of Final SH tube.
RH tube	Visual inspection	• No disorder of panel arrangement was observed. • A slight erosion of the tubes around soot blower was observed at the highest soot blower level.
SH header	Visual inspection	• No appearance abnormality was observed in stubs and the other weld portions.
	Dye penetrant inspection	• 4 stub weld portions of #3 panel from right of Platen SH inlet header were inspected. • No penetrant indication by crack was detected.
	Ultrasonic testing	• 1 ring of circumferential weld of right side of Final SH outlet header was inspected. • No flaw echo judged as a crack was detected.
	TOFD inspection (Ultrasonic testing)	• 1 ring of circumferential weld of right side of Final SH outlet header was inspected. • A number of flaw echoes from subtle blow holes and slag inclusions were detected. • No flaw echo judged as a crack was detected, although continuous stable flaw echoes were detected at about 80mm in depth from surface
	Replica inspection	• 1 replica taken from a circumferential weld of right side of Platen SH outlet header was inspected. • As a result, min. evaluated creep residual life was 270,000 hours.
Desuper heater	Replica inspection	• 2 replicas taken from one each of circumferential weld of right and left Desuper heater were inspected. • As a result, min. evaluated creep residual life was 96,000 hours for each left and right Desuper heater.
RH header	Visual inspection	• No appearance abnormality was observed in stubs and the other weld portions.
	Replica inspection	• 1 replica taken from a circumferential weld of left side of RH outlet header and 2 replicas taken from a circumferential weld of right side of RH outlet header were inspected. • As a result, min. evaluated creep residual life was 700,000 hours for left side and 270,000 hours for right side of RH outlet header.
Main steam pipe	Replica inspection	• 2 replicas taken from two circumferential welds of right Main steam pipe were inspected. • As a result, min. evaluated creep residual life was 69,000 hours.
Hot reheat pipe	Replica inspection	• 1 replica taken from a circumferential weld of right Hot reheat pipe was inspected. • As a result, min. evaluated creep residual life was 240,000 hours.

6.4 Air Heater (AH) Performance Improvement

Air heater (AH) performance improvement was conducted for Singrauli Unit 4 (rated output 200 MW) and Korba Unit 6 (rated output 500 MW).

In the 2nd field work, Study team and NTPC agreed that the field work would be conducted with the primary air heaters of Korba Unit 6, where significant air leakage occurred (not with the secondary air heaters).

Based on the results of calculating the efficiency of the air heater with operation data collected in the performance tests, Study team make improvement proposals that take the systems that Japanese electric utilities have employed into consideration.

6.4.1 Korba #6

(1) Current Status Assessment

According to the field work conducted so far, the air heaters of #6 have the following conditions and problems:

1) The air leakage ratios of the secondary air heaters are almost equal to the design value, but those of the primary air heaters are twice or greater than the design value.
2) The soft seals that are in contact with the air heaters are replaced at every periodic inspection, but air starts to leak three or four months after the periodic inspection.
3) According to the interview survey conducted in Korba, the imbalance in the outlet temperature between the primary and secondary air preheaters results from the fact that a larger amount of exhaust gas flows into the secondary air preheaters. The guide vane was not able to allocate appropriate gas flow to primary AH due to ash erosion.

(2) Efficiency Assessment Based on the Performance Test Data

Based on the data of the performance test conducted to study the efficiency of the air heaters on October 21, 2009, Study team calculated the air leakage ratio and temperature efficiency and looked into efficiency improvement items.

1) Test conditions

The test was conducted during coal-fired operation with a constant power generation load of 500 MW.

2) Test details

The temperature, CO, CO_2, and O_2 measurements were conducted by measuring points at the air inlets and outlets, and gas inlets and outlets of the air heaters according to the NTPC performance test procedure.

3) Consideration regarding the calculation results

Based on the performance test data, we calculated the efficiency and dew-point temperature of the air heaters in the following way:

- Air ratio (m): $m = \dfrac{21 - 0.062 \times (O_2)_{INL}}{21 - (O_2)_{INL}}$
  Constant: 0.062
- AH air leakage ratio: $\varepsilon = \dfrac{(O_2)_{OUTL} - (O_2)_{INL}}{21 - (O_2)_{OUTL}} \times 90$
- AH air side temperature efficiency: $\eta_A = \dfrac{t_{A2} - t_{A1}}{t_{G1} - t_{A1}} \times 100$
- Corrected AH outlet gas temperature: $t_{G2'} = t_{G2} + \dfrac{\varepsilon}{100} \times 0.941 \times (t_{G2} - t_{A1})$
  $\dfrac{\text{average air specific heat}}{\text{average gas specific heat}} = \dfrac{Cpa}{Cpg} = 0.941$
- Corrected gas temperature efficiency: $\eta_{G'} = \dfrac{t_{G1} - t_{G2'}}{t_{G1} - t_{A1}} \times 100$
- AH average temperature efficiency: $\eta = \dfrac{\eta_A + \eta_G}{2}$
- AH cold end metal temp.: $t_{dew} = \dfrac{t_{G2} + t_{A1}}{2}$

Symbol	Unit	Item
t_{G1}	°C	AH Inlet Gas Temperature
t_{G2}	°C	AH Outlet Gas Temperature
t_{A1}	°C	AH Inlet Air Temperature
t_{A2}	°C	AH Outlet Air Temperature
$(O_2)_{INL}$	%	AH Inlet Gas O_2
$(O_2)_{OUTL}$	%	AH Outlet Gas O_2
M		Air Ratio
ε	%	Air Leakage Ratio
ηA	%	AH Air Side Temperature Temp. Efficiency
$t_{G2'}$	°C	Corrected AH Outlet Gas Temperature
$\eta_{G'}$	%	Corrected AH Outlet Gas Temp. Efficiency
η	%	AH Average Temp. Efficiency
T_{dew}	°C	AH Cold End Metal Temp.

6.4.2 Singrauli Unit 4

(1) Current Status Assessment

According to the field work conducted so far, the air heaters of Unit 4 have the following conditions and problems:

1) All the radial seals are replaced at every periodic inspection. Soft seals are applied.
2) Immediately after a periodic inspection is conducted, the air leakage ratio is acceptable level, but it increases to after three or four months.
3) Erosion is more likely to occur in the periphery of the air heaters.
4) Immediately after a periodic inspection, the IDF load is 90% (current value: 100 to 110 A), but it increases to about 100% (current value: 140 A) immediately just before the next periodic inspection.
5) The problems relating to the air heaters are considered to result from the fact that the calorific value of the coal used is lower than that of the design coal by about 25%, causing the amounts of coal, air and ash to increase.

(2) Efficiency Assessment Based on the Performance Test Data

Based on the data of the performance test conducted to study the efficiency of the air heaters on October 14, 2009, Study team calculated the air leakage ratio and temperature efficiency and studied efficiency improvement items.

1) Test conditions

The test was conducted during coal-fired operation with a constant power generation load of 200 MW.

2) Test details

The temperature, CO, CO_2, and O_2 measurements were conducted at the measurement points at the air inlets and outlets, and gas inlets and outlets of the air heaters according to the NTPC performance test procedure.

3) Consideration regarding the calculation results

Based on the performance test data, we calculated the efficiency and dew-point temperature of the air heaters in the same way as previously described in the above:

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6.4.3 Recommendation for Efficiency Improvement

(1) Sector Plate Drive Unit (SDU)

The rotor of an air heater, when it is hot, deforms into a fan shape at the same time it expands toward the high-temperature side. The phenomenon in which the outer periphery of the rotor droops is called turn-down. Generally, the turn-down is greater than the expansion of the rotor shaft, causing a gap between the periphery of the rotor and sector plate on the high-temperature side (seal gap G). The inner periphery of the sector plate is joined with the rotor shaft and expands as the rotor shaft expands. As a result, the gap between the radial seal installed on the rotor at the high-temperature side and the sector plate forms a long triangle when the rotor is hot. The sector plate drive causes the outer periphery of the sector plate to move according to the degree of the turn-down of the rotor so as to decrease the seal gap.

(2) Floating Radial Seals (FRS)

It can be expected that the adoption of floating radial seals, which have a simpler function than sector plate drives have, will reduce leakage from the high-temperature radial seal and improve the air leakage ratio. Floating radial seals can be applied non-suspend type of sector plate AH. Floating radial seals use a spring to expand and contract the radial seal and maintain the gap between the rotor and sector plate with the turn-down of the rotor in mind.

(3) Carbon Circum Seals (CCS)

Study team propose that the metal-touch sealing method using carbon be adopted to prevent air from leaking from circumferential seals at the high-temperature (air outlet, gas inlet) and low-temperature sides (air-inlet, gas outlet) of air heaters. Carbon circum seals are installed between the rotor and housing at the high-temperature and low-temperature sides and allow higher pressure air to flow into the gaps between the rotor and housing so as to prevent air from leaking from these gaps.

(4) Review of Periodic Inspections for Air Heater Maintenance

According to the field work results, NTPC, when it carries out periodic inspection, calls on supervisors from the air heater manufacturer to carry out inspection work, but only when necessary. In Japan, every time a power station carries out a periodic inspection, they call on supervisors from the air heater manufacturers to inspect or replace the necessary items to reduce leakage from the air heaters and maintain the efficiency of the air heaters.

6.5 Turbine RLA

Turbine RLA (Remaining Life Assessment) was carried out in May 2010 for Korba #4 turbine by Alstom K.K. in Japan and NASL. The following assessments were included.

1) Turbine RLA

2) Steam path audit

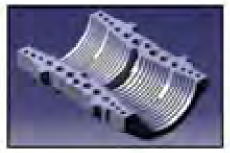
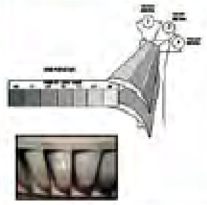
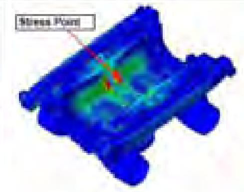
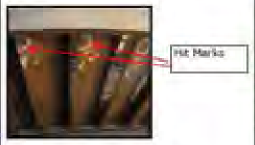
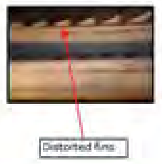
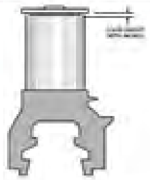
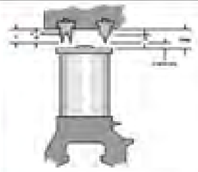
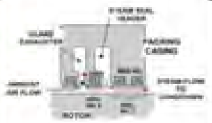
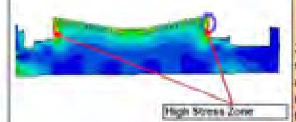
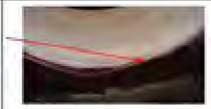
3) Main piping assessment (Main steam, Hot reheat, Cold reheat and Feed water piping)

Major findings and recommendations are shown in the attached summary.

OVERALL EXECUTIVE SUMMARY OF THE PROJECT (1/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

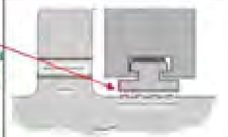
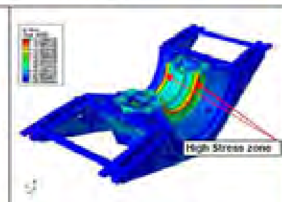
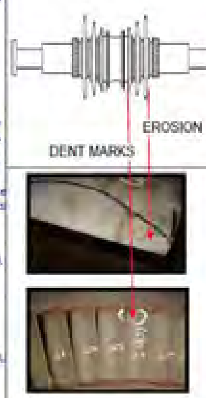
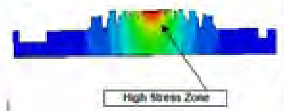
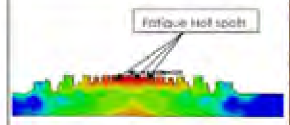
Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

Sl No		Component	Findings from Destructive Test (DT) / Non-Destructive Test (NDT)		Findings from Steam Path Audit (SPA)		Remaining Life & Other Findings				Conclusions	Recommendations
			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 exit 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. # 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.	 	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. Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 22 years.	 	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.
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 106.7 kW and an increase in heat rate 2.03 kJ/kWh. Due to the blasting cover deposit have been removed. Total of 106.7 kW and 2.03 kJ/kWh are recovered. # Tip Spill Strip:- The opening audit loss due to tip spill strips was -210.2 kW and an increase in heat rate -3.10 kJ/kWh and in closing loss was -104.3 kW and heat rate was -1.50 kJ/kWh. Total of -105.9 kW and -1.6 kJ/kWh are recovered # 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.	  	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. 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)		
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 (2/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

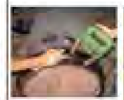
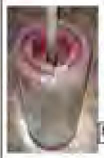
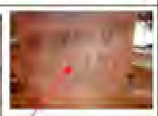
Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

Sl No		Component	Findings from Destructive Test (DT) / Non-Destructive Test (NDT): Key Observations/ Findings/ condition assessment	Findings from Destructive Test (DT) / Non-Destructive Test (NDT): Reference Location/Sketch	Findings from Steam Path Audit (SPA): Key Observations/ Findings/ condition assessment	Findings from Steam Path Audit (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.	Erosion observed on weld area inside the inner support plate.  Erosion observed on weld area inside the inner casing.	# Surface Roughness:- The opening audit loss due to surface roughness was 3505.0 kW and an increase in heat rate 54.45 kJ/kWh and in closing loss was 1140.9 kW and heat rate was 17.20 kJ/kWh. Total of 2444.1 kW and 37.17 kJ/kWh are recovered. # 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	 	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. 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.	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 = 486.2 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)	
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 errosion 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. # 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 122.5 kW and heat rate was 1.85 kJ/kWh. Total of 38.8 kW and 0.59 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. 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.	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.
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 (3/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

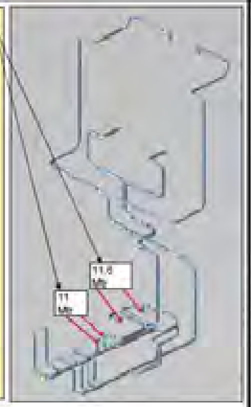
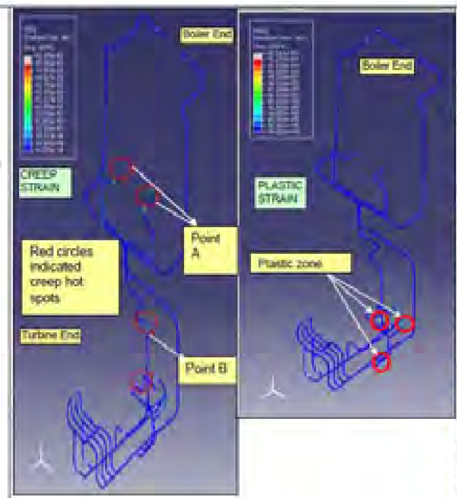
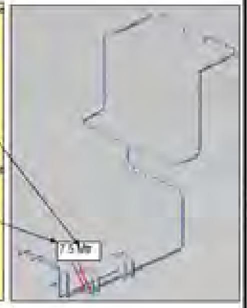
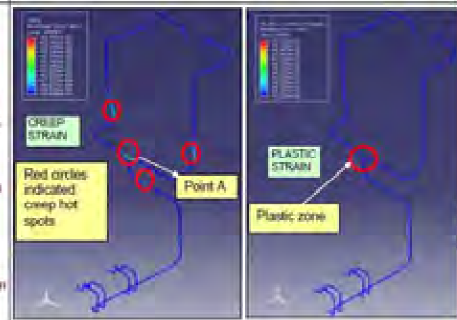
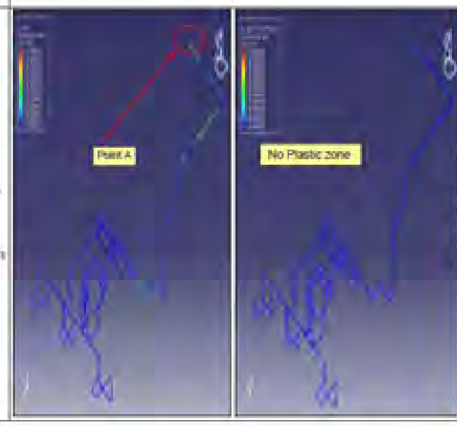
Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

			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 errosion, 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 (4/4)

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): Key Observations/ Findings/ condition assessment	CAESAR II / Hot & Cold Walk Down Findings: Key Observations/ Findings/ condition assessment	CAESAR II / Hot & Cold Walk Down Findings: 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
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 III-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 III_L to IV_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 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 6005 Code Stress: 152.8681 MPa Allowable: 184.3418 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 (localised 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 opern 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 (%): 35.8 @Node 1175 Code Stress: 49.1281 MPa Allowable: 137.8951 MPa (Sustained) Code Stress Ratio (%): 13.1 @Node 1195 Code Stress: 36.8209 MPa Allowable: 296.8034 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.

