Japan International Cooperation Agency
Ministry of Power
NTPC LTD

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

Final Report

November 2010

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

In response to a request from the Government of the Republic of India, the Government of Japan decided to conduct the Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent a study team led by Mr. Noriyuki Shimizu of Electric Power Development Co., Ltd. to India eight times during the period between December 2008 and October 2010.

The study team held discussions with the officials concerned in the Government of India and the NTPC Limited, and conducted studies in India. The study team conducted further studies in his home country based on the outcome obtained in India and came to the final phase to submit the report after compiling.

I hope this report will contribute to the promotion of enhancing efficiency of thermal power plants in the country and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the persons concerned for their close cooperation throughout the study.

November 2010

Atsuo KURODA
Vice President
Japan International Cooperation Agency

November 2010

LETTER OF TRANSMITTAL

Mr. Atsuo KURODA

Vice President
Japan International Cooperation Agency
Tokyo, Japan

We are pleased to submit the report of the Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India.

This study was conducted on the purposes of improve the efficiency of coal fired thermal power plants of NTPC on sustainable basis and transfer to counterpart the technology that is necessary to achieve the above efficiency improvements in India.

During the study period, we made our best effort for establishing optimum efficiency improvement plans and technical transfer training programs from technical, economic and environmental points of view, and for support to implement the plans as far as possible.

As a result, we appraise that the purposes have been attained as much as possible in the limited study period, while further study for implementation is on going in NTPC in terms of facility modification for efficiency improvement which needs certain lead times.

We wish, here taking this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Economy, Trade and Industry. We also wish to express our deep gratitude to officials/staffs concerned in the related Ministries of the Republic of India, NTPC Limited, Embassy of Japan in India and JICA India Office for the close cooperation and assistance extended to us during our study period.

Very truly yours,

Noriyuki Shimizu

Team Leader
The study team of the Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

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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

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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

<table>
<tr><th>No.</th><th>Plant name</th><th>Korba #6 (#4)</th><th>Singrauli #4 (#6)</th><th>Rihand #2 (#3)</th><th>Vindhyachal #7</th><th>Unchahar #3(#2)</th></tr>
<tr><td>18</td><td>Analysis of present performance and performance decrease</td><td>#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</td><td>#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</td><td>#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</td><td>—</td><td>—</td></tr>
<tr><td>19</td><td>Review and improvement of past and present O & M procedure</td><td colspan="3">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.</td><td>—</td><td>—</td></tr>
</table>

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

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

CHAPTER 1

INTRODUCTION

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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 Scope of the Study

The study is implemented based on the Scope of Works (SoW) signed by JICA, the Ministry of Power, and NTPC in October 2008. The specific scope of works was discussed and agreed between JICA and with NTPC in order to achieve purpose of this study efficiently.

(1) Scope of Works

The items of study and selected units are as follows. The details are described in Clause 5 Selection of Candidate Units and Study Scope.

1) Study Items:

a) Diagnosis of boiler problem
b) Combustion simulation
c) Boiler RLA
d) AH performance improvement
e) Turbine RLA
f) Turbine steam path audit
g) MS/HTR/LTR piping assessment
h) Advice to Seal fin replacement
i) Condenser assessment
j) Pump assessment
k) Control system assessment
l) BFPT parameter assessment
m) Generator assessment
n) Transformer assessment
o) Analysis of present performance and performance decrease
p) Plant performance test
q) Review and improvement of past and present O&M procedure
r) Financial analysis
s) Improvement of plant performance and application
t) Preparation of CDM application

2) 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.

1.5 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

1.6 Basic Policy of the Study

NTPC has been actively improving power generation efficiency, and has established an overall management system that includes the collection and record of data necessary for maintenance inspection and operation and the periodical inspection of facilities and equipment, with the support of the United States Agency for International Development (USAID). Because of this, as far as possible we will propose [technology and techniques] that have not been hitherto adopted by NTPC, without duplication of the technology transferred by USAID. In addition, we will provide an opportunity for NTPC to get in touch with Japanese efficiency improvement technology and systems at first hand through demonstrations at NTPC power stations. We will also intend to implement technology transfer by assessing technology that can be applied to NTPC through discussion with them.

(1) Basic Policy

1) We will investigate cases of efficiency improvement of coal-fired thermal power stations in Japan, and introduce cases that are applicable to NTPC.

2) Selection of candidate thermal power stations (units)
At the kick-off meeting, we will ask NTPC to select five candidate units from their existing power stations. Selection conditions are considered to include units that commenced operation in the 1980s, around 1985, and around the 2000s, and that can be found in a relatively large number in India so that the outcome of this effort can be developed broadly. Together with NTPC, we will visit and inspect the five units in power stations selected by NTPC based on these conditions, and select three units from the five units based on the results of this study. At the kick-off meeting, we will explain to NTPC the procedures for the selection of the five units from power stations, and ask NTPC to conduct investigations.

3) In the candidate thermal power stations (three units), equipment to be studied include boiler, turbine, condenser, generator, and major auxiliary machines (feed water heater, boiler feed water pump, boiler feed water pump turbine, circulating water pump, main transformer, and main control system).

4) For performance testing, USAID's manuals are available, and we understand that NTPC has already established performance testing methods, therefore NTPC will implement tests and compile testing results by itself, and Study team will witness, advise and confirm testing procedures as per Japanese procedure, propose additional testing items, and make assessments based on the testing results.

5) We will ask sub-vendors for facility/equipment assessments during periodical inspections and operation.

6) The timing for implementing performance tests and facility/equipment assessments will be finalized in consideration of the operating conditions of the candidate thermal power stations (three units).

7) We will review the results of facility/equipment assessments, conduct studies and assessments, and propose measures that include the upgrading of facilities and equipment.

8) We will conduct study concerning operation and maintenance, and provide suggestions regarding the efficient operation of the power stations.

9) As on-the-job training in India, Study team will witness and provide advice at performance tests, and personnel of NTPC will witness at the time of assessing facilities and equipment by Study team for the candidate thermal power stations (three units). The test equipment will be brought from Japan, if required.

10) A workshop in India will be held for two days each time, five times over two years of the study.

11) Seminar will be held two times over two years of the study. The schedule is set taking the contents into consideration.

- #1 Seminar: at #4 Field investigation
  Contents: 1) Presentation for efficiency enhancement, O&M and condition assessment of coal fired power plant in Japan, and sharing of the practice.

- #2 Seminar: at Final Field investigation
  Contents: 1) Improvement of past O&M procedure
  2) Plan of performance improvement
  3) Guide line concerning efficiency and reliability enhancement

12) Training for counterpart members (training in Japan) will be supposed to hold for six to eight days, with about six participants each time, four times over two years. We will plan the training program that consists of lectures and practice using the actual equipment as model, as well as on-site training on the periodical inspection at coal-fired thermal power stations.

13) Based on the results of facility/equipment assessments, we will submit a proposal for the improvement of facilities and equipment for the candidate thermal power stations (three units).

14) We will assess the effectiveness of the cost of upgrading facilities and equipment, and the amount of CO_2 reduction resulting from proposed efficiency improvement actions for the candidate thermal power stations (three units).

15) For economic and financial analysis, we will assess the economy of proposed measures for improvements.

16) We will review a clean development mechanism (CDM) in accordance with proposed efficiency improvements. However, to implement the CDM, we will delegate experienced consultants in India, and establish an organization where we can provide support for Study team to carry out its duties efficiently and effectively. Study team will formulate policies and plans for the application of the CDM and provide support for the preparation of a series of documents

necessary for the application. To obtain certification for the CDM from the United Nations, we will discuss and provide support based on existing methods (AM0061 and AM0062) because no certifications for the efficiency improvements of coal-fired thermal power stations have yet been obtained in India. Acquisition of rights on emission credit is out of scope of this study.

17) CenPEEP has already formulated guidelines and manuals. Therefore, we will compile the proposes described in each report as the guideline.

1.7 Counterpart Agencies

For the implementation of the study, Study team keeps contact with the following relevant organs and/or counter part agency.

(1) Relevant Organs

- Ministry of Power
- NTPC (Centre for Power Efficiency & Environmental Protection (CenPEEP) and the selected power stations

(2) Counterpart Agency

In order to investigate NTPC's existing coal-fired thermal power units, it is essential to coordinate closely with NTPC, such as in the implementation of performance tests, facility/equipment assessments during periodical inspections (during unit shutdown), the collection of the specifications and drawings of facilities and equipment, the collection of operation data and interviews regarding operation and maintenance. Therefore Study team requested NTPC to establish a counterpart team (C/P Team). 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.