6.6 Condenser Leak Buster

Condenser leak buster, which is air leak-in test using helium gas, was carried out for Singrauli #6 where two vacuum pumps were continuously in operation, from Aug. 6 to Aug. 10, 2009, by Fuji Electric Systems Co., Ltd.

The 130 points were tested and as the result of the test, following serious air leak positions were found. JICA-ST requested NTPC to take proper action to improve present situation.

Table 6.6-1 Summery of Test Result

No.	Test position	Air leak rate [kg/h]
1	A-BFPT gland sealing portion (Rear)	49.3
2	B-BFPT gland sealing portion (Rear)	23.5
3	LP turbine gland sealing portion (Packing and Bellow flange)	13.3
4	HP flush tank, flush box-1 and Drain flush tank B	12.3
5	Others	15.9
	Total	**114.3**

6.7 Pump Assessment

(1) Summary

Pump tests, using thermometric test method with Yates meter, by Torishima pump Mfg.Co.,Ltd., was carried out.

According to NTPC request, the tested pumps were selected as follows, and tests were carried out in October 2009.

	Unit	Pump	Test Date
1)	Korba power station #6	Turbine driven BFP (6B)	October 21 & 22
2)	Rihand power station #2	Motor driven BFP (2B)	October 13
		CWP (2B)	October 14
3)	Singrauli power station Stage I	CWP (NO.09)	October 26&27

The tests were carried out during operating condition, and pump operation parameters such as pressure, temperature and flow, pump vibration and bearing temperature were measured.

1) Korba Turbine driven BFP (6B)

A comparison is given below between recorded and the manufacturer's performance data.

Pump flow rate	(l/sec)	254.3
As-New Pump Head	(m)	2,316.5
Current Pump Head	(m)	2,168.0
Change from As-New	(%)	-6.4
As-New Pump to Power	(kW)	6,340.8
Current Pump to Power	(kW)	6,327.9
Change from As-New	(%)	-0.2
As-New Efficiency	(%)	82.1
Current Pump Efficiency	(%)	77.8
Change from As-New	(%)	-5.2

Above difference between original pump efficiency and tested one is normally due to an increase in running clearances from worn wear rings. A return to original efficiency levels can be attained by full refurbishment.

It is recommended to conduct pump test for the same pump every two years, and to carry out the test for other pumps.

2) Rihand Motor driven BFP (2B)

A comparison is given below between recorded and the manufacturer's performance data.

Pump flow rate	(l/sec)	267.7
As-New Pump Head	(kg/cm^2)	214.2
Current Pump Head	(kg/cm^2)	210.5
Change from As-New	(%)	-1.7
As-New Pump to Power	(kW)	6,945.0
Current Pump to Power	(kW)	7,840.7
Change from As-New	(%)	+12.9
As-New Efficiency	(%)	81.0
Current Pump Efficiency	(%)	70.5
Change from As-New	(%)	-13.0

Above difference between original pump efficiency and tested one is normally due to an increase in running clearances from worn wear rings. A return to original efficiency levels can be attained by full refurbishment.

It is recommended to conduct pump test for the same pump every two years, and to carry out the test for other pumps.

3) Rihand CWP (2B)

A comparison is given below between recorded and the manufacturer's performance data.

Pump flow rate	(l/sec)	8,351.6
As-New Pump Head	(m)	26.4
Current Pump Head	(m)	25.1
Change from As-New	(%)	-4.9
As-New Pump to Power	(kW)	2,725.1
Current Pump to Power	(kW)	2,639.7
Change from As-New	(%)	-3.1
As-New Efficiency	(%)	85.1
Current Pump Efficiency	(%)	83.7
Change from As-New	(%)	-1.6

This would appear to be in reasonable condition considering the age of the unit.

It is recommended to conduct pump test for the same pump every two years, and to carry out the test for other pumps.

4) Singrauli Stage I CWP (09)

A comparison is given below between recorded and the manufacturer's performance data.

Pump flow rate	(m^3/sec)	16,654.3
As-New Pump Head	(m)	24.4
Current Pump Head	(m)	25.5
Change from As-New	(%)	+4.5
As-New Pump to Power	(kW)	1,334.0
Current Pump to Power	(kW)	1,560.0
Change from As-New	(%)	+17.0
As-New Efficiency	(%)	83.0
Current Pump Efficiency	(%)	73.8
Change from As-New	(%)	-11.0

This efficiency decrease is not within acceptable scatter and would appear pump is not in acceptable condition. A return to original efficiency levels can be attained by full refurbishment.

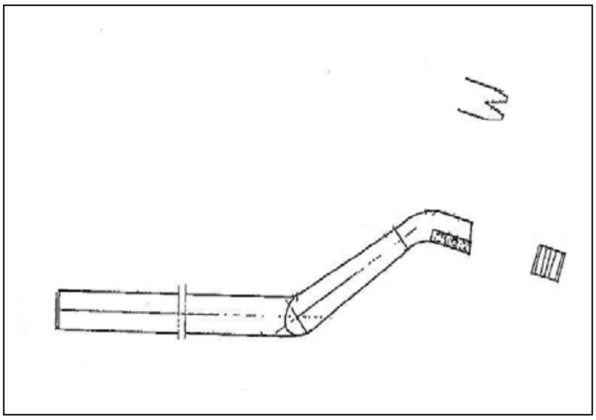
It is recommended to conduct pump test for the same pump every two years, and to carry out the test for other pumps.

6.8 Seal Fin Replacement

This item was newly requested by NTPC during the first field work to witness during turbine overhaul, and to provide advice by expert in order to share Japanese practice of this work at site. However, due to various constraints, since JICA-ST could not accept NTPC's request, JICA-ST requested NTPC to exclude this work from study scope and NTPC requested JICA-ST to provide the procedure of seal fin adjustment at site. This clause is prepared to explain the procedure of seal fin adjustment, including replacement at site.

Seal Fin Maintenance Procedure

1) At periodical maintenance, only measurement of gap is carried out, and no adjustment is carried out. If the gap is bigger than OEM's limitation, seal fins must be replaced with new one.
2) Other work than measurement of gap, burr at fin tip part or cracked part should be cut, and tip part should be smoothed by special tool, for example, shown below.



3) When replacing fins at site, first, removing caulking piece by scraping using hand grinder, and new fin will be set. (refer to attached sample drawing)
4) After replacement, gap between fin tip and top of blade must be measured by thickness gauge, and contact with blade must be checked by read line.
5) If gap is smaller than limit, there may be the case which gap is adjusted by grinding, by special grinding machine which can slide along inner circumferential surface of diaphragm.

Electric Power Development Co., Ltd.
Kyusyu Electric Power Co., Inc.
The Chugoku Electric Power Co., Inc.

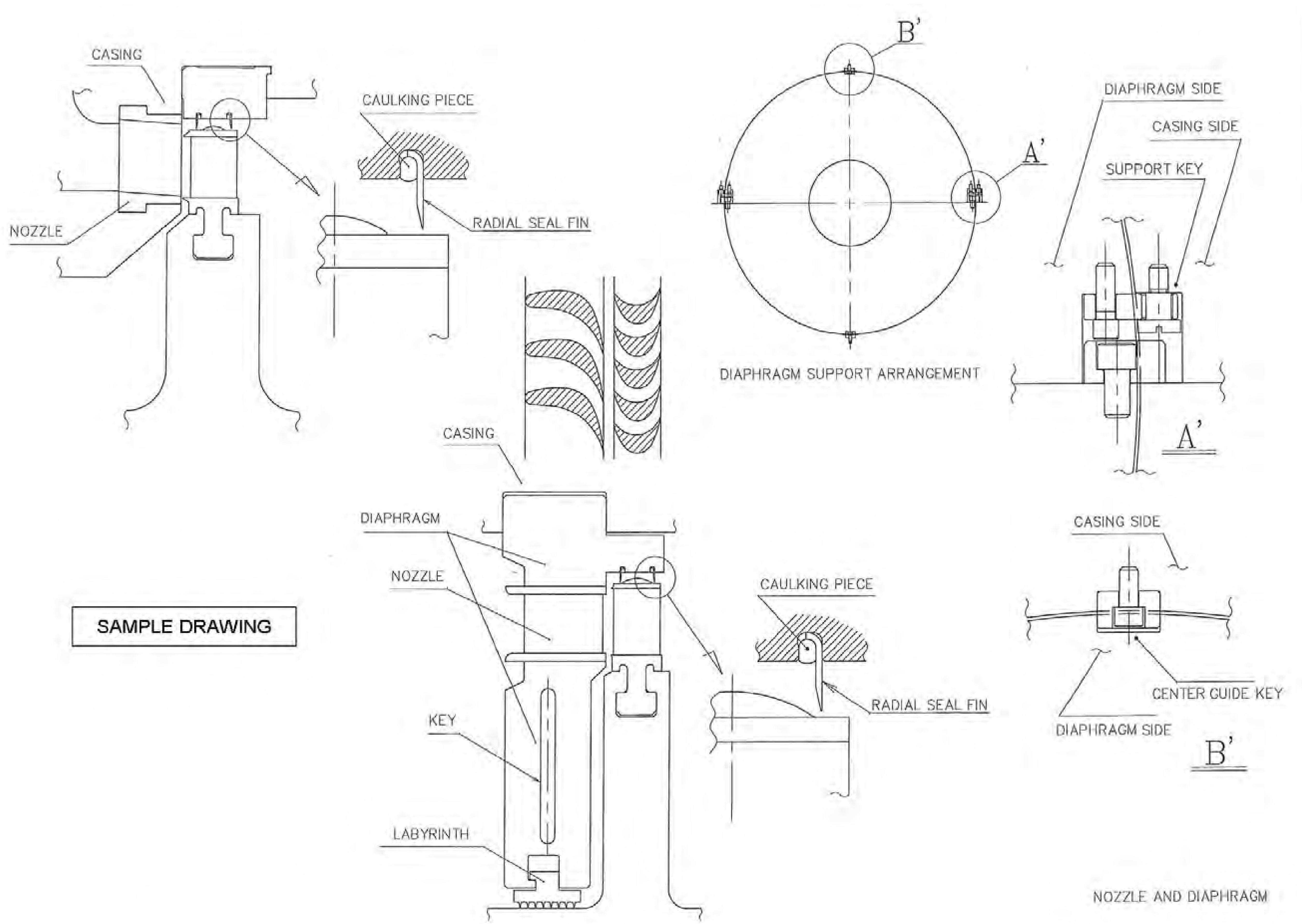


Fig. 6.8-1 Sample Drawing

6.9 Control System Assessment

6.9.1 Overview

(1) Objectives

The objectives of the assessment are to confirm the state of key facilities at a power station and to investigate the possibility of improving the reliability, operating performance and functionality of the power station through renovating or modifying its instrumentation and control systems.

(2) Units to be Assessed

Unchahar #3

(3) Schedule

October 26 to 29, 2009 (4 days)

(4) Team

Study team members and staff from Yokogawa Electric Corporation (6 members total)

6.9.2 Details

- Investigation of the power station facilities (central control room, C&I laboratory room, on-site instruments, etc.)
- Collection of operation data
- Hearing held with control-related engineers and operators
- Variable load test for checking controllability, etc.

6.9.3 Evaluation

Part of the operation was performed in manual mode, not in automatic mode, but no problems were observed. With regard to the plant control responsiveness, no particular problems were observed with the variable load test.

With regard to instrument status, the field work found that the instruments were operating normally and no particular problems were observed, including their operating conditions. In addition, no problems were observed with the calibration method and spare part management in the C&I laboratory.

In the fields of control and instrumentation (C&I), as a whole, an extremely high level has been achieved. In order to further improve plant efficiency and reliability, there is a need to introduce the latest technologies.

6.9.4 Improvement Proposals and Effects

A large problem is that the use of coal with high ash content causes boiler tube leakage. One possible measure is to improve the controllability and optimize the combustion and soot blowers.

Improvement proposals	Current	After improvement	Expected effects
Introduction of a new system for the optimization of combustion and soot blowers to reduce the amount of coal used and CO_2 emissions	—	Introduced	Boiler efficiency will increase by 0.4 to 0.5%. CO_2 emissions will decrease by 10,000 tons/year.

As a secondary effect, it can be expected that the number of shutdowns will decrease, causing the amount of fuel needed for start-up to decrease, and that the boiler will operate with a smaller amount of oxygen, causing boiler loss to decrease.

Secondary effect	Current	After improvement	Expected effect
The number of shutdowns will decrease, causing the amount of fuel used for start-up to decrease.	—	—	The amount of fuel for start-up will decrease by 23 kL each start-up.
The boiler will operate with a smaller amount of oxygen, causing boiler loss to decrease.	3.8%	3.3%	Combustion will improve, causing the amount of coal used to decrease by 3,234 tons/year.

6.10 BFP Turbine Parameter Assessment

According to NTPC request, BFP turbine parameter assessment was carried out for Korba #6, Rihand #3 and Vindhyachal #7, by comparing operation data with design data. JICA-ST already requested NTPC to provide design data sheet, performance curve and operation data of BFP and BFP turbine.

Theoretically, it is impossible to assess turbine performance, since it is impossible to get turbine exhaust enthalpy. Therefore, the following method was applied.

1) Based on turbine design data, turbine inner efficiency is gotten.
2) Using this inner efficiency and turbine operating parameters including steam flow, turbine power output is gotten.
3) On the other hand, as for BFP, using operating parameters and design pump efficiency, required pump shaft power is gotten.
4) If measured operation parameters are correct, turbine power output should be higher than pump shaft power.
5) Then, assuming either or both of turbine inner efficiency decrease and pump efficiency decrease, balance point is gotten.

If pump efficiency can be measured accurately, by Yates meter test, for example, more accurate assessment is possible

(1) Vindhyachal #7

Calculation result is shown below. As for BFP A, assuming that BFP efficiency is same as design figure, turbine output becomes same as pump shaft power when turbine inner efficiency is decreased by 1.3%. Assuming that both turbine and pump efficiency decrease level is nearly same, turbine output becomes same as pump shaft power when turbine inner efficiency decrease is 0.7% and pump efficiency decrease is 0.6%. As for BFP B, assuming that BFP efficiency is same as design figure, turbine output becomes same as pump shaft power when turbine inner efficiency is decreased by 5.8%. Assuming that both turbine and pump efficiency decrease level is nearly same, turbine output becomes same as pump shaft power when turbine inner efficiency decrease is 3% and pump efficiency decrease is 3%.

	CASE			Design Eff.	ηTin: -1.3% ηp: Design	ηTin: -0.7% ηp: -0.6%
BFP A	Turbine	ηin	%	85.8	84.7	85.2
		Steam Flow	t/h	41.2	41.2	41.2
		Turbine output	kW	6601	6515	6556
	Pump	FW Flow	t/h	869	869	869
		BP efficiency	%	80.5	80.5	80
		BFP efficiency	%	80	80	79.5
		Pump shaft power	kW	6515	6515	6556
	CASE			Design Eff.	ηTin: -5.8% ηp : Design	ηTin: -3% ηp :-3%
BFP B	Turbine	ηin	%	85.8	80.8	83.2
		Steam Flow	t/h	40.5	40.5	40.5
		Turbine output	kW	6468	6077	6264
	Pump	FW Flow	t/h	819	819	819
		BP efficiency	%	80.5	80.5	78.1
		BFP efficiency	%	80	80	77.6
		Pump shaft power	kW	6076	6076	6264

(2) Rihand #3

Calculation result is shown below. Using design efficiency for both turbine and pump, in both BFP A and BFP B, pump shaft power is approx. 6% bigger than turbine power output. Therefore, case study could not be done. We are afraid that there is feed water flow measurement error.

			CASE	Design Eff.
BFP A	Turbine	ηin	%	82.9
		Steam Flow	t/h	39.6
		Turbine output	kW	6173
	Pump	FW Flow	t/h	910
		BP efficiency	%	81.1
		BFP efficiency	%	81
		Pump shaft power	kW	6533
BFP B	Turbine	ηin	%	82.9
		Steam Flow	t/h	40.1
		Turbine output	kW	6241
	Pump	FW Flow	t/h	916.7
		BP efficiency	%	81.1
		BFP efficiency	%	81
		Pump shaft power	kW	6584

(3) Korba #6

Since turbine steam flow data was not available, calculation could not be done.

6.11 Generator Assessment

6.11.1 Target Generator for Assessment

As the results of #1 and #2 Field work, generator assessments (current condition assessment and remaining life assessment (RLA)) are carried out for the following generators due to NTPC request.

Table 6.11-1 Generators for Assessment

Unit	Main specifications
Korba #6	588 MVA, 16.2 kV, Stator: water cooled
Rihand #2	605 MVA, 20 kV, Stator: water cooled
Singrauli #4	235.3 MVA, 15.75 kV, Stator: water cooled

6.11.2 Korba#6 Generator Assessment

Korba#6 has carried out the tests with cooling water remaining inside the generator stator, which means that the tests were meaningless. The test results are shown in Table 6.11-2.

Table 6.11-2 IR Test and PI Test Results

Test item	Test record	Evaluation	Remark
Current condition assessment			
IR test	0.0628930 MΩ	Not available	
PI test	0.994	Not available	= IR (8 min) / IR (1 min)
RLA			
PI test	–	Not available	

6.11.3 Rihand#2 Generator Assessment

The test results are shown in Table 6.11-3.

Table 6.11-3 IR Test and PI Test Results

Test item	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
IR test	3-phase	1000 MΩ	Good	JP ≥ 50 MΩ, NTPC ≥ 21 MΩ
PI test	3-phase	3.75	Good	JP, NTPC ≥ 2.0
Tanδ test (ΔTanδ)	R	0.0074	Good	JP: Δtanδ < 2.5%
	Y	0.0108	Good	
	B	0.0124	Good	
Remaining life assessment				
PI test	3-phase	–	Not available	Variations in PI data
Tanδ test	–	–	Not available	No more than one test result

6.11.4 Singrauli#4 Generator Assessment

The test results are shown in Table 6.11-4.

Table 6.11-4 Current Status Assessment and RLA

	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
IR test	R	3100 MΩ	Good	JP ≥ 50 MΩ, NTPC ≥ 17 MΩ
	Y	3500 MΩ	Good	
	B	1900 MΩ	Good	
PI test	R	2.58	Good	JP, NTPC ≥ 2.0
	Y	2.86	Good	
	B	2.11	Good	
Tanδ test (ΔTanδ)	R	0.0001	Not available	JP: Δtanδ < 2.5% The test voltage is low.
	Y	-0.0003	Not available	
	B	0.0002	Not available	
Partial discharge test	–	–	Not available	The evaluation items differ from those in Japan. No explanation given.
RLA		**Operation years**	**Year**	
PI test	R	32 years	2015	Up to the caution level*1
		39 years	2022	Up to the danger level*1
	Y	29 years	2012	Up to the caution level*1
		36 years	2019	Up to the danger level*1
	B	–	Not available	The PI data does not show a deteriorating trend.
Tanδ test	All phases	–	Not available	The test voltage is low.

*1: Possibly due to variations in the stator dryness

6.12 Generator Transformer Assessment

6.12.1 Target Transformers for Assessment

As the results of #1 and #2 Field work, transformer assessments (current condition assessment and RLA) are carried out for the following generator transformers (GTs) due to NTPC request.

Table 6.12-1 Units for Transformer Assessment

Unit	Main specification
Korba #6	Single phase 200 MVA × 3 units, OFAF, Sealed type
Rihand #2	Single phase 201.7 MVA × 3 units, OFWF, Sealed type
Singrauli #6	Single phase 200 MVA × 1 unit, OFWF, Sealed type

6.12.2 Korba #6 GT Assessment

The assessment results are shown in Table 6.12-2.

Table 6.12-2 Current Condition Assessment and RLA for Korba#6 GT

	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
IR test	R	3500 MΩ	Good	Smallest value among the values measured between High Voltage–Ground, Low Voltage–Ground, and High Voltage–Low Voltage JP ≥ 80 MΩ
	Y	3500 MΩ	Good	
	B	3250 MΩ	Good	
Dissolved gas analysis	R	–	Good	
	Y	–	Good	
	B	–	Good	
$CO+CO_2$ analysis	R	0.4305 mL/g	Caution	Caution ≥ 0.2 mL/g Danger ≥ 2.0 mL/g
	Y	0.5082 mL/g	Caution	
	B	0.5943 mL/g	Caution	
Furfural analysis	R	0.00389 mg/g	Caution	Caution ≥ 0.0015 mg/g Danger ≥ 0.015 mg/g
	Y	0.00467 mg/g	Caution	
	B	0.00312 mg/g	Caution	
RLA		**Operation years**	**Year**	
$CO+CO_2$ analysis	R	53.7	Sep.-2042	Up to the average service life*1
	Y	45.5	Jul.-2034	
	B	38.9	Dec.-2027	
Furfural analysis	R	44.5	Jul.-2033	Up to the average service life*2
	Y	37.1	Feb.-2026	
	B	55.7	Aug.-2044	

*1: The average service life point was set to 1.1 mL/g, which is the average between the caution level (0.2 mL/g) and the danger level (2.0 mL/g).

*2: The average service life point was set to 0.00825 mg/g, which is the average between the caution level (0.0015 mg/g) and the danger level (0.015 mg/g).

6.12.3 Rihand#2 GT Assessment

The assessment results are shown in Table 6.12-3.

Table 6.12-3 Current Condition Assessment and RLA for Rihand#2 GT

	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
IR test	R	707 MΩ	Good	Smallest value among the values measured between High Voltage–Ground, Low Voltage–Ground, and High Voltage–Low Voltage JP ≥ 80 MΩ
	Y	979 MΩ	Good	
	B	835 MΩ	Good	
DGA	R	–	Good	.
	Y	–	Good	
	B	–	Good	
$CO+CO_2$ analysis	R	0.95 mL/g	Caution	Caution ≥ 0.2 mL/g
	Y	0.90 mL/g	Caution	Danger ≥ 2.0 mL/g
	B	0.97 mL/g	Caution	
Furfural analysis	R	0.16328 mg/g	Danger	Caution ≥ 0.0015 mg/g
	Y	0.07161 mg/g	Danger	Danger ≥ 0.015 mg/g
	B	0.07161 mg/g	Danger	The measured values are not reliable.
RLA		**Operation years**	**Year**	
$CO+CO_2$ analysis	R	23.9	41395	Up to the average service life*1
	Y	25.1	Jul.-2014	
	B	23.4	Nov.-2012	
Furfural analysis	R	–	Not available	Up to the average service life*2
	Y	–	Not available	The measured values are not reliable.
	B	–	Not available	

*1: The average service life point was set to 1.1 mL/g, which is the average between the caution level (0.2 mL/g) and the danger level (2.0 mL/g).

*2: The average service life point was set to 0.00825 mg/g, which is the average between the caution level (0.0015 mg/g) and the danger level (0.015 mg/g).

6.12.4 Singrauli#6 (R-Phase) GT Assessment

The assessment results are shown in Table 6.12-4.

Table 6.12-4 Current Status Assessment and RLA for Singrauli#6 R GT

	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
IR test	HV-LV	800 MΩ	Good	HV: High voltage coil, LV: Low voltage coil E: Earth JP ≥ 80 MΩ
	HV-E	500 MΩ	Good	
	LV-E	400 MΩ	Good	
DGA	R	–	Good	
$CO+CO_2$ analysis	R	1.38 mL/g	Caution	JP Caution ≥ 0.2 mL/g JP Danger ≥ 2.0 mL/g
Furfural analysis	R	0.0283 mg/g	Danger	JP Caution ≥ 0.0015 mg/g JP Danger ≥ 0.015 mg/g The measured values are not reliable.
RLA		**Operation years**	**Year**	
$CO+CO_2$ analysis	R	18	Jun-2005	Up to the average service life*1
		32.7	Sep-2019	Up to the danger level
Furfural analysis	R	–	Not available	Up to the average service life*2 The measured values are not reliable.

*1: The average service life point was set to 1.1 mL/g, which is the average between the caution level (0.2 mL/g) and the danger level (2.0 mL/g).

*2: The average service life point was set to 0.00825 mg/g, which is the average between the caution level (0.0015 mg/g) and the danger level (0.015 mg/g).

6.12.5 Korba #6 GT Assessment（3rd year: 2010）

According to NTPC request at #4 Field work, Korba #6 GT Assessment was conducted additionally.

The assessment results are shown in Table 6.12-5.

Electric Power Development Co., Ltd.
Kyusyu Electric Power Co., Inc.
The Chugoku Electric Power Co., Inc.

Table 6.12-5 Current Condition Assessment and RLA for Korba#6 GT (2010)

	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
Dissolved gas Analysis	R	–	Good	
	Y	–	Good	
	B	–	Good	
$CO+CO_2$ analysis	R	0.4400 mL/g	Caution	Caution ≥ 0.2 mL/g Danger ≥ 2.0 mL/g
	Y	0.5194 mL/g	Caution	
	B	0.6074 mL/g	Caution	
Furfural analysis	R	0.00463 mg/g	Caution	Caution ≥ 0.0015 mg/g Danger ≥ 0.015 mg/g
	Y	0.00541 mg/g	Caution	
	B	0.00386 mg/g	Caution	
RLA		**Operation years**	**Year**	
$CO+CO_2$ analysis	R	53.7	Sep.-2042	Up to the average service life*1
	Y	45.5	Jul.-2034	
	B	38.9	Dec.-2027	
Furfural analysis	R	38.2	Mar-2027	Up to the average service life*2
	Y	32.8	Oct-2021	
	B	45.9	Nov-2034	

*1: The average service life point was set to 1.1 mL/g, which is the average between the caution level (0.2 mL/g) and the danger level (2.0 mL/g).

*2: The average service life point was set to 0.00825 mg/g, which is the average between the caution level (0.0015 mg/g) and the danger level (0.015 mg/g).

6.13 Analysis of Current Performance and Performance Degradation

6.13.1 General

(1) Differences in the Performance Test between Study Team and NTPC

Table 6.13-1 Differences in the Boiler Performance Test Procedure between Study Team and NTPC

[frequency of test]

No.	Item	Study team	NTPC
1	Boiler performance	Measured. ....*[once per year]*	Measured. .... *[once per month]*
2	AH performance	Not measured. .... *[as necessary]*	Measured. .... *[once* every *3 months]*
3	Coal ultimate analysis	By analysis.	By formula using proximate analysis
4	Flue gas analysis	By gas analyzer (Utilizing “Orsat”, “simple gas analyzer” for checking purpose only).	By portable gas analyzer
5	Frequency of reading	Once every 30 minutes in a two hour test	More frequent reading than Study team

(2) Differences in the Turbine Performance Test Procedure between Study Team and NTPC

Table 6.13-2 Differences in the Turbine Performance Test Procedure between Study Team and NTPC

[frequency of test]

No.	Item	Study team	NTPC
1	Test item	Only turbine heat rate .... *[once per year]*	Turbine heat rate .... *[once per month]* HP&IP cylinder efficiency ....*[once every 6 months]* Condenser performance .... *[once per month]* HP heater performance *[once per* month *or once every 3 months]*
2	Frequency of reading	Once every 30 minutes in a two hours test	More frequent reading than Study team

(3) Differences in the Implementation of the Performance Tests

In the 3rd field work, Study team surveyed the implementation of the performance tests in Korba Unit 6, Singrauli Unit 4, and Rihand Unit 2. Study team summarized the differences in the implementation of the performance tests between NTPC and Study team as follows:

Table 6.13-3 Differences in the Actual Performance Test Practices between Study Team and NTPC

No.	Item	Study team	NTPC
1	Test Implementation Team	A) Organization: Operation Section B) Implementation: Subsidiary Company and Service Provider	Organization: EEMG Implementation: EEMG
2	Preparation of Test (day before)	A) Confirmation of measurement data value B) Calibration of Instrument/measurement devices, as necessary	A) Not applied. B) Not applied.
3	Test implementation	A) Meeting with relevant parties before start of test B) Confirmation of Operating conditions of test run C) Calibration of Gas analyzer D) Measurement timing is notified by paging every hour for ash sampling/local indicators value E) Field Measurement * Flue Gas Composition & Temp * Coal sampling * Fly Ash sampling * Bottom Ash sampling	A) Not applied B) Load is not fixed at rated out put C) Same as Study team D) Not applied E) Same as Study team

Sampling

NTPC sampled coal used for the performance tests from the coal feeder. The sampled coal was bagged and carried to the laboratory.