Counter part team members are

➢ 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

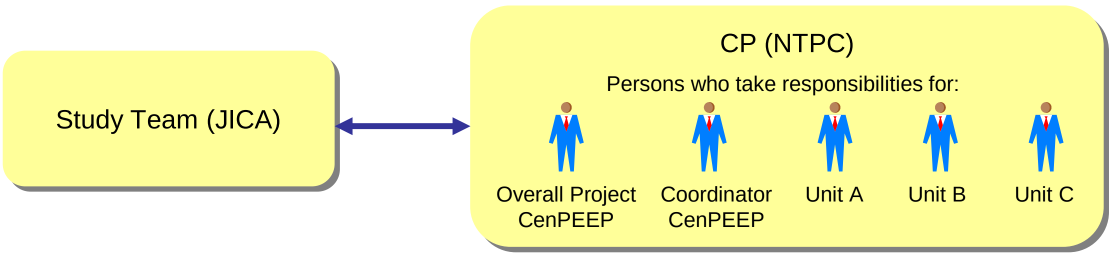

Fig. 1.7-1 Counterpart Team

1.8 Study Team Member

(1) Study Team Organization

Study team consists of the following 12 members based on the scope of work:

- One team leader in charge of thermal power
- One deputy team leader in charge of thermal power (boilers)
- One person in charge of thermal power (turbines, and remaining life assessment technology (B))
- One person in charge of thermal power (electrical)
- One person in charge of thermal power (control)
- One person in charge of thermal power (remaining life assessment technology (A))
- One person in charge of thermal power (efficiency assessment technology)
- One person in charge of measures for climatic change, and support for the application of CDM
- One person in charge of economic and financial analysis
- One coordinator (December 2008 to August 2009)
- One person in charge of preparation of training program in Japan

- One person in charge of preparation of training program in Japan (Boiler RLA)

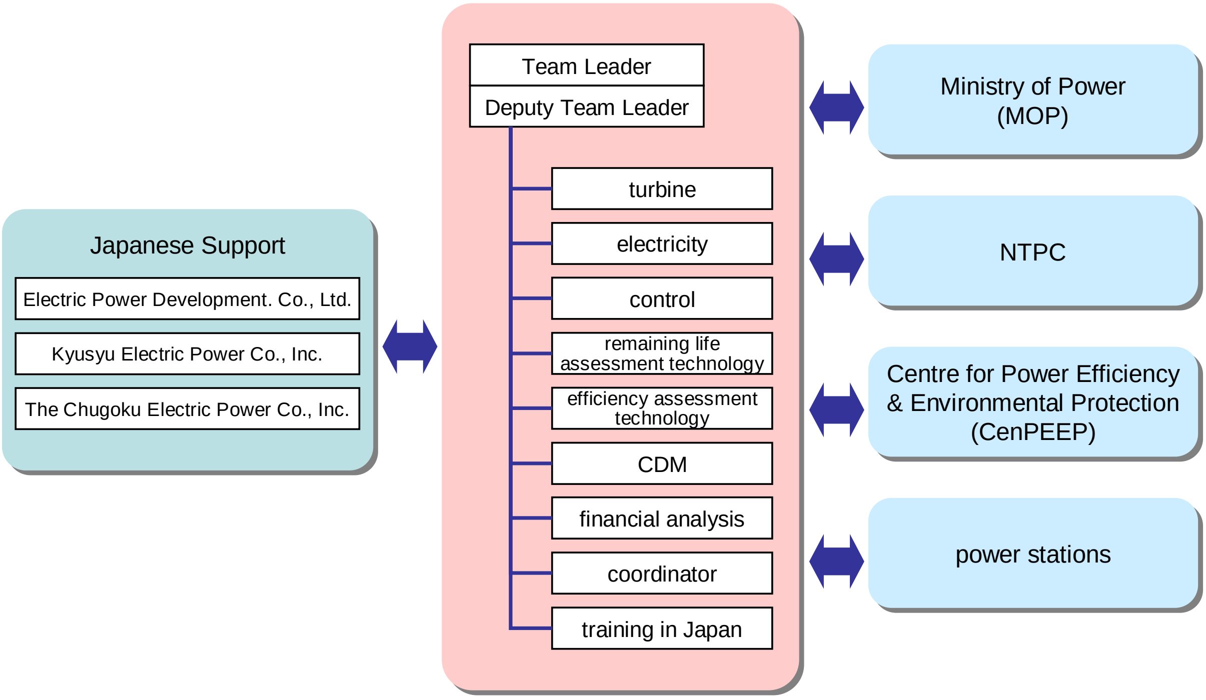

Fig. 1.8-1 Structure of Study Team

Study Team is consisted of the 11 members and 1 coordinator as shown in Table 1.8-1 below:

Table 1.8-1 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.

(2) Commission of Study

As described in “1.6 Basic Policy of the Study” it is desirable to implement facility/equipment assessments with the use of new technology that is owned by Japanese industrial companies and implemented by Japanese power companies. In order to tailor this study to the needs of NTPC, we will partially commission Japanese industrial companies as follows.

1) Commission in Japan

a) Remaining life assessment of boiler tubes and headers
To assess the remaining life of boiler tubes, we will commission capable and skilled Japanese companies for assessment that need special devices and skills and that require safe field work practices.

b) Assessment of turbine facilities
About the assessment of turbine proper, we will commission.

c) Assessment of leakage from condensers

We will conduct a field investigation by commission with a system to analyze and comprehend position where air enters into condensers, and the amount of leakage during the operation of a plant with the use of on-line equipment.

d) Assessment of large pumps

We will conduct a field investigation by commission with a system that can assess the operational performance of boiler feed water pump and circulating water pump.

e) Assessment of control systems

We will commission a Japanese company to conduct a field investigation for the soot blower control system which is assumed to be one of the causes of boiler tube leaks, in addition to the main control systems (boiler and turbine).

2) Commission in India

As described in “1.6 Basic Policy of the Study” we will commission CDM matters to a local experience of Consultant.

CHAPTER 2

POWER SECTOR IN INDIA

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Kyusyu Electric Power Co., Inc.
The Chugoku 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.

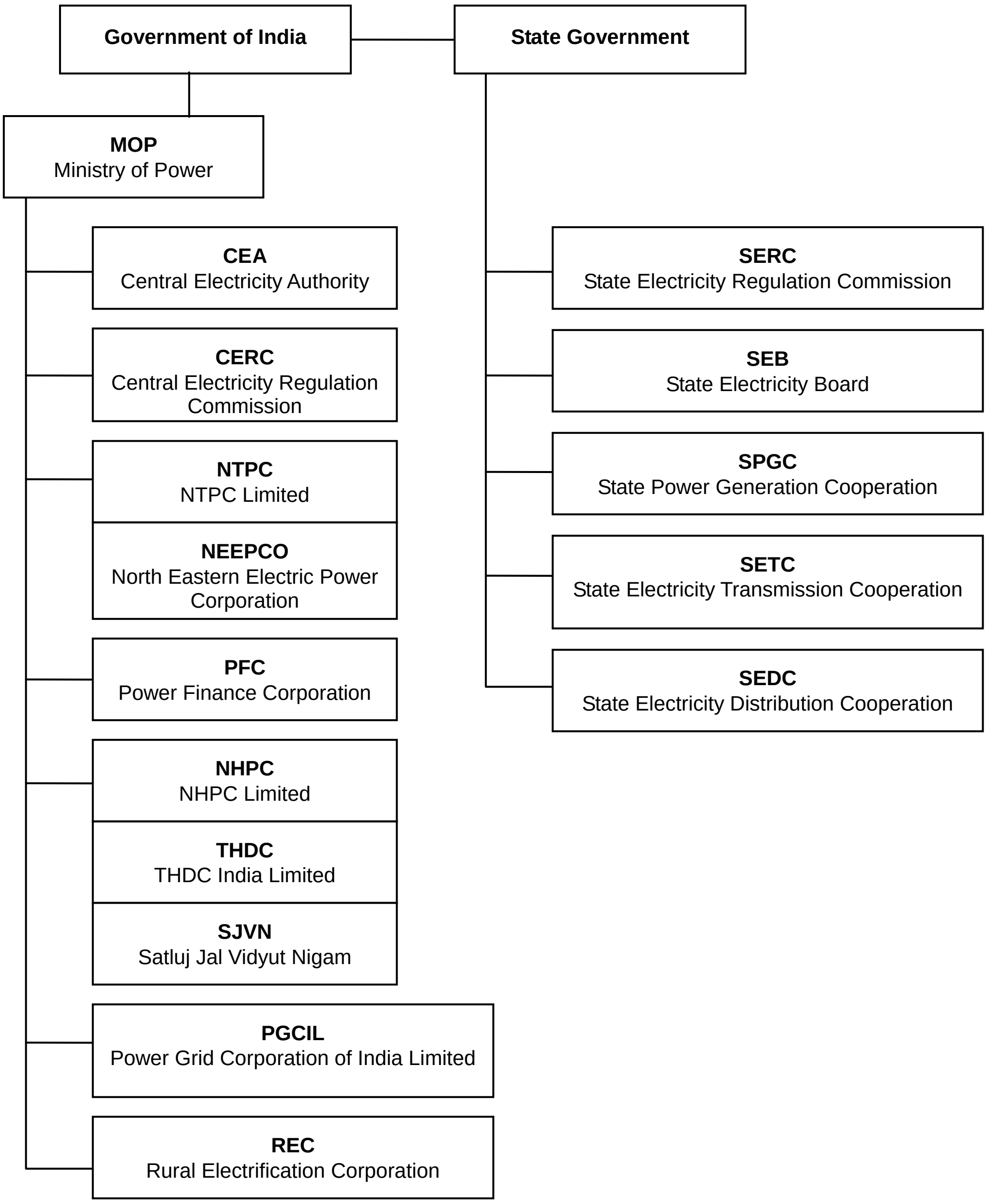

Fig. 2.1-1 Structure of Power Sector

(1) Outline of Power Sector

Central government and state government take major roles of power supply system such as design of policy, regulation, finance, power interchange, power generation, transmission of electricity, power distribution system and research and development. Each function of major power sectors is described below. The power producer is consisting of central sectors such as NTPC and NHPC, SEB and IPP.

1) Ministry of Power (MOP)

MOP is supervisory authority of power sector and they plan electricity policy, establishment of power sector legal system, formulation of long term power supply development based on the State Planning Commission plan, supervising of development plan implementation. In addition, Atomic Energy Commission and ministry of renewable energy supervise nuclear power and renewable energy respectively.