In accordance with Study team’s procedure, the sampled coal is sealed in a plastic bag so that the moisture content in the coal does not vary, and then it is carried to the laboratory.

Fig. 6.13-1 Coal Sampling Plastic Bag

NTPC samples fly ash from the hopper in the first row of the electrical dust collector (ESP). Every time fly ash is sampled from the hopper, fly ash drops out of the tray which causes scattering it to get stirred into the air. In addition, the amount of fly ash sampled differs from hopper to hopper.

In the field work at Korba Unit 6, Study team pointed out that fly ash was sampled from the emergency fly ash discharge line. The fly ash sampled up until then was sampled before the performance tests. Therefore, fly ash was sampled again from the ordinary fly ash discharge line. For this reason, the performance test period was extended.

In accordance with Study team's procedure, a fly ash extraction valve is installed, and a fly ash sampling storage bin is used to sample a constant amount of fly ash.

Fig. 6.13-2 Fly Ash Extraction Valve for Sampling

Fig. 6.13-3 Fly Ash Sampling Storage Bin

6.14 Review and Improvement of Past and Present O&M Procedure

6.14.1 Current Conditions of Thermal Power Station Operations

Study team researched and evaluated the operation and maintenance of the three candidate power stations, Korba #6, Rihand #2 and Singrauli #4.

6.14.2 Current Conditions of Operation

In India, the power supply is unable to fill the power demand, which means that power stations have to keep operating close to their maximum loads, exceeding the rated loads at which the power stations operate at highest efficiency. Even so, the power system frequency rarely reaches 50 Hz. In these power stations, Study team found problems that would normally require immediate shutdowns for repair if occurred in Japan. However, these power stations continued to operate by necessity and the problems were left as they were. Most of the time the power stations keep operating at output over their rated outputs (close to their maximum loads), and their load factors (LF) often exceed 100%.

6.14.3 Outline of a Power Station Management System

(1) Management system

The selected Units are basically managed under the organization shown below, and the Energy and Efficiency Management Group (EEMG) is in charge of their efficiency management.

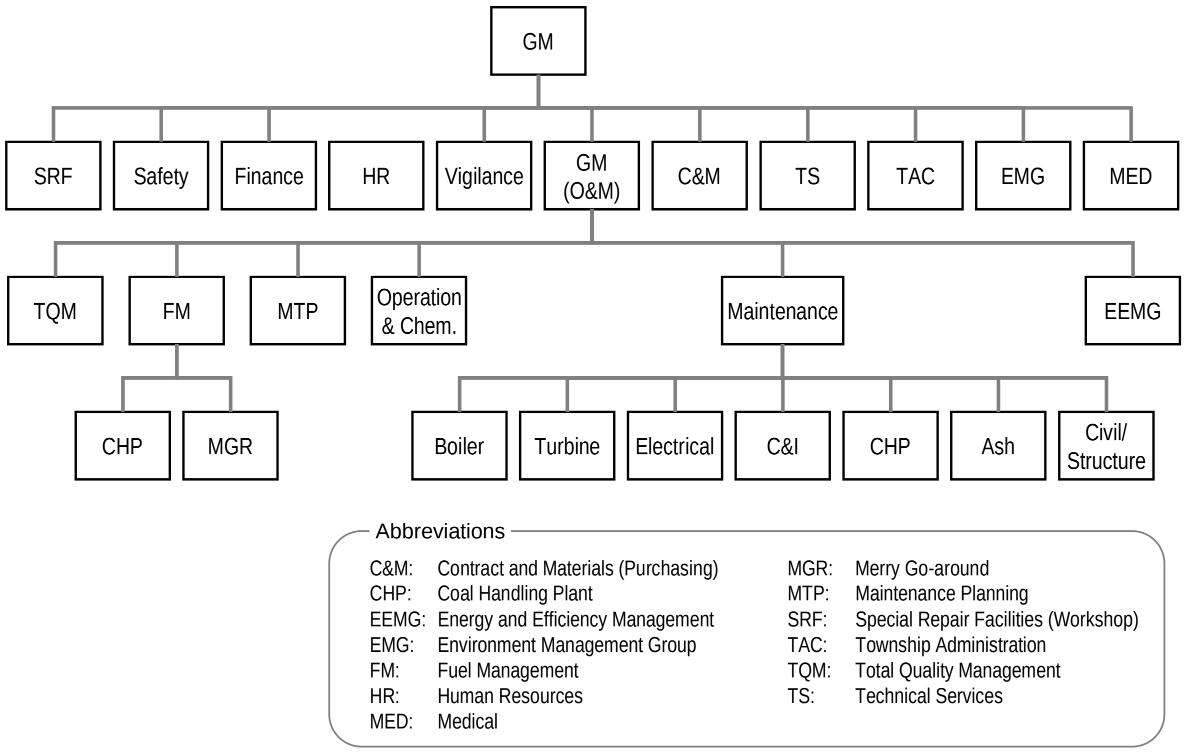


Fig. 6.14-1 Typical Organization of a Coal Fired Thermal Power Station

(2) Operating system

1) Operating personnel

Operating personnel are composed of the operators who operate and monitor operations from centralized control rooms and the local operators who operate and monitor operations of equipment on site. They are engaged in operating and monitoring 24 hours a day in three shifts from ① 6:30 to 13:30, ② 13:30 to 21:30 and ③ 21:30 to 6:30. The number of operators differs at each of the candidate Units. These power stations have a system that allows operating personnel to back up other shifts for start-ups and shutdowns and in the event of trouble.

Local operators conduct patrols to check equipment grouped into boilers, turbines, electric equipment, control & instrumentation and other types of equipment (BOP) at the start, in the middle and at the end of work in each shift, and also as needed.

(3) Maintenance System

These power stations maintain equipment under a system that divides the equipment into boilers, turbines, electric equipment, control & instrumentation, coal conveying equipment, ash disposal equipment, maintenance planning, and construction and civil engineering. With engineers working as maintenance managers, and supervisors and technicians working under the managers, the power stations handle almost all actual maintenance work internally, such as insulation, replacement of equipment, calibrating measuring instruments, inspecting and repairing printed circuit boards, and replacing consumable parts. They have excellent workshops, labs and spare parts system.

The India Boiler Regulations (IBR) requires boilers to be inspected every year, but there is no regulation on periodic inspections of turbines. NTPC conduct periodic inspections on turbines every four to six years. NTPC also conduct internal inspections of generators every three to six years to minimize plant shutdowns in consideration of inspection frequencies recommended by generator manufacturers and turbine inspection timings.

(4) Efficiency Management System

The Energy and Efficiency Management Group (EEMG) of each power station manages the energy and efficiency matters of the power station. The group conducts performance tests of each unit in the power station and possess measuring equipment and instruments required for the tests. (Japanese electric utilities outsource performance test field works, especially exhaust gas measurements, to specialized service providers.) The EEMG also summarizes and analyzes daily operation data of the power station to maintain or improve efficiency.

Each power station conducts performance tests according to the guidelines standardized under the ASME standard.

Power station performance tests are conducted at the following frequencies:

Boilers : Every month
Turbines
Heat rate : Every month
High-and medium-pressure internal turbine efficiency : Every six months
Condensers : Every month
Air heaters : Every three months
Plant performance test : Before and after each periodic inspection

(5) Power Station Management systems

NTPC mainly uses the following power station management systems: ISO9001 (quality control), ISO14001 (environmental management), OHSAS 18001 (occupational health and safety management system), 5 S's (Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization), and Shitsuke (discipline)), CMMS, PdM, the spares parts system, the know-how sharing system and the work improvement suggestion system.

Table 6.14-1 Comparison Table for Power Station Management system

Item	NTPC	Japanese electric utilities
ISO9001	Already applied	Already applied
ISO14001	Already applied	Already applied
5 S's (Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization), and Shitsuke (discipline))	Already applied	This is not applied as a system, but similar activities are conducted in a day to day exercise.
CMMS	Already applied	Already applied
Preventive maintenance (PdM)	Already applied	Already applied
Spares control system	Already applied company-wise	Controlled at each power station
Know-how sharing system (Sharing of case examples of accidents and technical information to other power stations)	Already applied	Already applied
Work improvement suggestion system (feedback system)	Already applied	Already applied

However, its 5 S’s system is not working properly and Study team found some safety and health problems during field works. For example, house keeping in boiler field is not well conducted. Broken pieces of iron plates and wires are scattered about and ash accumulates everywhere. Workers need to wear face masks in dusty critical areas in Japanese power stations. Study team also found many areas where thermal insulating materials and equipment covers/enclosures are not in place.

Although many slogans are posted in the work areas, the 5 S's system are not applied or sufficiently permeated.

6.14.4 Issues and Countermeasures about Operation of Power Generation Equipment

(1) Evaluation of current states

Study team researched operation and maintenance in the candidate units and found that they introduced and utilize management systems similar to those in Japanese electric utilities.

The power stations keep operating close to their maximum loads and reach a load factor of close to or more than 90%. They perform well in spite of using domestic high-ash coal. This indicates that they have established excellent operation and maintenance techniques. However, there is still room for improvement in the more detailed aspects.

(2) Suggestions for improvement

1) Patrols

Patrols enable early detection and repair of problems and thereby achieve highly reliable operation.

Although the NTPC already conducts patrols, Study team suggests the following measures to improve patrol performance in terms of detection of abnormalities and human safety.

a) Patrol kit
b) Use of a hearing bar
c) Marking on indicators
d) Check for seat leaks by using thermo-labels

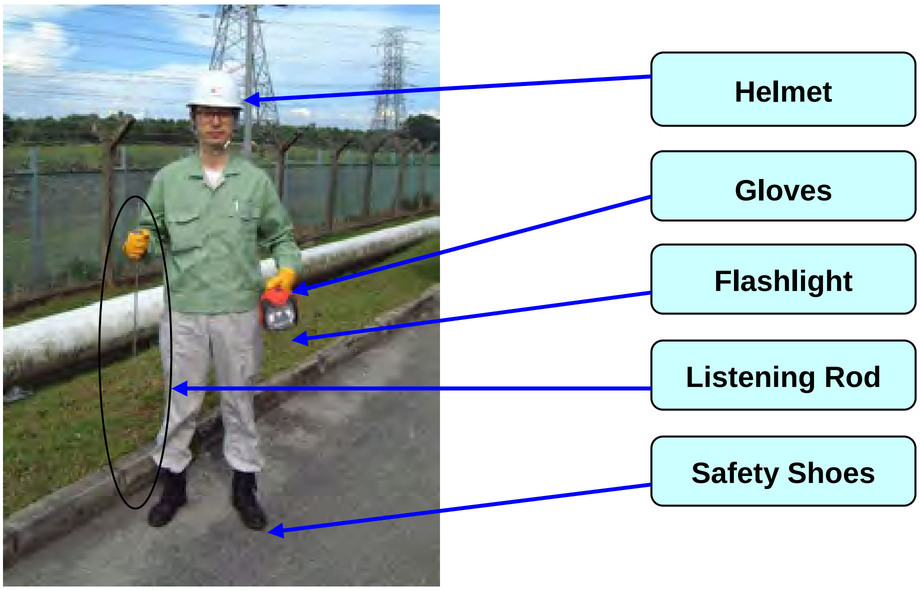


Fig. 6.14-2 Typical Patrol Kit

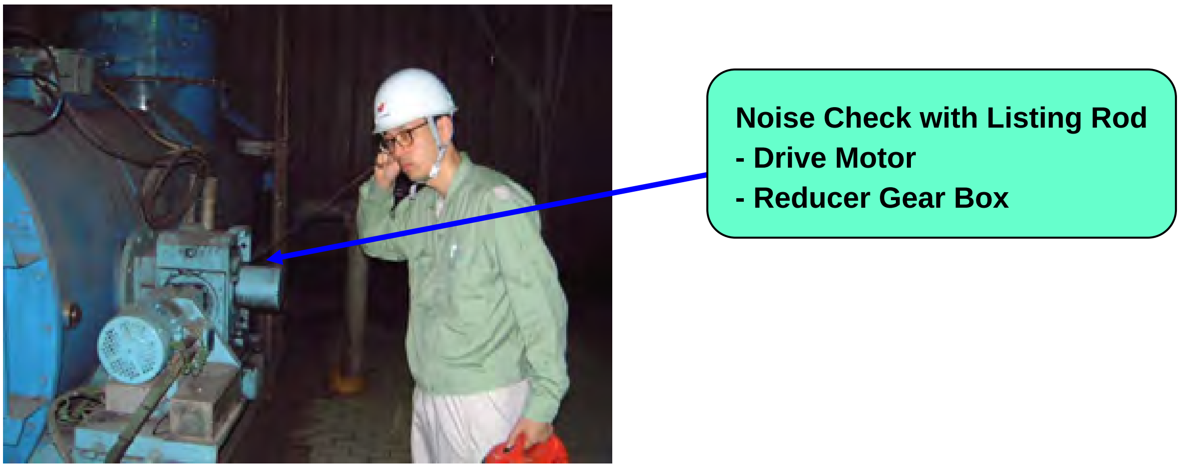


Fig. 6.14-3 Noise Inspection with Listing Rod

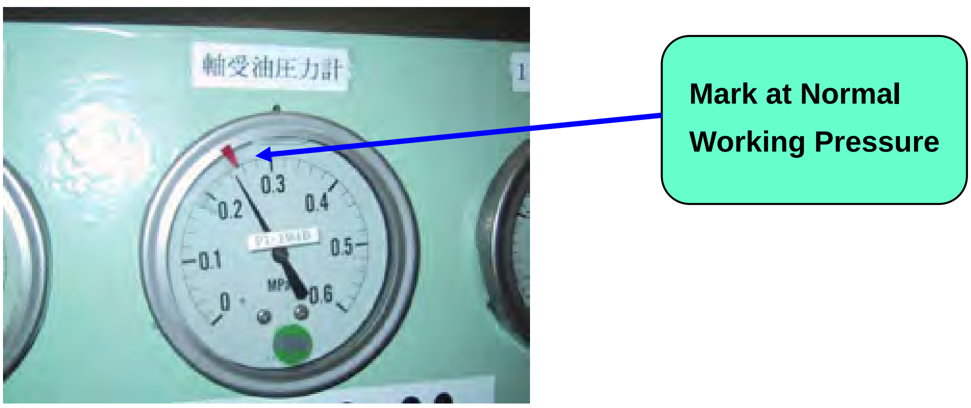


Fig. 6.14-4 Indication of Normal Working Value

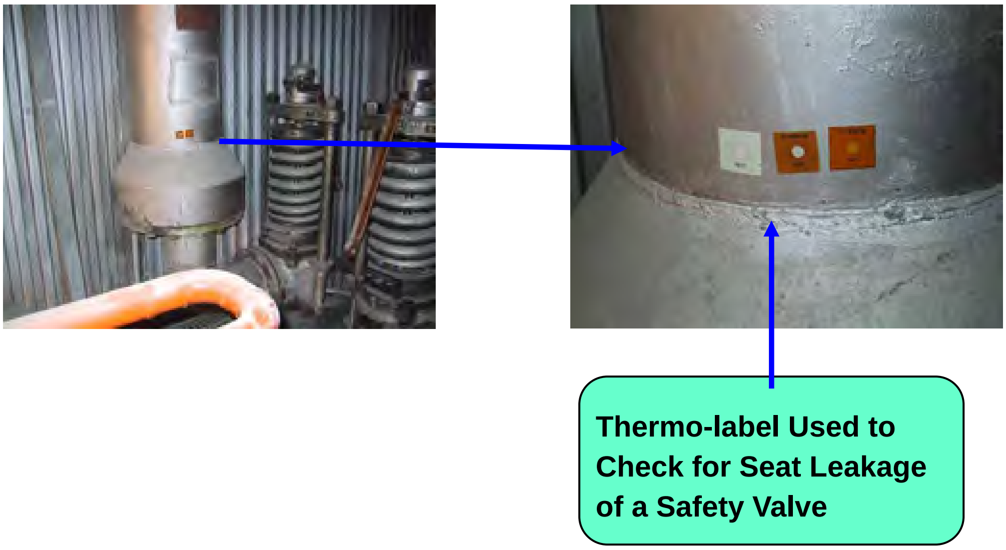


Fig. 6.14-5 Thermo-label

2) Safety management

Pictures with the slogan of safety first are posted on walls in several areas in the power stations. However, there are only a few local operators and workers who wear safety shoes and other safety gear when doing their work. It is advisable to thoroughly educate all employees from managers to workers about the importance of safety and reemphasize the necessity of putting on safety gear for them. Japanese power stations are making efforts to get workers to perform their duties with a consciousness of safety by, for example, assigning safety managers of power stations and subcontractors, providing safety education to all employees from managers to workers using safety manuals when they join power stations, holding KY (Kiken-Yochi, or danger prediction) meetings before starting work every morning, and holding safety manager meetings to check for intricate works among subcontractors.

6.15 Economic and Financial Analysis

6.15.1 Concept

The Economic and Financial Analysis is focused mainly on items that could be expected to give rise to a certain value of economic increment as a result of the proposed technical improvements, which are covered in the technical assessment done by our Study Team.

Concerning the methods used for this Analysis, firstly, we conducted a Cost Benefit Analysis, to evaluate nominal economic value of incremental profit due to the proposed technical improvements. Then, taking into account the Cost of Capital, we attempted to clarify the real value of the investment. In general, the purpose of a study taking into account the cost of capital is to evaluate the investment value of a project, asset, or company in terms of the concept of the time value of money, and this evaluation method is generally called the "DCF" - Discounted Cash Flow Approach.

As an additional study of effectiveness that would arise from the proposed technical improvements, we conducted an evaluation regarding the environmental value added by the reduction of CO_2 emissions.

6.15.2 Scope

During the 3rd phase of field investigation, as an optional idea, we considered the possibilities of carrying out an analysis regarding the economic impact to a whole power plant or a unit. However, due to the difficulties of collecting adequate information for the analysis, we conducted an analysis of the economic impact for each specific item.

In accordance with the technical recommendations, which could be expected to have a certain value of economic increment as assessed by the JICA-ST technical assessment, the scope of the financial analysis was selected as shown in the following table.

Table 6.15-1 Current items for Financial Analysis

Plant (# =Unit)	Korba #6	Singrauli #4	Rihand #2	Unchahar #3
Boiler	Air Heater Renovation (Chapter 6.4)*	Air Heater Renovation (Chapter6.4)*		
Turbine	Turbine Seal Fin Replacement (Chapter 6.13)*	Turbine Seal Fin Replacement (Chapter 6.13)*	Turbine Seal Fin Replacement (Chapter 6.13)*	
Control System				New System for Optimization of Combustion & Soot Blower Installation (Chapter 6.9)*

Note: * References are to technical improvement proposals in this report

6.15.3 Method

We make a comprehensive evaluation of the economic impact (of the proposed technical improvements) with a combination of the following analysis methods: CBA, PO, NPV, IRR and BCR.

6.15.3.1 Assumption

Due to the limitations and difficulties of collecting cost information in India for this analysis, we conduct financial analysis with data that is currently available within our study period because some material or equipment related to technical improvement items are new and not common in India, so that in order to make up for a lack of Indian some local cost information, we supplement it with implementation costs in cases of Japan and other countries. However, under this situation for colleting cost information, as much as possible, this analysis made efforts to use Indian local cost (e.g. calculation of initial installation labor cost by Indian labor rate and a work-hour estimation according to Japanese experience.

Please understand the possibility that different conclusions of financial assessment may be reached in the future based on assumptions at the time of preparation for each actual implementation to be planned by NTPC because the assumption will be directly affected by the differences of Prices, logistics and spec which the supplier can provide. So before the implementation, careful assumption and cost estimation would be essential.

6.15.3.2 Cost Benefit Analysis

The Cost Benefit Analysis (CBA) compares the incremental profit (such as the reduction of fuel costs through plant efficiency improvement) gained by the implementation of the technical improvement with the initial cost of the implementation. If there are any additional expenses or costs caused by the implementation (such as for materials, maintenance and/or scrapping of old equipment), CBA recognizes these things as negative factors for incremental profit.

CBA also considers assessment of lifetime of new equipment. And with "PO" – Payout time, we measure profitability or liquidity of an investment, being the time required to recover an investment.

(1) Image of CBA Method

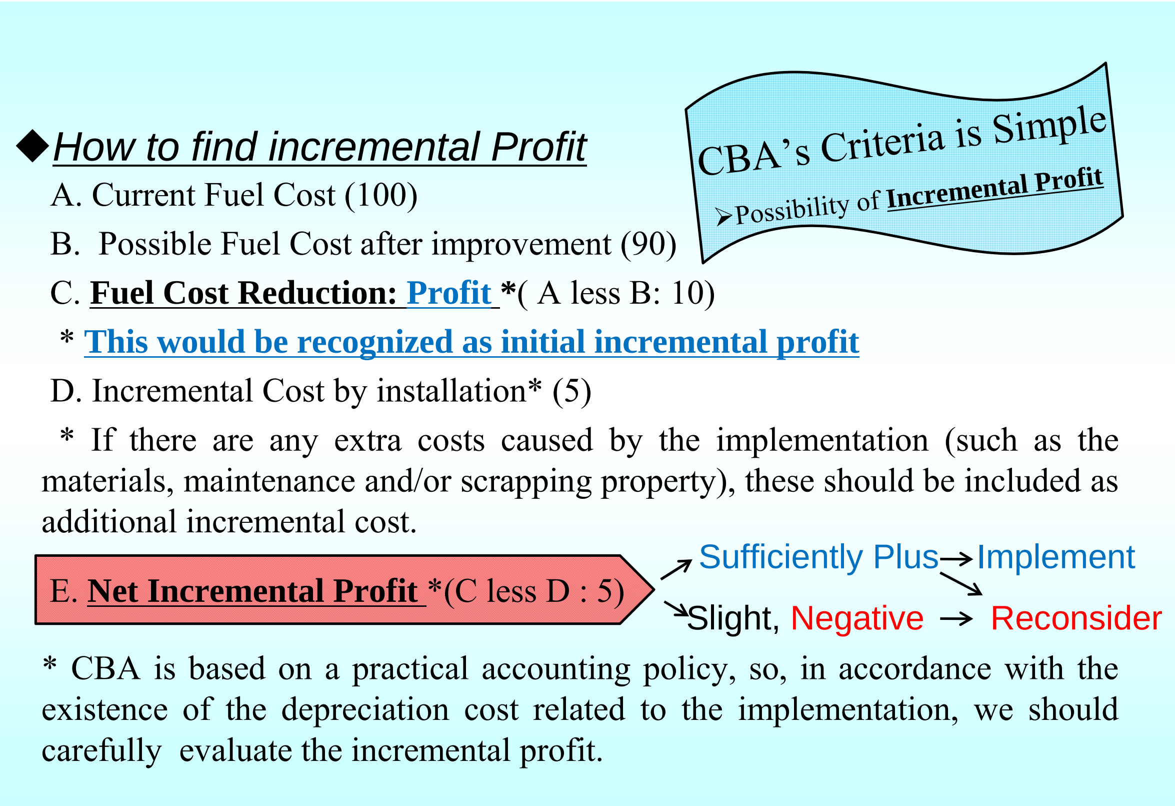


Fig. 6.15-1 Image of the CBA-Cost Benefit Analysis

The Figures above is an image of the CBA-Cost Benefit Analysis. CBA's Criteria is very simple to find a "Possibility of Incremental Profit". Firstly we find a Current Fuel Consumption Cost, and with the "Possible Fuel Consumption Cost due to the improvement of unit efficiency", we deduct it from the current cost. This Fuel Cost Reduction, we recognize as the initial incremental profit. And then, if there are any extra costs due to implementation item (as yearly based), we subtract them from the initial incremental profit. According to the volume of this Net Incremental Profit, we basically evaluate whether each proposal is profitable or not.

(2) CBA Practice

As an example of CBA in practice, we show a case study of Korba #6 - Air Heater Seal Renovation by Sector Plate Drive Unit (SDU).

A. Current Fuel Cost = Generation (kWh) × Fuel Consumption Rate (kg/kWh) × Fuel Unit Price (Rs./kg)

= X (kWh) × Y (kg/kWh) × Z (Rs./kg)

B. Possible Fuel Cost due to improvement of unit efficiency = X (kWh) × Y (kg/kWh) × $\frac{1}{(1+0.5\%)}$ × Z (Rs./kg)

C. Fuel Cost Reduction (= A–B) = **Rs.10,068,920**

D. Incremental Cost of Installation : Rs. 8,103,168

E. Net Incremental Profit (= C–D) : Rs. 1,965,752 (years 1-4)

F. Future Net Incremental Profit : Rs. 10,068,920 (from year 5)*2

Sufficient Return?
In comparison with the implementation cost, incremental profit can cover the cost

*1: This figure was calculated by Capacity and annually-averaged PLF of the power plant
*2: Due to completion of depreciation on the end of year 4

Fig. 6.15-2 Process of evaluating cost benefit by incremental profit

In order for proceeding CBA, as assumptions, we need a current cost and performance data and estimated incremental efficiency ratio with the installation cost. Under the assumptions of current cost and performance data provided by NTPC and the estimated incremental efficiency ratio of 0.5% with the installation cost of Rs.32 million (both figure provided by JICA-ST), we conduct CBA Practice. (a current cost and performance data of NTPC plant would not be disclosed in this report because of the confidentiality)

As a result, this CBA regarding the Air Heater Seal Renovation by SDU at Korba #6 shows that an annual incremental profit of slightly more than Rs.10 million would be expected from year 5 onwards (under the given assumptions).

Furthermore, in order to evaluate more exactly the incremental profit due to implementation of each improvement item, we should recognize degradation effect and lifetime of items. For example, improved boiler efficiency by Air Heater Seal Renovation by SDU would be reduced due to degradation of improvement item itself from 0.43% to 0.41% during the operating period of one and a half years between periodical maintenances. In conversion to plant efficiency, incremental efficiency as a relative value would be decreased from 0.50% to 0.48% in 1.5 years. For convenience of financial evaluation, we simplified the degraded incremental efficiency from a once-every-1.5-years maintenance basis to a once-every-1-year maintenance basis, and finally leveled the value of improved performance based on values at the beginning and the end of an operating period. According to the figure below, the leveled improved performance ratio on the once-every-1-year maintenance basis would come out as 100.495% (average for each year of beginning-100.50% and end-100.49%). Regarding the lifetime of Air Heater Seal Renovation by SDU, it would be expected to be more than 10 years based on experiences in Japan, so we set the evaluation period for Air Heater Seal Renovation by SDU as 10 years.

	Brand-New	1yr later	after maintenance	2 yrs later	after maintenance	3 yrs later
Degradetion of Improved Performance (a)	100.50%	100.49%	100.50%	100.49%	100.50%	100.49%
Degradation Coefficient (r) = a / (100.50%)	1.0000	0.9999	1.0000	0.9999	1.0000	0.9999

Averaged Improved Performance for simulation	1st year	2nd year	3rd year	4th year and following
Average of each year of beginning and end above "a"	100.495%	100.495%	100.495%	(as same as a before..)

Fig. 6.15-3 Degradation of Air Heater Seal Renovation by SDU or FRS at Korba #6

From the chart below, we can visually understand that this technical improvement would be profitable. By this implementation which would be expected to make a 0.5%-efficiency improvement, the unit could expect a Rs. 67 million incremental profit over 10 years and recovery of the Rs. 32.4 million investment in 3.3 years. So if we have no other more cost effective option, we should simply choose this technical proposal as a candidate for practical implementation. This CBA simulation includes the concept of the degradation effect (0.5%-brand-new incremental efficiency converted to 0.495%-leveled degraded efficiency). If degradation of the improvement item is ignored, the unit would show an additional incremental profit of Rs.1.2 million over 10 years.

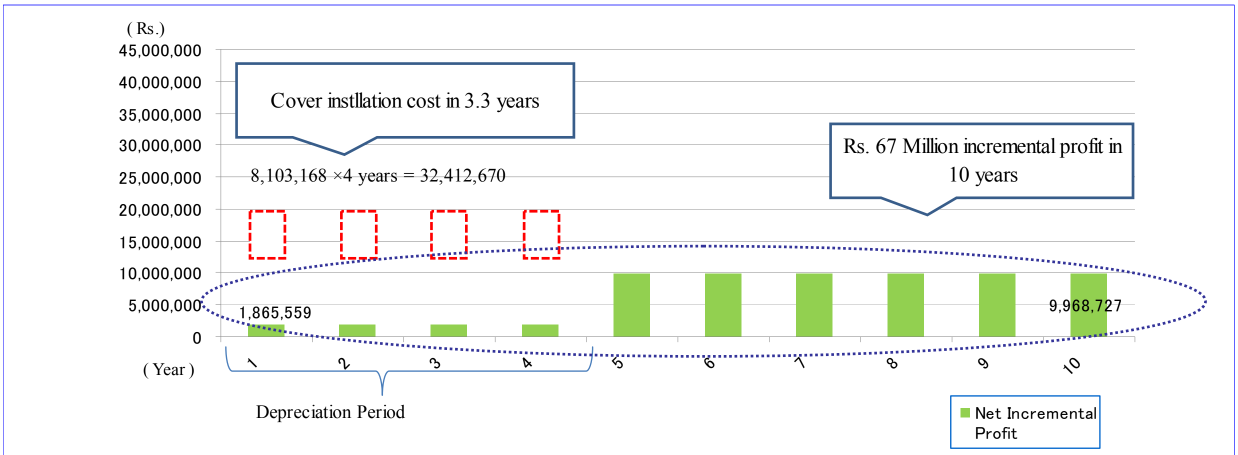


Fig. 6.15-4 Anticipated long term incremental profit with the concept of degradation

6.15.3.3 Sensitivity Analysis

In order to support decision making of implementation with uncertainty in the mid- and long-term, for example, the possibility of fuel price escalation, we provide evaluation in some cases using Sensitivity Analysis.