2) Central Electricity Authority (CEA)

CEA provides advice to MOP concerning overall power sector activities. They have right to review hydro power project development plan and issue development license. Development license without hydro power project is transferred to central and state government power regulatory commissions at present.

3) Central Electricity Regulatory Commission (CERC)

CERC was established on the base of power regulatory commission act in 1998 and their major functions are follows:

a) Regulation of Electricity tariff (central sector power producer wholesale power costs, power trade cost over the states etc.)
b) Regulation of electricity transmission cost, regulation of electricity transmission among states
c) Enhancing efficiency of Power sector, promotion of competition
d) Others (arbitration and decision for electricity tariff)

State Electricity Regulatory Commission (SERC) of the state government has charge of power regulatory.

4) NTPC Limited

NTPC was founded by the government in order to develop large scale thermal power stations, which could not be carried out by the SEB, utilizing governmental fund. NTPC is operating thermal power stations and expanding their business such as hydro power, consultation of power plant and international business.

5) NHPC Limited

NHPC was founded by the government in order to develop large scale hydro power stations, which could not be carried out by the SEB, utilizing governmental fund. NHPC is operating hydro power stations domestically and they developed hydro power in Nepal and Bhutan.

6) Power Grid Corporation of India Ltd. (PGCIL)

PGCIL constructs and operates the interconnection transmission lines among areas and/or connection transmission lines of wide-area electric power supply.

7) Power Finance Corporation (PFC)

PFC was founded by the government in 1986 as one of the public finance corporations in order to provide the finance for power business. They provide loan and services not only to central sector but also to SEB, power distribution division and private sector projects (IPP).

8) Power Trading Corporation (PTC)

PTC was founded in 1996 and they mainly develop their businesses in trading surplus electricity, trading electricity among areas and power import from Nepal and Bhutan. Major Shareholders are central sector power business companies and banks.

9) Rural Electrification Corporation (REC)

REC was founded by the government in 1969 for financing of rural electrification business and it's promotion. They provide the finance to SEB, rural electrification association and hydro power projects which compete against PFC.

10) North Eastern Electric Power Corporation Ltd. (NEEPCO)

NEEPCO was founded to development of hydro power, natural gas and coal mine. They are one of the central power sector wholesalers and operate their own power plants of 1,130 MW capacity.

11) Tehri Hydro Development Corporation Ltd. (THDC)

THDC was founded as a joint venture company by the central government and Uttar Pradesh state in order to develop hydro projects along with arm of Bhagirathi and Tehri river.

12) Reliance Energy Ltd. (REL)

REL has power plants of 941 MW capacity which locate in Maharashtra, Karnataka, Kerala, Andhra Pradesh and Goa states. They plan to develop 13,510 MW capacity power stations including hydro power.

13) Jai Prakash Associates Ltd.

Jai Prakash Associates has a 300 MW and a 400 MW hydro power plants in Himachal Pradesh and Uttarkhand states respectively. They are mobilizing 1,000 MW Karcham Wangtoo hydro power project which will start commercial operation in 2010.

14) Tata Power Company Ltd.

Tata Power has power plants of 2,323 MW capacity which locate in Maharashtra, Jharkahand and Karnataka states including hydro and wind power. They also have transmission business together with Power Grid as a joint venture company.

2.1.3 Power Demand and Supply

(1) Power Demand

Energy requirement, peak demand and shortage from 2001 to 2008 are shown below.

Table 2.1-1 Power Demand and Supply Position

Year	Energy Requirement (GWh)	Energy Availability (GWh)	Energy Shortage (%)	Peak Demand (MW)	Peak Availability (MW)	Peak shortage (%)
2001	522,537	483,350	7.5%	78,441	69,189	11.8%
2002	545,983	497,890	8.8%	81,492	71,547	12.2%
2003	559,264	519,398	7.1%	84,574	75,066	11.2%
2004	591,373	548,115	7.3%	87,906	77,652	11.7%
2005	631,554	578,819	8.4%	93,255	81,792	12.3%
2006	690,587	624,496	9.6%	100,715	86,818	13.8%
2007	737,052	664,660	9.8%	108,866	90,793	16.6%
2008	777,039	691,038	11.1%	109,809	96,785	11.9%

Source: MOP Annual Report 2008-09

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.

The following table shows power demand and supply position by district. North, Western and north-Eastern have energy shortage compared to Southern and Eastern. Western and north-Eastern have energy peak shortage compared to other districts.

Table 2.1-2 Power Demand and Supply Position by District (Apr 2008 to Mar 2009)

Region	Energy			Peak		
	Requirement (GWh)	Availability (GWh)	Shortage (%)	Demand (MW)	Availability (MW)	Shortage (%)
Northern	224,218	199,928	10.8%	33,034	29,504	10.7%
Western	245,486	213,724	16.0%	37,240	30,154	19.0%
Southern	204,086	188,865	7.5%	28,340	26,244	7.4%
Eastern	82,127	78,370	4.6%	12,901	11,689	9.4%
North-Eastern	9,407	8,134	13.5%	1,820	1,358	25.4%

Source: CEA Home Page-Monthly Review of Power Sector

(2) Power Consumption

Amount of Power consumption from 1955 to 2004 is shown in the following table and graph. 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.

Table 2.1-3 Amount of Power Consumption by Sector (1995 to 2004)

(GWh)

Year	Domestic	Commercial	Industrial	Traction	Agriculture	Misc.	Total
55	934	546	5,323	405	316	435	7,959
60	1,492	848	9,584	454	833	630	13,841
65	2,355	1,650	18,876	1,057	1,892	905	26,735
68	3,184	2,126	25,891	1,247	3,465	1,439	37,352
73	4,645	2,988	32,481	1,531	6,310	2,292	50,247
78	7,576	4,330	47,728	2,186	12,028	3,445	77,293
79	8,402	4,657	45,956	2,301	13,452	3,316	78,084
84	15,506	6,937	63,019	2,880	20,961	4,765	114,068
89	29,577	9,548	80,694	4,070	44,056	7,474	175,419
91	35,854	12,032	87,288	4,520	58,557	9,394	207,645
96	55,267	17,519	104,165	6,594	84,019	12,642	280,206
01	79,694	24,139	107,296	8,106	81,673	21,551	322,459
02	83,355	25,437	114,959	8,797	84,486	22,564	339,598
03	89,736	28,201	124,573	9,210	87,089	22,128	360,937
04	95,659	31,381	137,589	9,495	88,555	23,455	386,134

Source: CEA General review 2006

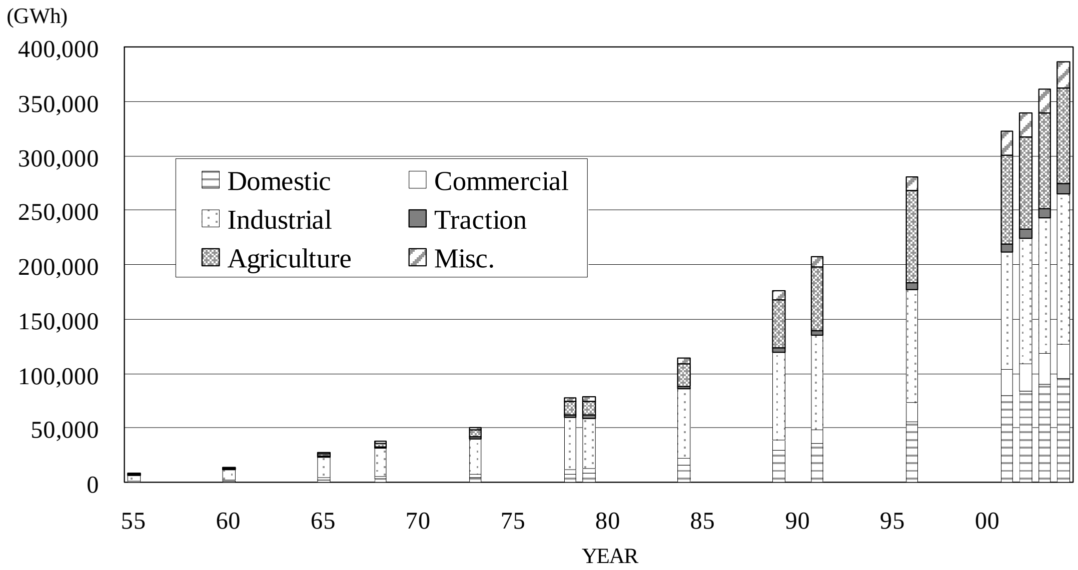

Fig. 2.1-2 Amount of Power Consumption by Sector (1995 to 2004)

(3) Forecast of Power Demand

According to power consumption table above, 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. "Key Inputs for Accelerated Development of Indian Power Sector for 11th Plan and Beyond Report" which prepared by MOP mentioned that assumption power demand for future is shown in the table below.

Table 2.1-4 Forecast of Power Demand

Year	Energy ($\times 10^3$ GWh)		Installed Capacity (MW)	
	GDP 8%	GDP 9%	GDP 8%	GDP 9%
2006-07	700	700	140,000	140,000
2011-12	1,029	1,077	206,000	215,000
2016-17	1,511	1,657	303,000	331,000
2021-22	2,221	2,550	445,000	510,000

Source: Key Inputs for Accelerated Development of Indian Power Sector for 11th Plan and Beyond Report

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 11th 5 years power development plan.