(1) Sensitivity Analysis Practice

As one possible case, we show a Sensitivity Analysis related to fuel price fluctuation. With the assumption that the fuel unit price escalates at a yearly compound rate of 10%, we estimate the additional incremental value or loss. This is a comparison study with the base case of Korba #6 - Air Heater Seal Renovation by SDU (with no fuel price escalation) as in chapter 6.15.3.2-(2) "CBA Practice", and the case of fuel price escalation. Except for the fuel price escalation factor, all other assumptions are the same for both cases.

According to our analysis, if the fuel unit price escalation is compounded yearly at 10%, the unit can expect a huge cost benefit – incremental profit would be more than 135% up in 10 years (from Rs.9,968,727 to Rs.23,505,736). The cost benefit of comparing the investment and the incremental profit would be almost 4 times. With the Rs.32.4 million investment, the unit can get benefit worth Rs.126.5 million as the incremental profit over 10 years. This sensitivity simulation was conducted taking into account the concept of degradation as we did in chapter 6.15.3.2-(2) "CBA Practice".

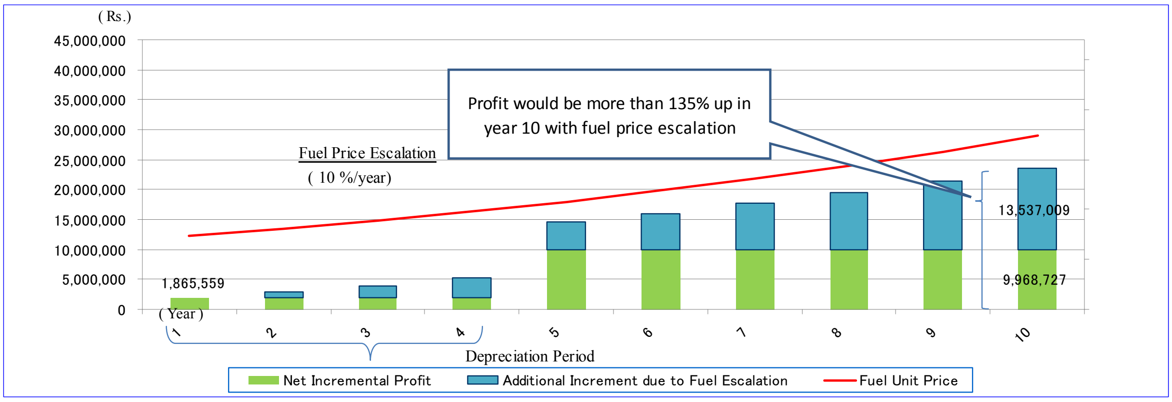


Fig. 6.15-5 Anticipated additional incremental profit due to fuel price escalation

The Sensitivity Analysis suggests that the cost benefit of the implementation proposals with fuel price escalation have the possibility of being much greater than the base case.

6.15.3.4 DCF approach

➢ **NPV**

The value of future cash flows should be discounted using the assumed Cost of Capital. By this "DCF" -Discounted Cash Flow Approach, we can find out the investment value. If the sum of the present values (PVs) of the benefits arising from implementation is lower than the cost of initial investment, we should reconsider the justification of the investment. This is a standard financial analysis method called "NPV" -Net Present Value, to evaluate the excess or shortfall of cash flows, in present value terms, once an investment has been made.

- **IRR**

We also conduct "IRR" – Internal Rate of Return evaluation. IRR is used for the measurement and comparison of the profitability of investments, and IRR also follows from NPV as a function of the rate of return. We compare an anticipated Cost of Capital with a hurdle rate. A rate of return for which this function is zero is an internal rate of return.

IRR is an indicator of the efficiency of an investment Rate and NPV is an indicator of the magnitude of an investment value.

The concept of IRR as given above is simple, however the actual calculation is very difficult, because each year's future value is not fixed but variable. So in general, we use prepared formulas incorporated into spreadsheet software, which work through an automated regression analysis method

- **BCR**

"BCR" – Benefit Cost Ratio is an indicator of the efficiency of an investment. BCR compares all benefits and costs, and should be expressed in discounted present values.

- **Cost of Capital**

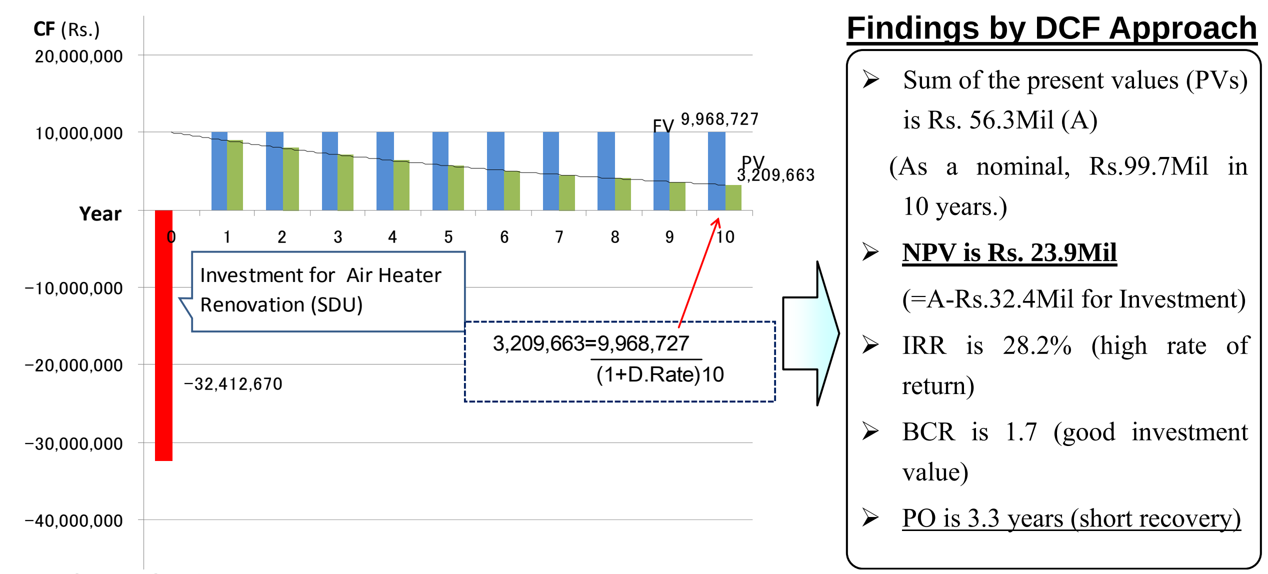
The cost of capital is the cost of a company's finance (e.g. interest on debt and dividend on stock). As a result of discussions about the expected cost of capital in the near future with CenPEEP, following NTPC's suggestion, **we have set the cost of capital as 12% for the following DCF Approach analysis**.

At the 1st Page, NTPC's 33rd Annual Report state the significance of the financial management through control of the cost of capital as the one of the corporate objectives, "(for the financial soundness) to continuously strive to reduce the cost of capital through prudent management of deployed funds, leveraging opportunities in domestic and international financial markets". While making efforts to reduce the cost of capital, we have to pursue profit that can recover the financial cost with a sufficient margin for reinvestment of the future.

(1) DCF Approach in Practice

As an example of DCF Approach in practice, we show a case study of Korba #6 - Air Heater Seal Renovation by SDU (with no fuel price escalation) with the same assumptions of current performance and cost data, and with the same premise of 0.5%-efficiency improvement as in chapter 6.15.3.2-(2)"CBA Practice". As a result of the chapter 6.15.3.2-(2)"CBA Practice" calculation, that technical improvement would be basically profitable (a current cost and performance data of NTPC plant would not be disclosed in this report because of the confidentiality).

However, until we confirm the findings by analysis using DCF Approach method, we can't conclude if the technical improvement would be effective or not with (the incorporation of) the concept of the time value of money.



Air Heater Seal Renovation (by SDU)

Year	0	1	2	3	4	5	6	7	8	9	10
Incremental Profit by Fuel Reduction		10,068,920	10,068,920	10,068,920	10,068,920	10,068,920	10,068,920	10,068,920	10,068,920	10,068,920	10,068,920
Improved Performance with Degra	100.500%	100.495%	100.495%	100.495%	100.495%	100.495%	100.495%	100.495%	100.495%	100.495%	100.495%
Incremental Profit with Degradation	(Brand-New)	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**
Accompanied O&M Cost											
Other Profit or Loss											
Future Cash Flow (FCF)		**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**	**9,968,727**
Investment	**32,412,670**										
Present value of FCF		**8,900,649**	**7,947,008**	**7,095,543**	**6,335,306**	**5,656,523**	**5,050,467**	**4,509,346**	**4,026,202**	**3,594,823**	**3,209,663**
Discount Rate	**12.0%**										
IRR	**28.2%**										
NPV	**Rs. 23,912,861**										
POA	**3.3 years**										
BCR	**1.7**										

Fig. 6.15-6 Evaluation of long term incremental profit by DCF approach

The figures above that result from an analysis by DCF Approach methods indicate that the Air Heater Seal Renovation by SDU investment proposal at Korba #6, under the conditions of a 0.5%-efficiency improvement and a 12%-cost of capital during the operation period, would be very profitable.

6.15.3.5 Conclusion - the Economic and Financial Analysis

In order to provide further supporting information so the most cost effective improvement items can be chosen, we conduct Comparative Analysis regarding each result of the Cost Benefit Analysis and DCF Approach Analysis as shown the chart below. Careful individual evaluation for each item is necessary.

However, because business resources, especially cash for capital expenditure are limited, we should conduct financial management with the concept of the leverage effect (i.e. Cost Benefit Analysis in comparison with the magnitude of each implementation cost). On the other hand, from the perspective of the business environment, there seem to be uncertainties that increase rapidly with time, which

means that on a case-by-case basis, we should chose options with short recovery times, in comparison with others, even if these are less profitable.
Capacity of the plant unit (i.e. at Korba#6: 500MW, at Singrauli#4: 200MW) is one of the most important factors which would effect profit creation. For example, even though the efficiency improvement ratio of Air Heater Seal Renovation by FRS at Singrauli #4 is higher than that for Korba #6 with the same installation cost, the proposal at Singrauli #4 would not cover its installation cost, and result in NPV of negative. This is because the cost benefit derived from fuel cost reduction would be affected by the capacity of the plant unit and/or plant load factor (PLF). In the case of NTPC plants, generally the PLFs are almost at the same high rates due to overload response to high electricity demand in India, so in particular the capacity would affect the earnings of incremental profit on a similar amount of investment.

If we can make the order of implementation results of the financial management analysis above, the first option would be Turbine Seal Fin Replacement at Rihand #2, and the Second option would be Air Heater Seal Renovation by SDU at Korba #6, then by FRS at Korba #6. This is because, the first one could be expected to realize sufficient NPV with a lesser amount of investment in 6 years and the other 2 options of Air Heater Seal Renovation by SDU and by FRS could realize relatively big NPV with longer recovery period of 10 years and more amount of investment in comparison with the first one.

Of course, if the company has sufficient cash to implement all improvement items which are “Excellent” or “Good”, unless there are specific issues which we should consider for the investment, we can choose improvement items to suit the needs of each plant.

Table 6.15-2 Comparative Analysis Table of "Economic and Financial Analysis"

Plant Unit		Korba #6 500 MW	Singrauli #4 200 MW	Rihand #2 500 MW	Unchahar #3 210 MW
Items		Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Turbine Seal Fin (TSF)	System for Optimization(CI)
Assumption	Lifetime of Improvement Item	(AH-S) *10 years* (AH-F) *10 years* (TSF) *6 years*	(AH-S) *10 years* (AH-F) *10 years* (TSF) *6 years*	(TSF) *6 years*	(CI) *10 years*
Assumption	Installation Cost *(Relative Value)*	(AH-S) medium (AH-F) medium (TSF) medium	(AH-S) medium (AH-F) medium (TSF) low	(TSF) low	(CI) high
Assumption	Accompanied O&M Cost	(AH-F) low	(AH-F) low	—	(CI) high
CBA (Cost Benefit Analysis)	Net Incremental Profit(Relatively)	(AH-S) big (AH-F) big (TSF) small	(AH-S) medium (AH-F) medium (TSF) small	(TSF) medium	(CI) negative
CBA (Cost Benefit Analysis)	POA	(AH-S) 3.3 years (AH-F) 3.9 years (TSF) 4.1 years	(AH-S) 5.6 years (AH-F) 7.0 years (TSF) 1.2 years	(TSF) 1.2 years	(CI) NA
DCF (Discounted Cash Flow Approach Analysis)	Discount Rate (Cost of Capital)	12%	12%	12%	12%
DCF	**NPV**	(AH-S) big (AH-F) big (TSF) **negative**	(AH-S) small (AH-F) **negative** (TSF) small	(TSF) medium	(CI) **negative**
DCF	**IRR** (Excess 12% :profitable)	(AH-S) much higher than 12% (AH-F) much higher than 12% (TSF) less than 12%	(AH-S) higher than 12% (AH-F) less than 12% (TSF) much higher than 12%	(TSF) much higher than 12%	(CI) NA (IRR is negative)
DCF	BCR	(AH-S) more than 1 (AH-F) more than 1 (TSF) less than 1	(AH-S) more than 1 (AH-F) less than 1 (TSF) more than 1	(TSF) more than 1	(CI) NA (BCR is negative)
Financial Comments		(AH-S) Huge NPV, IRR much higher than 12% stands for "Good Investment". Short recovery (POA:3.3), No accompanying cost <u>Excellent</u>	(AH-S) A certain volume of NPV, IRR little higher than 12% stands for "acceptable". Recovery Period is not Short (POA:5.6), No accompanying cost <u>Good</u>	(TSF) Goodly volume of NPV, IRR much higher than 12% stands for "Good Investment". Rapid Recovery (POA:1.2), No accompanyng cost <u>Excellent</u>	(CI) Due to huge installation cost and expensive accompanying maintenance fee, this item would not be a profitable. Even after depreciation period, incremental profit and NPV would be negative
		(AH-F) Huge NPV, IRR much higher than 12% stands for "Good Investment". Short recovery (POA:3.9), No accompanying cost <u>Excellent</u>	(AH-F) NPV is Negative, so it could not be Recommended. If we make some practical efforts (e.g. Reduction of installation cost by20%, and/or extend life time), NPV would be positive and we might choose this proposal.		
		(TSF) NPV is Negative, so it could not be Recommended. If we make some practical efforts (e.g. Reduction of installation cost by20%, and/or extend life time), NPV would be positive and we might choose this proposal.	(TSF) A certain volume of NPV, IRR much higher than 12% stands for "Good Investment". Rapid Recovery (POA:1.2) <u>Good</u>		

Color stands for the level of recommendation by Financial view point (reference purpose)

[light blue]	Excellent	(Huge return(NPV) and the rapid recovery of the installation cost would be expected)
[green]	Good	(Sufficient return(NPV) and the short time recovery of the installation cost would be expected)
[yellow]	Not recommended	(Huge installation and/or accompanying cost in comparison with a incremental profit)

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Kyusyu Electric Power Co., Inc.
The Chugoku Electric Power Co., Inc.