(4) Power Supply (Power Generation Capacity)

Power generation capacity by energy source from 1995 to 2007 is shown in the following table. 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)

Table 2.1-5 Power Generation Capacity by Energy Sources (1995 to 2007)

year	Hydro (MW)	Thermal * (MW)	Nuclear (MW)	REP (MW)	Total (MW)	Addition (%)
95	20,986	60,083	2,225	-	83,294	-
96	21,658	61,010	2,225	902	85,795	3.0
97	21,904	64,005	2,225	968	89,102	3.9
98	22,479	67,566	2,225	1,024	93,294	4.7
99	23,857	70,193	2,680	1,155	97,885	4.9
00	25,153	72,343	2,860	1,270	101,626	3.8
01	26,269	74,429	2,720	1,628	105,046	3.4
02	26,767	76,762	2,720	1,628	107,877	2.7
03	29,507	77,969	2,720	2,488	112,684	4.5
04	30,942	80,902	2,770	3,812	118,426	5.1
05	32,326	82,410	3,360	6,191	124,287	4.9
06	34,654	86,015	3,900	7,760	132,329	6.5
07	35,909	91,907	4,120	11,125	143,061	8.1

Source: CEA Annual report 2007-08
*: Thermal: included in coal, gas and diesel

Comparing ratios of 1996 and 2007, the hydroelectric power has kept almost constant from 25.2% to 25.1%, the nuclear power has slightly increased from 2.6% to 2.9%, the renewable has increased form 1.1% to 7.8% and thermal power has decreased from 71.0% to 64.2%, respectively. Due to the increase of renewable energy power, the ratio of each power generation category has improved to some extent from heavy dependence on the thermal power generation.

Power plant capacity by power sector is shown in the following table. Private Sector's thermal and renewable power capacity was increased and their installed capacity from 2005 to 2008 was more than state sector capacity.

Table 2.1-6 Power Plant Capacity by Sector (as on 2008 March)

(MW)

Type	Central Sector	State Sector	Private Sector	Total
Hydro	8,592.0	26,086.8	1,230.0	35,908.8
Thermal	35,649.0	46,486.3	9,771.5	91,906.8
Nuclear	4,120.0	0.0	0.0	4,120.0
Renewable (incl. small hydro, biomass etc)	0.0	2,116.3	9,009.1	11,125.4
Total	48,361.0	74,689.4	20,010.7	143,061.0
Percentage (%)	34	52	14	100.0

Source: CEA Annual report 2007-08

Table 2.1-7 Trend of Power Plant Capacity by Sector (from 2005 to 2008)

(MW)

Year	Central Sector	State Sector	Private Sector	Total
2005-2006	1,320.0	1,363.0	785.8	3,468.8
2006-2007	3,890.0	1,671.0	1,291.8	6,852.8
2007-2008	3,240.0	2,898.0	4,593.8	10,731.8
Total	8,450.0	5,932.0	6,671.4	21,053.4
Percentage (%)	40	28	32	100.0

Source: CEA Annual report 2007-08

The total power plant capacity in India is 152,148 MW at 2009 August. The detail is shown in the following table.

Table 2.1-8 Power Plant Capacity (as on 2009 August)

Type of Station	Installed Capacity (MW)	Ratio (%)
Thermal	97,869	64.3
Coal	80,284	52.8
Gas	16,386	10.8
Oil	1,200	7.9
Hydro	36,917	24.4
Nuclear	4,120	2.7
Renewable (incl. small hydro, biomass etc)	13,242	8.7
Total	**152,148**	**100**

Source: MOP web site on September 2009

According to the 11th 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 trend of thermal power plant's PLF from 1955 to 2007 is indicated in the table below. 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.

Table 2.1-9 Thermal Power Plant PLF

Year	Central	State	Private	Overall
2000-01	74.3	65.6	73.1	69.0
2001-02	74.3	67.0	74.7	69.9
2002-03	77.1	68.7	78.9	72.1
2003-04	78.7	68.4	80.5	72.7
2004-05	81.7	69.6	85.1	74.8
2005-06	82.1	67.1	85.4	73.6
2006-07	84.8	70.6	86.3	76.8
2007-08	86.7	71.9	90.8	78.6
2008-09	84.3	71.2	91.0	77.2

$$\text{PLF}(\%) = \frac{\text{Power Generation per year (MWh)}}{\text{Rated Output (MW)} \times 24\text{(h)} \times 365\text{(d)}} \times 100$$

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 following table summarizes the power development plan for 10th five-year plan.

Table 2.1-10 10th 5-Year Plan (Actual)

(MW)

Particular	Hydro	Thermal	Nuclear	Total
Original Program	14,393	25,417	1,300	41,110
Capacity Slipped	(6,507)	(14,554)	(220)	(21,281)
Backup Added	0	1,251	100	1,351
Total	**7,886**	**12,114**	**1,180**	**21,180**

Source: National Electricity Plan, CEA. April 2007

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.

Because the result of development in the 10th plan was less than the expected level, the Government has indicated the large-scale increase in the 11th plan.

For reference, details of the targets and actual achievements during the various Plans are furnished below.

Table 2.1-11 5-Year Plan (Target and Actual)

Plan	Target (MW)	Achievement (MW)	%
1st (51-56)	1,300	1,100	84.6
2nd (56-61)	3,500	2,250	64.3
3rd (61-66)	7,040	4,520	64.2
4th (69-74)	9,264	4,579	49.5
5th (74-79)	12,499	10,202	81.6
6th (80-85)	19,666	14,226	72.3
7th (85-90)	22,245	21,401	96.2
8th (92-97)	30,538	16,423	53.8
9th (97-02)	40,245	19,015	47.5
10th (02-07)	41,110	21,180	51.76

Source: White Paper on Strategy for 11th Plan, CEA. August 2007

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. The following table indicates the breakdown.

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.

Table 2.1-12 11th 5-Year Plan

(MW)

Particular	Hydro	Thermal	Nuclear	Total
Under Construction	12,115	50,509.2	3,160	65,784.2
Committed	3,392	11,213.7	220	14825.7
Total	**15,507**	**61,722.9**	**3,380**	**80,609.9**
<Breakdown>				
Central Gov. Sector	8,654	21,496	3,380	33,530
State Gov. Sector	3,362	22,001.4	0	25,363.4
Private Sector	3,491	18,225.5	0	21,716.5
Total	**15,507**	**61,722.9**	**3,380**	**80,609.9**

Source: CEA IRP Division. Jun 2009

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. These Issues identified are as follows:

- Manufacturing Capability of Main Plant and Balance of Plant Equipment to be commensurate with capacity addition.
- Adequate Construction and Erection Agencies
- Availability of Adequate Fuel and Key materials
- Adequate Transportation facilities for Equipment and Fuel
- Manpower development including training facilities commensurate with large capacity addition
- Slow process of decision making and cumbersome payment procedure adopted by Utilities

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.

In particular

1) To apply the multi year tariff
2) Availability Based Tariff
3) Deletion of the provision for elimination of cross subsidies
4) Open access to in inter-State transmission
5) Time of day metering
6) Tariff based competitive bidding process for development of power plant and Transmission project

(2) State-Wise Estimated Average rates of Electricity and NTPC Cost of Generation

The state-wise estimated average rates of electricity and NTPC Cost of Generation as on 2008 March is shown the table below.

Table 2.1-13 State-Wise Estimated Average Rates of Electricity (updated upto 31.03.2008)