6.15.4 Environmental Value Added Analysis

We conduct an evaluation regarding the environmental value added by the reduction of CO_2 emissions. The method for this analysis is simple and similar to the one used for the cost benefit analysis in chapter 6.15.3.2 "Cost Benefit Analysis". Furthermore, we evaluate total CO_2 Emission reduction in each item's lifetime with due regard for degradation effect using the same Degradation coefficient as of chapter 6.15.3.2-(2) "CBA Practice" as follows,

Formula

Formula

CO_2 Emission/Unit (kg-CO_2/kWh) =

Fuel Consumption Rate(kg / kWh) × Carbon Content of Fuel (%) × Relative Atomic Weight (44/12)

CO_2 Emission (kg-CO_2) = CO_2 Emission/Unit (kg-CO_2/kWh) × Generation (kWh)

Fig. 6.15-7 Formulas for Calculating CO_2 Emission per Unit and in Total

Cost Benefit for Emission Reduction (CBER)

Cost benefit for CO_2 emission reduction (CBER) is calculated by dividing the cost of investment (If there are any accompanying incremental costs or expenses due to the implementation, they would be considered as part of the cost of investment) by the volume of the emission-reduction.

CBER also considers the lifetime of each improvement item (i.e. for Air Heater Seal Renovation, 10 years, Turbine Seal Fin Replacement, 6 years). Firstly we estimate the total volume of CO_2 Reduction that could be achieved by each improvement item over its lifetime. Then, in order to evaluate the CO_2 reduction efficiency of the unit, we calculate CBER per year and compare each item's cost benefit for CO_2 reduction.

Cost benefit for Emission reduction = Investment / CO_2 Reduction

6.15.4.1 Conclusion - Environmental Value Added Analysis

This chart below is the Comparative Analysis Table of "Environmental Value Added Analysis". This is provided for making a comprehensive evaluation in terms of the environment (CO_2 Emission Reduction) with a combination of the magnitude (t-CO_2 for a period) and cost benefit unit (t-CO_2/Rs.).

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The Chugoku Electric Power Co., Inc.

Table 6.15-3 Comparative Analysis Table of "Environmental Value Added Analysis"

Plant Unit	Korba #6 500 MW	Singrauli #4 200 MW	Rihand #2 500 MW	Unchahar #3 210 MW
Items	Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Turbine Seal Fin (TSF)	System for Optimization(CI)
Assumption: Lifetime of Improvement Item	(AH-S) *10 years* (AH-F) *10 years* (TSF) *6 years*	(AH-S) *10 years* (AH-F) *10 years* (TSF) *6 years*	(TSF) *6 years*	(CI) *10 years*
Assumption: Installation Cost *(Relative Value)*	(AH-S) medium (AH-F) medium (TSF) medium	(AH-S) medium (AH-F) medium (TSF) low	(TSF) low	(CI) high
Assumption: Accompanied O&M Cost	(AH-F) low	(AH-F) low	—	(CI) high
CO2 Reduction *(for lifetime)* *(Relative Value)*	(AH-S) big (AH-F) big (TSF) small	(AH-S) medium (AH-F) medium (TSF) small	(TSF) small	(CI) medium
Reduction Cost Rate *(Rs./t-CO2)* *(Relative Value)*	(AH-S) low (AH-F) low (TSF) high	(AH-S) low (AH-F) medium (TSF) low	(TSF) medium	(CI) high
Financial Comments	(AH-S) With a goodly volume of Reduction, Cost is relatively lowest Excellent (AH-F) With a goodly volume of Reduction, Cost is relatively low Excellent (TSF) Although a small volume of Reduction, Cost is relatively expensive Careful examination about the cost-balance would be necessary.	(AH-S) With a certain volume of Reduction, Cost is relatively low Good (AH-F) With a certain volume of Reduction, Cost is relatively medium Good (TSF) Although a small volume of Reduction, Cost is relatively low Good	(TSF) Although a small volume of Reduction, Cost is relatively medium Good	(CI) Although a certain volume of Reduction, Cost is relatively expensive Careful examination about the cost-balance would be necessary.

6.16 Application of CDM

In order to answer high expectations of NTPC regarding the application of CDM, we present specific and accurate information on climate change and global warming. We committed the work of preparation of PDD for the application of CDM to an experienced consultant.

6.16.1 Outline of CDM

(1) The Kyoto protocol

In order to assist the Parties to achieve their GHG emission reduction targets, the Kyoto protocol defines three innovative "flexibility mechanisms" including CDM to lower the overall costs to meet the targets.

(2) Outline of CDM

The purpose of CDM is to assist to accomplish the GHG emission reduction targets of Annex I Parties (investing countries) under the Kyoto Protocol, as well as to contribute to sustainable development of non- Annex I Parties (host countries).

(3) CDM Project Cycle

The procedures include a third-party assessment by DOE through processes called validation and verification, final approval of project registration and issuance of CERs by the EB.

(4) Preparation of PDD

Project participants shall prepare PDD and shall submit PDD for validation and registration.

(5) Selection of Methodology

Project participants, when preparing PDD, shall select whether adaptation of approved Methodology (Large Scale and Small Scale) or development of new Methodology.

6.16.2 Implementation of Preparation of PDD Draft

(1) Commission of the work of Preparation of PDD Draft

We committed the work of Preparation of PDD Draft to Ernst & Young Pvt .Ltd.

(2) Thermal power generation units and energy efficiency improvement measures

Thermal power generation unit	Proposed energy efficiency improvement measures	
	Initial measure proposed	Final measures selected
Singrauli #4	Air heater performance improvement	Air heater performance improvement
	Turbine seal fin replacement	—
Korba #6	Air heater performance improvement	Air heater performance improvement
	Turbine seal fin replacement	—
Rihand #2	Turbine seal fin replacement	BFP performance improvement

(3) Application of Small Scale CDM

We originally thought that we would apply Large Scale Methodologies. However, considering scales of emission reductions estimated based on the proposed improvement measures and NTPC's request, we changed to apply Small Scale Methodologies, AMS II.B (Supply side energy efficiency improvements-generation), instead of Large Scale Methodologies for three PDDs.

By applying Small Scale CDM, we can utilize simplified modalities and procedures.

6.16.3 Summary of PDD Draft

(1) Singrauli #4

1) Summary of Small scale project activity

   a) Title of the Small Scale project activity
   b) Description of the Small Scale project activity
   c) Project participants
   d) Technical description of the Small Scale project activity

2) Application of a baseline and monitoring methodology

   a) Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity
   b) Justification of the choice of the project category
   c) Description of the project boundary
   d) Description of Baseline and its development
   e) Description for demonstrating Additionality

3) Duration of the project activity/ crediting period

4) Environmental impact assessment

5) Stakeholders' comments

(2) Korba #6

1) Summary of Small scale project activity

   a) Title of the Small Scale project activity
   b) Description of the Small Scale project activity
   c) Project participants
   d) Technical description of the Small Scale project activity

2) Application of a baseline and monitoring methodology

   a) Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity
   b) Justification of the choice of the project category
   c) Description of the project boundary
   d) Description of Baseline and its development
   e) Description for demonstrating Additionality

3) Duration of the project activity/ crediting period

4) Environmental impact assessment

5) Stakeholders' comments

(3) Rihand #2

1) Summary of Small scale project activity

   a) Title of the Small Scale project activity
   b) Description of the Small Scale project activity
   c) Project participants
   d) Technical description of the Small Scale project activity

2) Application of a baseline and monitoring methodology

   a) Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity
   b) Justification of the choice of the project category
   c) Description of the project boundary
   d) Description of Baseline and its development
   e) Description for demonstrating Additionality

3) Duration of the project activity/ crediting period

4) Environmental impact assessment

5) Stakeholders' comments

   The local stakeholders' consultation was not implemented according to request of NTPC.

6.16.4 Planning of schedule of preparatory works for CDM procedure for submission and approval

(1) The way forward for the identified CDM projects

1) CDM Documentation
2) Host country approval prior to request for registration
3) Validation by DOE
4) Registration of project with UNFCCC

(2) Coordination Team

1) Coordinating with the CDM consultant to provide data and reply to clarifications
2) Coordinating with the validator (DOE), EB as and when required
3) Ensuring proper implementation and compliance of monitoring and data archiving procedures, for the parameters mentioned in the PDD

(3) CDM Transaction Cost

1) Consultant Fee: Fixed fee and success fee
2) Validation Fee (one time)
3) UNFCCC registration fee (one time)
4) UNFCCC Issuance fee (at every issuance)
5) Verification fee (for every verification)

(4) CDM – Indian Experience

1) The total Number
2) The reasons for longer time duration for successful registration
3) Critical points
    a) Prior consideration of CDM
    b) Baseline Data
    c) Demonstration of Additionality
    d) Monitoring Procedures

6.17 Recommendation

The attached table shows recommendation plan of study items.

Table 6.17-1 Recommendation Plan of Study Items (1/5)

Efficiency | Reliability | Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
1	Location (State)	Chattisgarh	UP	UP	MP	UP
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210
3	Turbine Make	KWU	#4 LMZ #6 KWU	#2 GEC	KWU	KWU
4	Boiler Make	BHEL	BHEL	#2 ICL	BHEL	BHEL
5	Overhaul Scope	B+IP+LP	#4: B+HP+(IP)+LP #6: B+LP	#2 B+IP+LP	B	#3 B+HP+IP #2 B+LP
6	Age	#4 1987, #6 1989	#4 1983, #6 1986	#2 1989, #3 2004	1999	#3 1999, #2 1989
7	Shut down period	#4 9 Mar – 12 June 2010	#4: 27 May - 10 July 2010 #6: 18 Oct - 11 Nov 2009	#2: 10 July - 18 Aug 2010	18July - 16Aug 2009	#3: 1 Sep - 5 Oct 2009 #2: 18 Oct - 11 Nov 2009
8	Diagnosis of boiler problem	—	—	—	**RESULT** - Current heat absorption in furnace is still high after addition of wall SH. - Exhaust gas flow at outlet of radiant superheater is expected to be not uniform. **RECOMMENDATION** - Add Wall SH left and right sides of furnace. - Apply the cross-connecting pipes between Division SH and Platen SH.	—
9	Combustion simulation	—	—	—	**RESULT** - The combination of lower levels mill (ABCDEFGH) operation and minus 10 degree burner tilt is the best condition for mitigation of flue gas right/left temperature imbalance without modification of pressure parts. - It was found that heat absorption at furnace is high compared to design value. When the burner tilt turns up, heat absorption in the furnace will be reduced. This may improve low MS and RH steam temperature matters. **RECOMMENDATION** - Carry out trial operation by applying the best parameters written above to the current boiler. For further mitigation of temperature imbalance, modify the boiler by applying the cross-connecting pipes between Division SH and Platen SH. - To increase SH and RH steam temperature, remove front Division SH, and add the same heating surface to rear Division SH by modification of rear Division SH. In addition, apply wall SH at left and right sides of furnace where Division SH is located. Removal of front Division SH is also effective for mitigation of temperature imbalance.	—

Table 6.17-1 Recommendation Plan of Study Items (2/5)

Efficiency | Reliability | Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
10	Boiler RLA	—	**#6** **RESULT** - As a whole, creep damage was not remarkable with no creep void and creep strain observed in each evaluated component. - Residual life of desuperheater was estimated to be 100,000, which was minimum among tested boiler pressure parts and headers. - Residual life of main steam pipe was estimated to be 21,000 hours. - Thickness decrease by erosion and attrition were observed in water wall tubes and SH tubes respectively. **RECOMMENDATION** - Implement RLA including outer diameter measurement and replica for main steam pipe again before reaching 21,000 hours, and preferably periodically later on. - Alternative standard criteria for tube replacement such as tsr (Thickness Shell Required) can be considered. In Japan boiler tube replacement is based on calculations of tsr which is a function of allowable stress, design pressure & design OD. NTPC can also consider the use of such criteria in consultation with OEM rather than the method of thickness decrease ratio from design thickness. - Conduct RLA focusing or emphasizing on critical parts after identification of critical ones by considering creep life instead of all high temperature & pressure parts, which NTPC focuses on currently. - For implementation of new RLA technology, training in Japan is recommended such as SUS scale detection, TOFD inspection and evaluation of metallurgical deterioration using SEM &TEM.	—	—	**#2** **RESULT** - As a whole, creep damage was not remarkable with no creep void and creep strain observed in each evaluated component. - Residual life of final superheater tube was estimated to be 35,000 hours, which was minimum among tested boiler pressure parts and headers. - Residual life of main steam pipe was estimated to be 69,000 hours in coarse grain HAZ region. The estimated residual life in base metal varies from 8,000 to 130,000 hrs due to no OD measurements applied, while microstructure shows a little degradation. - Thickness decrease by erosion was observed in water wall tubes. **RECOMMENDATION** - For accurate estimation of residual life of main steam pipe, creep strain (OD) measurement along with microstructure is recommended to be carried out preferably within 8,000 hrs or practically at the earliest opportunity. - Alternative standard criteria for tube replacement such as tsr (Thickness Shell Required) can be considered. In Japan boiler tube replacement is based on calculations of tsr which is a function of allowable stress, design pressure & design OD. NTPC can also consider the use of such criteria in consultation with OEM rather than the method of thickness decrease ratio from design thickness. - Conduct RLA focusing or emphasizing on critical parts after identification of critical ones by considering creep life instead of all high temperature & pressure parts, which NTPC focuses on currently. - For implementation of new RLA technology, training in Japan is recommended such as SUS scale detection, TOFD inspection and evaluation of metallurgical deterioration using SEM &TEM.
11	AH performance improvement	**#6** **Primary AH** **RESULT** - Air leak of A-AH and B-AH is higher than the design value. Leakage air greatly affects AH outlet gas/air temperature. - Imbalance in outlet temperature between Primary AH and Secondary AH is observed and this is assumed to be caused by gas flow imbalance between them. - AH cold end metal temperature is lower than dew point temperature of 66 degree C. This seems to be caused by large air leak in PAH and low gas flow rate in Primary AH due to imbalance between Primary AH and Secondary AH. **RECOMMENDATION** - Improve seal performance applying SDU or Floating Radial Seals. - In addition to guide vane flow regulation, study the possibility of gas duct re-arrangement considering vacant space around AHs for substantial measure against imbalance gas flow between Primary and Secondary AHs. - Confirm AH cold end metal temperature after applying the above measures. - Furthermore, for better O&M, review the current field activities of periodic inspection for AH by utilizing supervisors from licenser of OEM.	**#4** **RESULT** - Air leakage of A-AH and B-AH is higher than the design value. Leakage air greatly affects AH outlet gas/air temperature. - Temperature efficiency is lower than design. This seems due to low heat exchange performance of AH element and/or insufficient soot blowing operation. **RECOMMENDATION** - Improve seal performance applying SDU or Floating Radial Seals. - Collect the historical data such as AH inlet/outlet air/gas temperature and soot blowing operation from just after periodical inspections in order to evaluate AH heating element heat transfer condition for improvement of low temperature efficiency of AH. - Furthermore, for better O&M, review the current field activities of periodic inspections for AH by utilizing supervisors from licenser of OEM.			