S. No.	Name of Utility	Tariff effective from	Domestic 1kW 100kWh/mth	Domestic 4kW 400kWh/mth	Domestic 10kW 100kWh/mth	Commercial 2kW 300kWh/mth	Commercial 10kW 1500kWh/mth	Commercial 30kW 4500kWh/mth	Commercial 50kW 7500kWh/mth	Agriculture 2HP 400kWh/mth	Agriculture 5HP 1000kWh/mth	Agriculture 10HP 2000kWh/mth
1	Andhra Pradesh	01-04-2007	238.50	396.63	492.25	599.33	624.67	628.89	629.73	29.38	23.75	21.88
2	Assam	04-08-2006	310.00	411.50	445.00	528.33	528.33	536.31	536.31	240.00	240.00	240.00
3	Bihar	01-11-2006	233.20 U 76.32 R	294.05	362.52	515.87 U 51.94 R	503.85	500.09	499.33	51.50 RS 61.50 US	51.50 RS 61.50 US	51.50 RS 61.50 US
4	Chhattishgarh	01-10-2006	189.10	238.50	334.58	436.41	519.17	519.37	519.41	32.50	32.50	42.50
5	Gujarat	01-04-2007	348.00 U 264.00 R	462.00 U 368.50 R	526.80 U 427.90 R	564.58	595.42	590.14	589.08	55.00	55.00	55.00
6	Haryana	01-11-2006	356.20	410.05	450.82	468.00	468.00	468.00	468.00	17.50	17.50	17.50
7	Himachal Pradesh	01-04-2007	216.00	263.50	283.00	450.67	437.33	448.44	447.56	208.00	205.00	204.00
8	Jammu & Kashmir	01-04-2007	129.50	188.88	214.75	222.00	262.00	268.67	270.00	49.50	40.33	27.50
9	Jharkhand	01-01-2004	163.00 U 74.00 R	183.00	182.00	438.67	438.67	438.67	438.67	28.75	28.75	28.75
10	Karnataka	01-11-2006	292.43 D 292.43 E 260.93 F	418.30 D 413.05 E 381.55 F	482.32 D 473.92 E 442.42 F	637.88 D 618.63 E 609.87 F	651.18 D 630.53 E 623.18 F	653.39 D 632.51 E 625.39 F	653.84 D 632.91 E 625.83 F	45.00 G 110.00 H	45.00 G 110.00 H	55.00 G 115.00 H
11	Kerala*	01-04-2006	187.00	398.89	517.61	727.84	889.90	962.74	969.98	74.80	74.80	74.80
12	Madhya Pradesh	16-04-2007	347.44 U 341.74 R	442.25 U 430.38 R	463.18 U 451.05 R	615.86	617.31	617.55	617.60	188.75	213.50	221.75
13	Maharashtra	01-05-2007	270.36	422.57	560.09	533.98	599.14	646.83	650.81	90.00 I 75.00 J	90.00 I 75.00 J	90.00 I 75.00 J
14	Meghalaya	01-10-2004	180.00	246.25	275.50	409.33	446.67	452.89	454.13	116.00	116.00	116.00
15	Orissa	01-04-2007	135.20	247.00	286.00	384.80	443.04	452.75	454.69	102.00	102.00	102.00
16	Punjab	01-04-2006	247.10	374.15	408.80	469.30	469.30	469.30	469.30	0.00	0.00	0.00
17	Rajasthan	01-01-2005	417.50 U 390.25 R	396.88 U 363.81 R	392.75 U 358.53 R	556.67	554.00	555.78	556.13	78.75	75.60	74.55
18	Tamil Nadu	01-04-2007	120.00	216.25	269.50	602.00	607.60	608.53	608.72	0.00	0.00	0.00
19	Uttar Pradesh	10-05-2007	249.00 U 59.00 R	359.00 U 209.00 R	359.00 U 239.00 R	452.33 U 209.00 R	452.33 U 269.00 R	452.33 U 279.00 R	452.33 U 281.00 R	224.00 U 45.00 R	224.00 U 45.00 R	224.00 U 45.00 R
20	Uttaranchal	01-04-2006	215.00	215.00	215.00	315.00 W 365.00 M	315.00 W 365.00 M	315.00 W 365.00 M	315.00 W 365.00 M	81.60 U 69.00 R	78.00 65.40 R	76.80 U 64.20 R
21	West Bengal	01-04-2007	248.33 U 237.11 R	406.43 U 391.49 R	529.24 U 523.26 R	443.27 U 441.48 R	583.96 U 583.59 R	604.05 U 603.93 R	608.07 U 608.00 R	147.00	147.00	147.00
22	Arunachal Pradesh	01-02-2000	162.50	211.88	231.75	370.00	390.00	393.33	394.00	-	-	-
23	Goa	01-04-2002	122.00	170.75	216.50	327.00	357.00	373.67	377.00	102.00	102.00	102.00
24	Manipur	03-09-2002	262.20	299.70	302.20	302.20	302.20	381.80	381.80	272.20	272.20	272.20
25	Mizoram (Distt.HQ & sub.Divn.Area) Other Areas	25-07-2005	170.00 180.00	247.50 195.00	249.00 198.00	266.67	266.67	266.67	266.67	69.94	69.94	69.94
26	Nagaland	01-04-2006	272.00	310.25	337.70	398.00	431.60	467.20	438.32	150.00	150.00	150.00
27	Sikkim	01-04-2006	105.75	266.06	322.43	335.25	396.45	408.15	410.49	180.00	247.50	326.25
28	Tripura	01-07-2006	215.00	365.00	365.00	353.33	456.67	456.67	456.67	87.46	87.46	134.92
29	A&N Islands	01-07-2003	130.00	275.00	326.00	406.67	465.33	475.11	477.07	90.00	90.00	90.00
30	Chandigarh	01-08-2005	179.00	304.00	304.00	347.00	347.00	347.00	347.00	165.00	165.00	165.00
31	Dadra & Nagar Haveli	01-10-2006	130.00	172.50	204.00	248.33	265.67	268.56	269.13	55.00	55.00	55.00
32	Daman & Diu	01-10-2006	130.00	172.50	204.00	248.33	265.67	268.56	269.13	55.00	55.00	55.50
33	Delhi BYPL/BRPL/NDPL	01-10-2006	277.20	346.50	434.70	596.75	596.75	622.76	622.76	162.20	162.20	162.20
34	Delhi NDMC	01-04-2006	158.00	252.25	327.70	462.00	525.00	525.00	525.00	-	-	-
35	Lakshadweep	01-09-2004	100.00	300.00	300.00	480.00	480.00	480.00	480.00	-	-	-
36	Pondicherry	16-04-2002	55.00	113.75	150.50	274.74	325.34	333.78	335.47	0.00	20.67	19.83
37	Torrent Power Ltd. (Ahmedabad)	01-04-2007	345.15	399.26	427.64	527.88	586.51	592.79	594.54	311.64	311.64	311.64
38	Kolkata (CESC)	01-04-2007	279.84	462.48	533.62	450.53	579.26	597.30	600.91	-	-	-
39	D.V.C. (A) Bihar Area (B) West Bengal Area	01-09-2000	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
40	Durgapur Projects Ltd.	01-04-2007	189.00	254.93	264.33	272.43	293.40	294.83	295.12	479.39	479.39	479.39
41	Mumbai (B.E.S.T) Mumbai (Reliance Energy) Mumbai (TATA'S)	01-04-2007 24-04-2007 01-05-2007	123.77 235.99 240.12	317.59 449.24 444.52	597.01 613.86 648.92	503.62 658.16 736.65	947.60 841.40 691.45	1,079.63 828.34 964.82	1,106.03 828.34 964.82	- 115.41 -	- 115.41 -	- 115.41 -

U: Urban, R: Rural, D: Bangalore Metro Area, E: Areas under other local bodies, F: Areas under Village Panchayats, G: General, H: Urban feeders, I: Category 1 Zone Areas, J: Category 2 Zone Areas, M: Without TOD meter, W: With TOD meter

* In Kerala, Kerala State Electricity Regulatory Commission has approved continuation of the existing tariffs (effective from 01.10.2002) and other charges by the Kerala State Electricity Board.

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. The table below shows the breakdown.

Table 2.1-14 World Bank Financed Project

Project	Amount (US$ mil.)	Approval Date
Uttar Pradesh Power Sector Restructuring Project	150	April, 2000
Second Renewable Energy	130	June, 2000
Rajastan Power Sector Restructuring Project	180	January, 2001
Powergrid System Development Project –II	450	May, 2001
Powergrid System Development Project –III	400	January 2006
Rampur Hydropower Project	400	September, 2007
Haryana Power System Improvement Project	330	August, 2009
Coal-Fired Generation Rehabilitation	180	Jun, 2009
Power System Development IV - Additional Financing	400	October, 2009
Power System Development IV	600	March 2008
Total	**3,220**	

Source: World Bank website (India)

(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. The table below shows the breakdown.

Table 2.1-15 ADB-Financed Project

Project	Amount (US$ mil.)	Approval Date
Power Transmission Improvement (Sector) Loan	250	2000
Gujarat Power Sector Development Program (Policy Loan)	150	2000
Gujarat Power Sector Development Program (Project Loan)	200	2000
Madhya Pradesh Power Sector Development Program	150	2001
Madhya Pradesh Power Sector Development Program (Project Loan)	200	2001
State Power Reform Project	150	2002
Assam Power Sector Development Program	150	2003
Assam Power Sector Development Program (Project Loan)	100	2003
Power Grid Development I (Sector Loan)	400	2004
Uttarkhand Power Sector Investment Program	300	2006
Madhya Pradesh Power Sector Investment Program	620	2007
National Power Grid Development Investment Program	1000	2008
Integrated Renewable Energy Development Project	200	2008
Uttarakhand Power Sector Investment Program - Project 2	300	2009
Mundra Ultra Mega Power Project	450	2009
Energy Efficiency Enhancement Project in Assam	200	2009
Total	**4,820**	

Source: Asian Development Bank

(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

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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. Location of power plants is shown in the figure below.

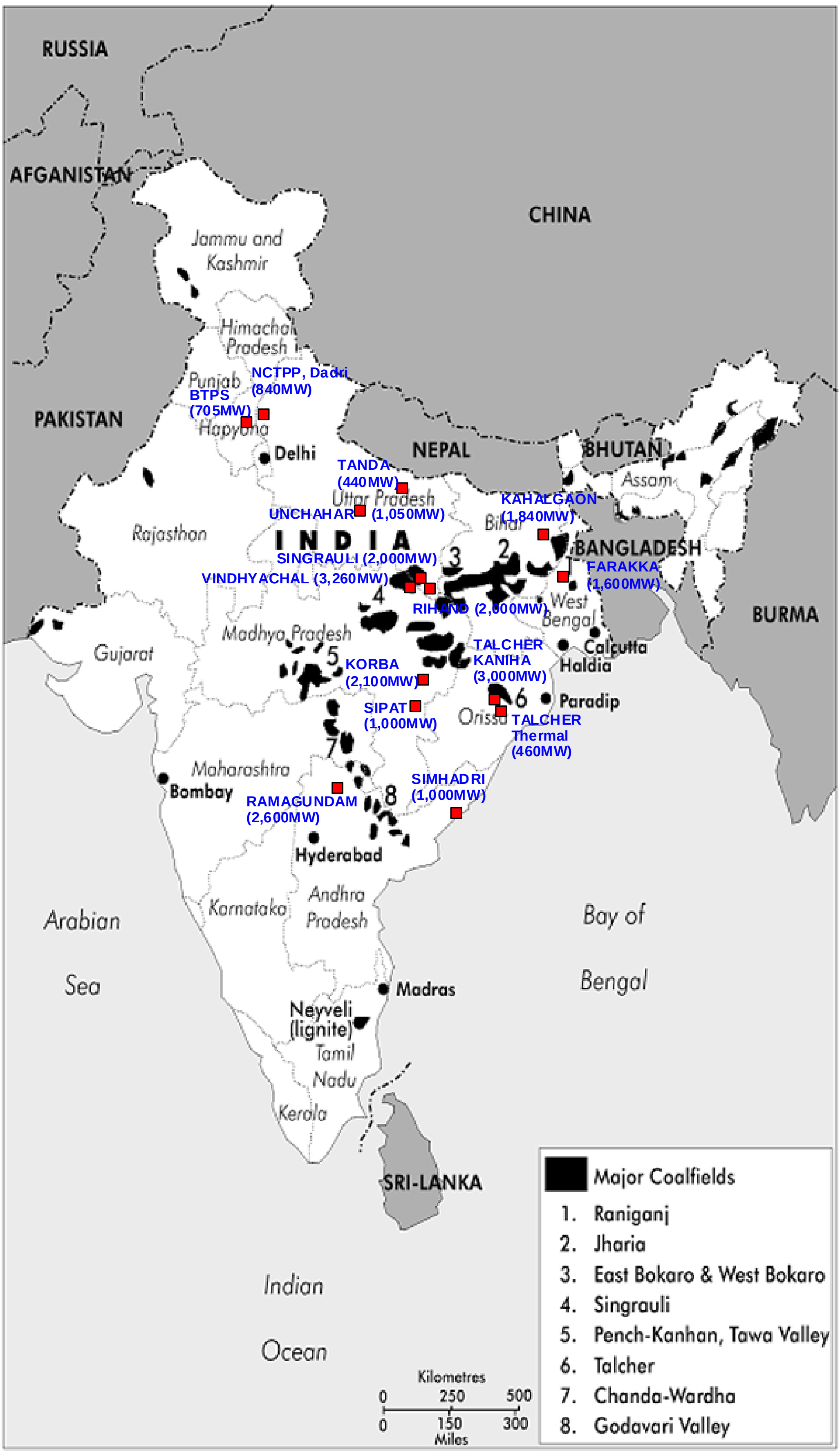
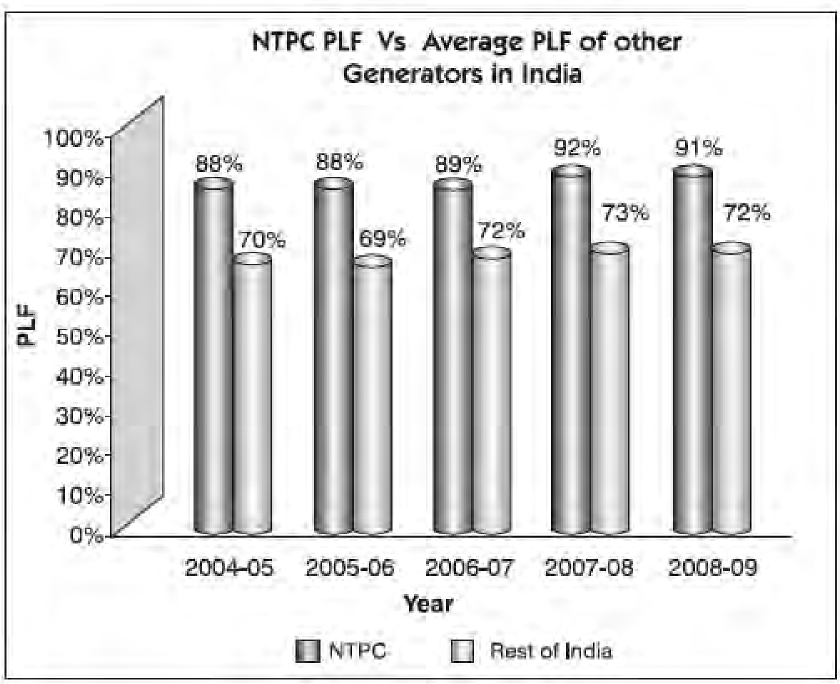


Fig. 3.1-1 Location of NTPC Thermal Power Plant

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. NTPC PLF vs Average PLF of other generators in India is indicated below.

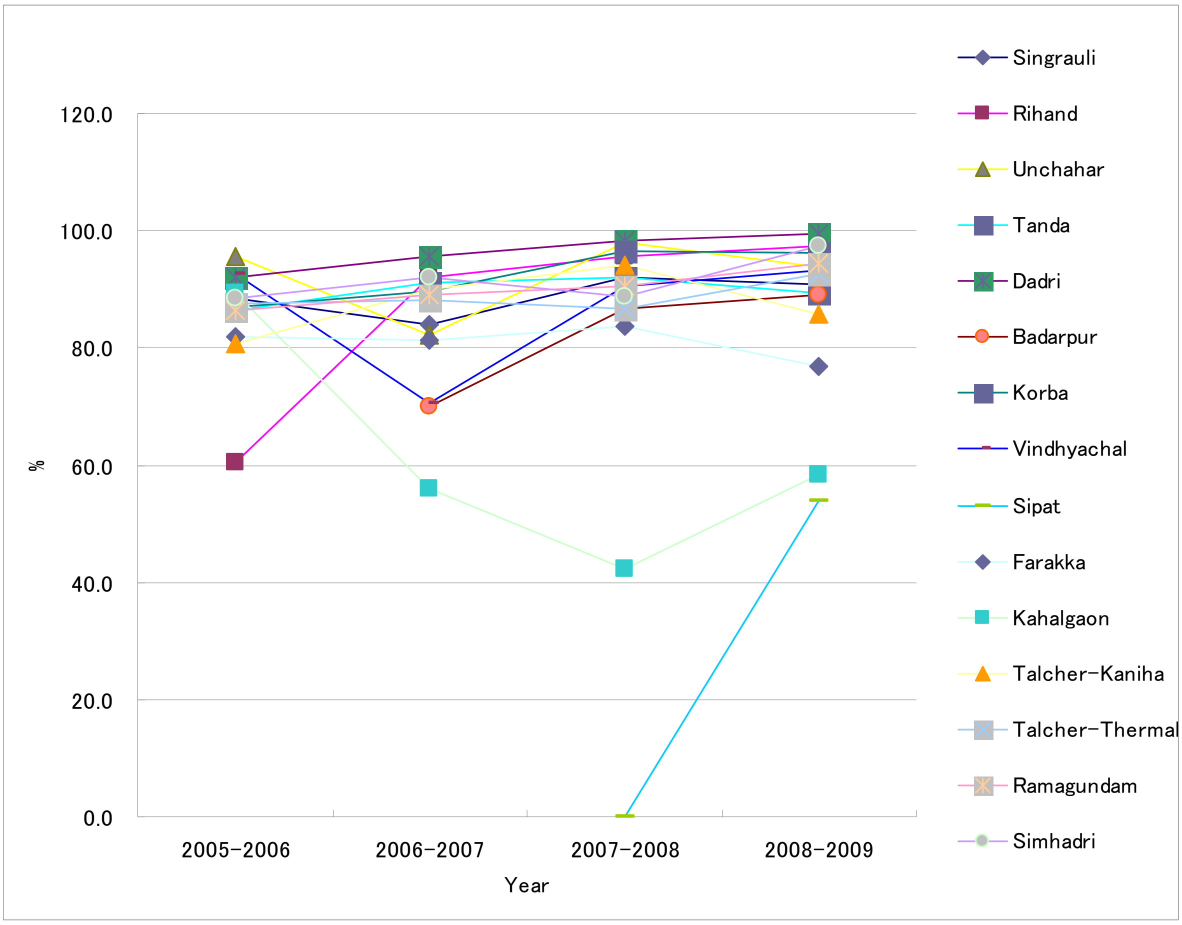


Source: NTPC Annual Report

Fig. 3.2-1 NTPC PLF vs. Average PLF Other Generators in India (including coal, gas and liquid)

Table 3.2-1 NTPC Coal Fired Power Plant: Plant Load Factor (%)

Power Plant	2005-2006	2006-2007	2007-2008	2008-2009
Singrauli	88.5	83.8	91.9	90.7
Rihand	60.5	91.9	95.7	97.2
Unchahar	95.7	82.2	98.0	93.7
Tanda	86.4	91.1	91.9	89.4
Dadri	92.0	95.7	98.3	99.4
Badarpur		70.0	86.7	89.1
Korba	87.0	89.7	96.4	96.2
Vindhyachal	92.5	70.6	90.7	93.1
Sipat			0.0	53.9
Farakka	81.8	81.3	83.8	76.8
Kahalgaon	89.3	56.1	42.4	58.5
Talcher-Kaniha	80.6	90.0	94.2	85.8
Talcher-Thermal	87.6	88.1	86.6	92.7
Ramagundam	86.5	88.9	90.4	94.5
Simhadri	88.4	92.1	88.8	97.4
Average	85.9	83.7	82.4	87.2



Source: NTPC Annual Report

Fig. 3.2-2 PLF for each Power Plant

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.

(There are five (5) Load Dispatch Centers, northern (NRLDC), eastern (ERLDC), western (WRLDC), southern (SRLDC), northeastern (NERLDC) and national (NLDC).)

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.