Table 6.17-1 Recommendation Plan of Study Items (3/5)

Efficiency Reliability Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
12	Turbine RLA	#4 RESULT - The unit is generally in good conditions. - No significant defect is observed in turbine and piping. - Remaining life of IP rotor is estimated to be 16 years. Remaining life of IP casing, LP rotor, LP casing is estimated to be more than 20 years. - Remaining life of MS piping is estimated to be more than 20 years, and HRH piping to be 13.6 years. - According to Steam Path Audit, 90% of losses of turbine (output & heat rate) are come from surface roughness. RECOMMENDATION Turbine - Carry out inspection and microstructure analysis of stressed location at next overhaul. - Carry out cleaning of blade surface at next overhaul. - For IP turbine, carry out RLA in 5 years. - LP last stage rotating blades need to be replaced. Piping - For MS piping, carry out micro structure analysis, thickness measurement, strain mequrement EMAT for stressed location at next overhaul. - For other piping, carry out inspection in 5 years. - Indicated hangers need to be corrected.				
13	Condenser assessment	—	#6 RESULT - Air ingress from gland seal packing of both A-BFPT and B-BFPT were 44% and 21% of total ingress measured respectively. RECOMMENDATION - Inspect these area and conduct necessary repair.	—	—	—
14	Pump assessment	#6 BFP-6B RESULT - Pump efficiency is decreased from the design value. RECOMMENDATION - Refurbish inner parts of the pump after economic evaluation. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	CWP Stage-I 09 RESULT - Pump efficiency is decreased from the design value. RECOMMENDATION - Refurbish inner parts of the pump after economic evaluation. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	#2 BFP-2B RESULT - Pump efficiency is decreased from the design value. RECOMMENDATION - Refurbish inner parts of the pump. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps. CWP-2B RESULT - Pump is considered to be in acceptable condition. RECOMMENDATION - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	—	—

Table 6.17-1 Recommendation Plan of Study Items (4/5)

Efficiency | Reliability | Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
15	Control system assessment	—	—	—	—	#3 RESULT - No problems were observed including load ramp test while part of the operation mode was not in automatic but in manual mode. - Instruments were operating normally and no particular problems were observed, including their operating conditions, calibration method and spare part management in the C&I laboratory. - Extremely high level has been achieved in the fields of control and instrumentation (C&I) RECOMMENDATION - For further improvement in plant efficiency and reliability, introduction of latest technologies may be required. - To reduce frequent boiler tube leakage incidents, optimization of combustion and soot blow operation is recommendable in addition to refurbishment of boiler pressure parts and verification of operation parameters which may be recommended by observation in each sector.
16	Generator assessment	#6 RESULT - Insulation diagnosis could not be evaluated because appropriate data was not available. RECOMMENDATION - Carry out the tests in the condition that the stator cooling water is properly drained and dried out.	#4 RESULT - Current stator insulation of the generator is in good condition considering PI data of more than 2.0 - B phase PI data fluctuates without trend of deterioration while R and Y phase PI data decreases along with operation time - Tanδ of Y phase becomes smaller when the test voltage increases contrary to the theoretical behavior. RECOMMENDATION - Conduct insulation diagnosis test for each phase periodically in the future and monitor trend of deterioration. - For Tanδ test, review test data enough in order to get proper data.	#2 RESULT - Current stator insulation of the generator is in good condition with preferable Average PI data of 3.7 being in the normal range of over 2.0. RECOMMENDATION - Conduct the insulation diagnosis periodically in the future and grasp the deterioration trend because Rihand#2 generator is 20 years old and Japanese technical book reports that stator coil insulation strength of generator might accelerate its deterioration faster after 20-25 years operation.	—	—
17	Transformer assessment	#6 RESULT - Estimated total lifetime is 39 to 54 years, and 38 to 56 years based on $CO+CO_2$ analysis and furfural analysis respectively. RECOMMENDATION - Review test data enough and get proper test data because some data are inconsistent from technical point of view. - Conduct furfural test periodically so that Korba#6 can grasp furfural generation trend and improve the accuracy of the RLA because the test was conducted only once.	#6 RESULT - It is estimated that the GT condition had already reached to Average lifetime point in 2005 (18 years operation) and will reach to Dangerous level in 2019 (33 years operation) according to RLA by $CO+CO_2$ analysis. - There is big difference in furfural data between 2006 and 2008 while no big difference in DGA during the period. RECOMMENDATION - For confirmation of actual GT condition, sample the insulation paper and measure DP. If sampling the insulation paper is difficult, options such as conducting DGA with shorter interval to monitor trend and evaluating furfural analysis with proper test data may be taken. - As for furfural, check theoretical consistency of the data and get proper test results.	#2 RESULT - Estimated total lifetime is 24 to 26 years. RECOMMENDATION - For confirmation of actual GT condition, sample the insulation paper and measure DP. If sampling the insulation paper is difficult, options such as conducting DGA with shorter interval to monitor trend and evaluation of furfural analysis with proper test data may be taken. - As for furfural, check theoretical consistency of the data and get proper test results.	—	—
			RESULT - Insulation oil treatment is often conducted due to moisture increase in oil. RECOMMENDATION - Conduct cooler leak check and take the countermeasures if there is a leak.	RESULT - Insulation oil treatment is often conducted due to moisture increase in oil. RECOMMENDATION - Conduct cooler leak check and take the countermeasures if there is a leak.		

Table 6.17-1 Recommendation Plan of Study Items (5/5)

Efficiency / Reliability / Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
18	Analysis of present performance and performance decrease	#6 **1.Boiler efficiency** RESULT - Boiler efficiency is decreased from design value. - Average gas temperature (after gas flow correction) of Primary AH and Secondary AH outlets is higher than design outlet gas temperature. It is estimated that exhaust gas amount of flow is imbalanced. - Air leak in Primary AH is higher than design value. RECOMMENDATION - Improve exhaust gas flow imbalance between Primary AH and Secondary AH (refer to AH performance improvement). - Improve Primary AH seal performance (refer to AH performance improvement). **2.Turbine heat rate** RESULT - Turbine heat rate is increased from design value. - HP turbine efficiency is decreased from design value. RECOMMENDATION - Replace HP turbine seal fin in order to increase efficiency. - Review inconsistency in data for heat rate calculation, if any, and carry out calibration of required instruments before performance test. - Measure extraction steam pressure and temperature at turbine end. - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	#4 **1.Boiler efficiency** RESULT - Boiler efficiency is decreased from design value. - AH outlet gas temperature is lower than design value. - AH outlet air temperature of Primary AH and Secondary AH outlets are lower than design value. It is estimated that heat exchange performance is decreased. - Air leakage is higher than design value RECOMMENDATION - Improve temperature efficiency (refer to AH performance improvement). - Improve AH seal performance (refer to AH performance improvement). **2.Turbine heat rate** RESULT - Turbine heat rate is increased from design value. - HP turbine efficiency is decreased from design value. RECOMMENDATION - Replace HP turbine seal fin in order to increase efficiency. - Review inconsistency in data for heat rate calculation, if any, and carry out calibration of required instruments before performance test. - Measure extraction steam pressure and temperature at turbine end. - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	#2 **1.Boiler efficiency** RESULT - Boiler efficiency is decreased from design value. - Average gas temperature (after gas flow correction) of Primary AH and Secondary AH outlets is higher than design outlet gas temperature. The average secondary air preheaters inlet exhaust gas temperature is higher than design value. - Air leak is higher than design value (assumption). - Unit is operated under slightly higher O2 concentration at economiser outlet RECOMMENDATION - Observe and adjust at economizer outlet gas temperature during operation. - Improve AH seal performance through consultation with OEM. - Observe and adjust O2 value at economizer outlet during operation to realize better boiler efficiency. **2.Turbine heat rate** RESULT - Turbine heat rate is increased from design value. - HP turbine efficiency is decrease from design value. - IP turbine efficiency is decreased from design value. RECOMMENDATION - Replace IP turbine seal fin in order to increase efficiency. - Review inconsistency in data for heat rate calculation, if any, and carry out calibration of required instruments before performance test. - Review historical trends of heat rate and HP/IP turbine efficiency whether they have been gradually decreased or were originally lower than design values. - Measure extraction steam pressure and temperature at turbine end. - Investigate seal welding of partition plate - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	—	—
19	Review and improvement of past and present O & M procedure	RESULT - Picked-up five O&M procedures are properly edited as manuals. - Some recommendations were found through monitoring of operation including field patrol activities in order to improve technical and safety performance further. RECOMMENDATION **Safety Aspect** - Wear suitable safety gear (working clothes, helmet, gloves, safety shoes, flash light). - Encourage safety mind further through safety education. - Implement safety monitoring patrol and hold KY (Kiken-Yochi, danger prediction) meeting. - Indicate dangerous condition clearly to persons around intricate works in the same area. - Manage the entry and exit status into and from closed space by applying "In and Out Status Board". - Carry out field housecleaning by vacuum cleaner instead of air blow. - Enhance application of 5S(Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization), and Shitsuke (discipline)) especially in local field. **Improvement of Patrol** - Use suitable detection gear （flash light, listening rod）. - Use listening rod to detect abnormal noise of rotating machines. - Put marks to local gauges to show normal working values. - Put thermo label to effectively detect steam leak from safety valve seat.			—	—

CHAPTER 7 TRAINING PROGRAM

Counter part Training program in Japan was planed as 3 kinds of training programs such as “Periodic inspection”, “Efficiency management” and “Facility Condition Monitoring and Diagnostic Technology” in accordance with the result of JICA S/W survey and/or coordination between NTPC and Study team.

In addition, “Boiler Remaining Life Assessment” was requested by counter part (NTPC) throughout the second year’s survey activities, therefore training program was planed in 3rd year’s contract. Similarly, the combustion simulation was requested by NTPC that was planned and implemented by Study team in 3rd year’s contract. The details of the above three counter part trainings are as follows;

7.1 Periodic Inspection, Efficiency Management, Facility Condition Monitoring and Diagnostic Technology Training

Upon coordination with the organizations concerned, this training program in Japan has been carried out for NTPC according to a contract that JICA Chugoku concluded with Power Engineering and Training Services, Inc..

These training program implementation timings and number of participants are as follows.

1) Periodic Inspection Training Course (Once)
   Timing: June 2009 (Already implemented)
   Number of participants: 6 peoples

2) Efficiency Management Training Course (Twice)[1]
   Timing: First training: October 2009 (Already implemented)
   Second training: February 2010 (Already implemented)
   Number of participants: First training: 6 peoples
   Second training: 6 peoples

3) Facility Condition Monitoring and Diagnostic Technology Training Course (Once)
   Timing: August 2010 (Already implemented)
   Number of participants: 6 peoples

7.2 Boiler Residual Life Assessment Technique Training Course

On this JICA study, counterpart (NTPC) highly desired to learn the boiler residual life assessment techniques demonstrated at 3rd site survey such as SUS scale deposition detection, TOFD inspection, advanced metallurgical observation technique. Therefore, the training program of advanced boiler

[1] This course was implemented twice with the same program and with changing the attendants.

residual life assessment techniques in Japan including lectures and practice is planed in the 3rd year contract.

Upon coordination with the organizations concerned, this training program in Japan has been carried out for NTPC according to a contract that JICA Kyushu concluded with Kyuden Sangyo co., Inc..

This training program implementation timing and number of participants are as follows.

1) Boiler Residual Life Assessment Technique Training Course (Once)
   Timing: August to September 2010 (Already implemented)
   Number of participants: 6 peoples

7.3 Boiler Combustion Simulation Training Course

Counterpart (NTPC) highly desired to learn the combustion simulation calculation procedure and assessment techniques after explanation of combustion simulation result during the 3rd Site Survey Work Shop. Therefore, the training program of boiler combustion simulation was planed and implemented in the 3rd years Contract.

This training program implementation timing and number of participants are as follows.

1) Boiler Combustion Simulation Training Course (Once)
   Timing: August 2010 (Already implemented)
   Number of Participant: 2 peoples

7.4 Evaluation of the Trainings

7.4.1 Evaluation of Training Programs

(1) Periodic Inspection, Efficiency Management, Facility Condition Monitoring and Diagnostic Technology Training

In addition to initial plan of this Program, site visit to power stations and some curriculums such as combustion adjustment were arranged and implemented from NTPC requests.

As a result of implementation program based on NTPC requests, evaluation from participants were shown that knowledge and experiences acquired from this Program would be profitable and useful at their power stations in India.

Consequently, the objective of this Training Program was satisfied and it contributed to technology transfer which was also one of the objectives of this Study.

Through this Training Program, following point should be improved when this kind of training programs will be implemented in future. Although participants of this Training Program were considered those who concerned this Study initially, those who were not related to this Study directly were included in fact.

(2) Boiler Residual Life Assessment Technique Training

As a result of implementation program based on NTPC requests, evaluation of participants were shown that knowledge and experience acquired from this training program on boiler residual life assessment techniques would be profitable and useful at their power stations in India for the improvement of facility operation and maintenance and eventually boiler residual life assessment would be introduced and dispersed in NTPC power stations.

Consequently, the objective of this program was satisfied and it contributed to technology transfer which was also one of the objectives of this study.

7.4.2 Evaluation of Training Program and Implementation

(1) Boiler Combustion Simulation Training

As a result of implementation program based on NTPC requests, evaluation from participants were shown that simulation theory and analytical techniques acquired from this program was able to understand and simulation result was useful for boiler operation improvement and modification plan of boiler at their Vindhyachal power station Unit 7 & 8.

From the above observation, the objective of this Training is achieved and it was contributed to technology transfer to NTPC.