With the support of USAID, CenPEEP has been conducting the following activities:

(1) Performance Testing

- Boiler Performance testing & Optimization
- Mill performance testing using Dirty Pitot & Rotary Sampler
- Furnace Performance Tests using High Velocity Thermocouples (HVT) probes
- Air preheater tests and gap analysis
- Clean air flow test using L type Pitot test
- Turbine Cycle Heat rate Test
- HP & IP Enthalpy drop test
- BFP performance test
- Feedwater heater & Condenser Performance testing
- Cooling Tower tests

(2) Techniques

- High Volume Sampler for collecting fly ash samples to find out un-burnt Carbon in Fly ash
- Air-in-leak assessment in Boiler using High Velocity Thermocouple (HVT) probe and survey of flue gas composition at various points
- Condenser tube cleaning using Water Powered Cleaners
- Condenser Helium leak detection for air ingress
- Eddy current induction heating for opening & closing of Turbine studs/cup nuts
- Technologies for equipment diagnostics
    1) Use of IR Thermography
    2) Acoustic leak survey of valves
    3) Acoustic survey of compressor house
- PDM Survey of Generator Transformer using acoustics, vibration, DGA & IRT

(3) Best Practices & Systems

- Introducing new overhaul practice of US Utilities
- Best O&M practices of US Utilities for subcritical units
- Risk evaluation And Prioritization & Financial Risk Optimization based on ASME manual

(4) Development of Guidelines/Knowledge Sharing

- Heat rate Improvement Guidelines based on learning from US experts and institutions

- Workshops/Training Programs on Plant performance techniques & O&M practices
- Issue of Performance Optimizers on proven technologies
- Technical paper presentation & Participation in International conferences
- Visit to US utilities by NTPC executives

(5) Supply of Test equipments

➢ Instruments for performance testing, diagnosis and condition monitoring for speedy implementation of the project

- Instruments list for Turbine performance testing
  1) Pressure Transmitters & RTDs
  2) Portable DAS Box
  3) Portable Power Meter (Yokogawa)
  4) Conco Pumping Unit Acces. for condenser tube cleaning
  5) Portable helium leak detector with Accessories
  6) Ultrasonic flow meter

- Instruments list for Boiler performance testing
  1) Gas Analyzer with conditioning system
  2) High velocity thermocouples
  3) In-situ fly ash samplers
  4) Dirty Pitot kit & Isokinetic coal sampler
  5) 'S' Type pitots

- Instruments list for Diagnostic
  1) Ultrasonic (Acoustics) Emission Detector for Partial Discharge in Transformers and valve leaks
  2) Video scope for inspection of equipment like HT Motors

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

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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.

(1) #1 Work shop (January 29 and 30)

Study team introduced Japanese practice by following presentation.

1) Introduction (Mr. Shimizu)
2) Boiler maintenance & performance improvement (Mr. Miyagi)
3) Boiler RLA (Mr. Hayakawa)
4) Turbine maintenance & performance improvement (Mr. Koizumi)
5) Pump assessment (Mr. Koizumi)
6) Condenser leak buster (Mr. Koizumi)
7) Efficiency management (Mr. Morooka)
8) Diagnosis of transformer (Mr. Fujimori)
9) Instrument & Control system (Mr. Okame)

All the slides are attached in Clause 8.2.1.

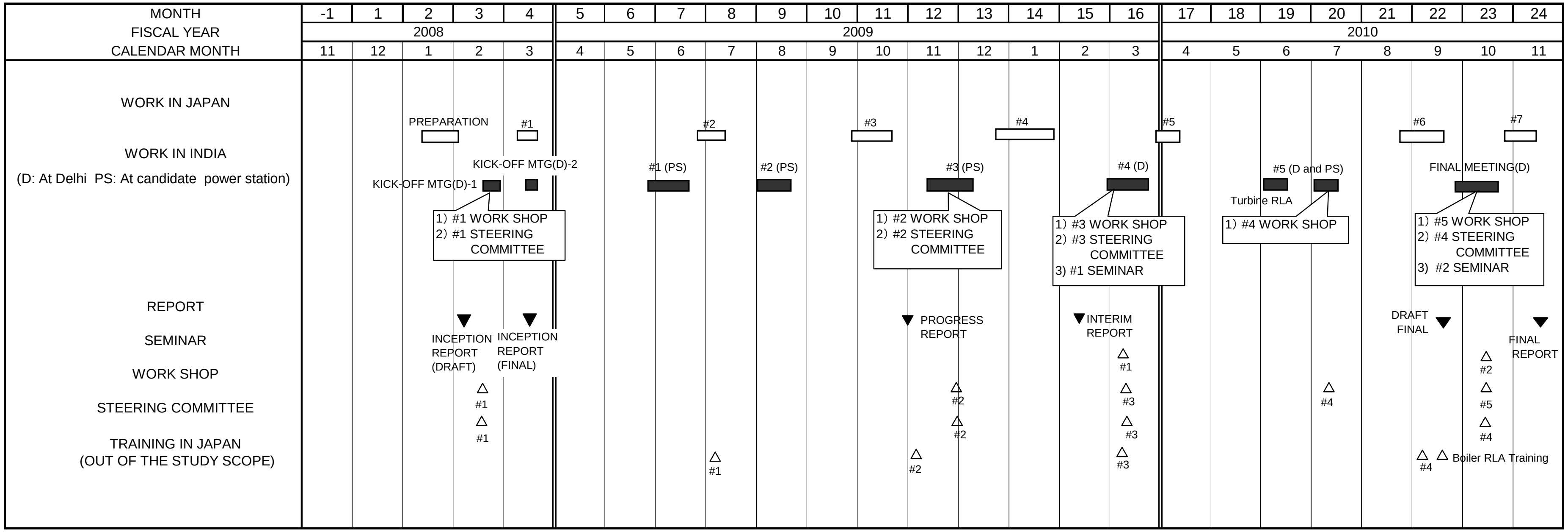
(2) #1 Steering Committee

NTPC and Study team discussed together with MOP and JICA India about the contents of Inception report. The MoM is attached in Clause 8.1.

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



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 (refer to Table 4.3-1), by visiting 5 units, two days per each unit, which NTPC nominated as shown in Table 4.3-2, 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 location 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 eight units finally depending on respective investigation theme by reflecting applicability of each investigation theme to nominated units. The detail is mentioned in Clause 5.

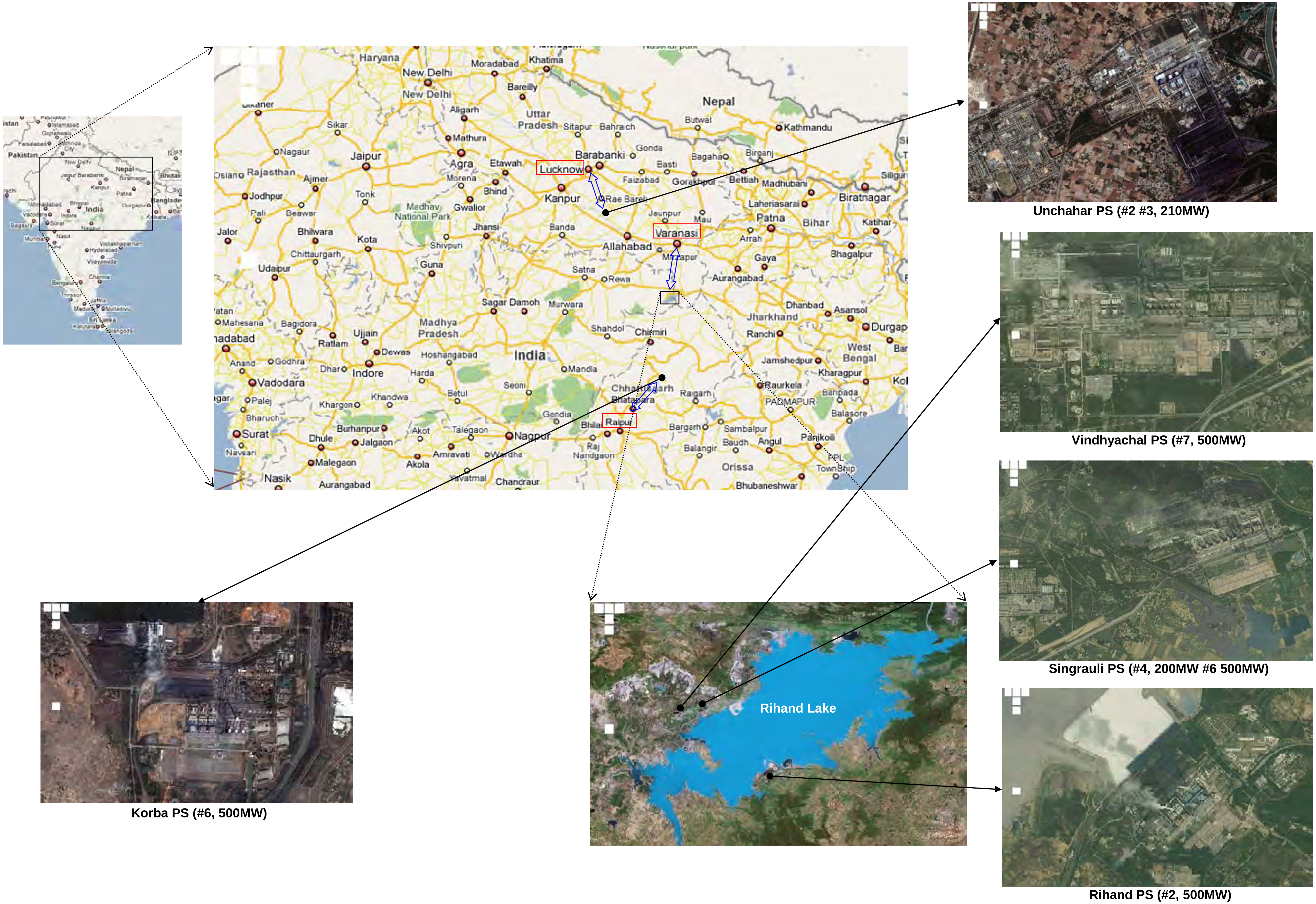


Fig. 4.3-1 Five Candidate Power Station

Table 4.3-1 Itinerary for Visit to 5 Candidate Power Stations

Day	Date		Night Stay	Activity
1	17-May	Sunday	Delhi	Arrival at Delhi via JAL471(17:45), TG315(20:45), etc.
2	18-May	Monday	Delhi	Meeting at CenPEEP, Noida, Meetings with Alstom India and NASL
3	19-May	Tuesday	Vindhyachal Guest House	Departure To Vindhyachal; Delhi to Varanasi by Flight IC-406 Air India (10:05 - 11:20)
				Varanasi to Vindhyachal by Car (12:00 - 18:00)
4	20-May	Wednesday	Vindhyachal Guest House	Vindhyachal Unit 7
5	21-May	Thursday	Vindhyachal Guest House	Vindhyachal Unit 7
6	22-May	Friday	Vindhyachal Guest House	Singrauli Unit 4
7	23-May	Saturday	Vindhyachal Guest House	Singrauli Unit 4
8	24-May	Sunday	Rihand Guest House	Departure to Rihand by Car (10:00-12:00)
9	25-May	Monday	Rihand Guest House	Rihand Unit 2
10	26-May	Tuesday	Rihand Guest House	Rihand Unit 2
11	27-May	Wednesday	Delhi Hotel	Departure to Delhi via Varanasi; IC-405 Air India (15:40 17:00); Stay at Hotel
12	28-May	Thursday	Korba Guest House	Depatrture to Korba; Delhi - Raipur flight IC-869 Air India (05:50 - 07:30);
13	29-May	Friday	Korba Guest House	Korba Unit 6
14	30-May	Saturday	Raipur Hotel	Departure to Raipur by Car (15:00 - 20:00); Stay at Hotel;
15	31-May	Sunday	Delhi	Raipur to Delhi by Flight IC 869, Air India (08:05 - 10:40)
16	1-Jun	Monday	Unchahar Guest House	Departure To Unchahar; Delhi to Lucknow by Flight IC-411 Air India (08:05 - 09:00)
				Lucknow to Unchahar by Mini Coach (09:30 - 11:30); Unchahar Unit 3 - 2nd Half
17	2-Jun	Tuesday	Unchahar Guest House	Unchahar Unit 3
18	3-Jun	Wednesday	Delhi	Unchahar Unit 3 - 1st Half; Departure to Delhi - 2nd Half
				Unchahar to Lucknow by Car (14:00 - 16:00)
				Lucknow to Delhi by Flight IC - 812 Air India (17:50 - 18:45)
19	4-Jun	Thursday	Delhi	Meeting at CenPEEP, Noida, Meetings with Alstom India and NASL
20	5-Jun	Friday	-	Meeting at CenPEEP, Noida / Delhi, (Meetings with Alstom India and NASL)
				Leave for Japan by JAL(19:35), TG316(23:30), etc.
21	6-Jun	Saturday	-	Arrive in Japan

Table 4.3-2 Brief Details and Criteria of Power Plant Selection

No	Criteria of selection / plant name	Korba U6**	Singrauli U4	Rihand U2	Vindhyachal U7*	Unchahar U3	Badarpur U4*
1	Location (State)	Chatisgarh	UP	UP	MP	UP	Delhi
2	Capacity (MW)	500	200	500	500	210	210
3	Turbine Make	KWU	LMZ	GEC	KWU	KWU	LMZ
4	Boiler Make***	BHEL	BHEL	ICL	BHEL	BHEL	BHEL
5	Overhaul Scope****	B+IP+LP	B+HP+IP +LP	B+IP+LP	B	B+HP+IP +LP	B
6	Age	1989	1983	1989	1999	1999	1978
7	Cost effectiveness	2	3	3	3	2	3
8	Possibility as a model plant	3	3	2	3	2	3
9	Motivation of power plant personnel	3	3	3	3	3	3
10	Actual plan for rehabilitation	3	3	3	2	1	2
11	Budget capability	3	3	3	3	3	3
12	Safety and hygienic site	3	3	3	3	3	3
13	Accessibility to the site	2	2	2	2	2	3
14	Necessary data & information available	3	3	3	3	3	2
15	Shut down period*****	1 Oct – 30 Oct 09	1 Aug – 14 Sept 09	9Aug – 17 Sept	1July – 25 July 09	11 Oct – 14 Nov 09	1 July – 20 July
16	Past improvement plan was not applied	3	3	3	3	3	3

- *Presently six units are shown but after having confirmation of re-engineering study by JICA, one of Vindhyachal /Badarpur will be selected.
- **Most of the 500 MW units in India are of this type / similar
- ***BHEL and ICL boiler are CE design
- ****B-Boiler, HP-HP turbine, IP-IP turbine, LP-LP turbine
- ***** Shut down period: As per current plan; some changes may be required to be made after unit selection

4.4 #2 Field Work

#2 Field work was carried out from July 21, 2009 to August 8, 2009. (refer to Table 4.4-1) 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. (refer to Table 4.5-1) Study team carried out following actions for the candidate units based on the scope matrix (refer to Table 5.1-4). During those tests and assessment, demonstration was performed as On-the-Job Training, which is corresponding to #2 workshop. Further, Study team 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. (refer to Table 4.6-1) 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. (refer to Table 4.7-1) 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. (refer to Table 4.8-1) 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.

Table 4.4-1 Itinerary of July Visit

				Shimizu	Miyagi	Morooka	Hayakawa	Yakabe (Kyuden Sangyo)	Kuba	Fujimori	Okame	Koizumi	Kawashima (Fuji)	Hirose (Fuji)	Sato (Fuji)	Iriki (Fuji)	Kuroda (Torishima)	Scott (Torishima)	
	17	Fri	Activity									Arrival at Delhi	→						17
			Stay									Delhi	Delhi						
	18	Sat	Activity									Holiday	→						18
			Stay									Delhi	Delhi						
	19	Sun	Activity									Delhi to Varanasi IC 406(10:15) Varanasi to Vindhyachar (car)	→						19
			Stay									Vindhyachar	Vindhyachar						
	20	Mon	Activity									Singrauli #6	→						20
			Stay									Vindhyachar	Vindhyachar						
	21	Tue	Activity	Arrival at Delhi	→	→	→	→	→	→	→	Vindhyachar to Varanasi (car) Varanasi to Delhi IT 334 (13:45)	→ Delhi to Japan						21
			Stay	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi							
	22	Wed	Activity	Internal preparation Meeting with CenPEEP	→	→	→	→	→	→	→	→							22
			Stay	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi							
	23	Thu	Activity	Delhi to Raipur IC869 (05:50) Raipur to Korba (car) Korba #6	→	→	→	→	→	→	→	→							23
			Stay	Korba	Korba	Korba	Korba	Korba	Korba	Korba	Korba	Korba							
	24	Fri	Activity	Korba #6	→	→	→	→	→	→	→	→							24
			Stay	Korba	Korba	Korba	Korba	Korba	Korba	Korba	Korba	Korba							
July	25	Sat	Activity	Korba #6	→	→	→	→	→	→	→	→							25
			Stay	Korba	Korba	Korba	Korba	Korba	Korba	Korba	Korba	Korba							
	26	Sun	Activity	Korba to Raipur (car) Raipur to Delhi IT3657 (18:20)	→	→	→	→	→	→	→	→							26
			Stay	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi	Delhi							
	27	Mon	Activity	Delhi to Varanasi IC 406 (10:15) Varanasi to Rihand (car)	→	→	→	→	→	→	→	→							27
			Stay	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand							
	28	Tue	Activity	Rihand #2, #3	→	→	→	→	→	→	→	→	Arrival at Delhi	→	→	→			28
			Stay	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Delhi	Delhi	Delhi	Delhi			
	29	Wed	Activity	Rihand #2, #3	→	→	→	→	→	→	→	→	Delhi to Varanasi IC 406(10:15) Varanasi to Vindhyachar (car)	→	→	→	Delhi to Varanasi IC 406 (10:15) Varanasi to Rihand (car)	→	29
			Stay	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Rihand	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Rihand	Rihand	
	30	Thu	Activity	AM : Rihand #2,#3 Rihand to Singrauli (car) PM : Singrauli #4, #6	→	→	→	→	→	→	→	→	Singrauli #6	→	→	→	AM : Rihand #2 Rihand to Singrauli (car) PM : Singrauli #4	→	30
			Stay	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Singrauli	Singrauli	
	31	Fri	Activity	Singrauli #4, #6	→	→	→	→	→	→	→	→	Singrauli #6	→	→	→	Singrauli to Varanasi (car) Varanasi to Delhi IC-405 (15:40)	→	31
			Stay	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar			
	1	Sat	Activity	Singrauli #4, #6	→	→	→	→	→	→	→	→	Singrauli #6	→	→	→			1
			Stay	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar			
	2	Sun	Activity	Holiday	→	→	→	→	→	→	→	→	Singrauli #6	→	→	→			2
			Stay	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar	Vindhyachar			
	3	Mon	Activity	Vindhyachar #7	→	→	Vindhyachar to Varanasi (car) Baranash to Delhi 9W-724(14:40)	→	→	→	Vindhyachar to Unchahar (car)	→	Vindhyachar to Varanasi (car) Varanasi to Delhi IT 334 (13:45) Delhi to Japan	→	→	→			3
			Stay	Vindhyachar	Vindhyachar	Vindhyachar	Delhi	Delhi	Delhi	Delhi	Unchahar	Unchahar							
August	4	Tue	Activity	Vindhyachar #7	→	→	Meeting with CenPEEP Delhi to Japan		Payment Delhi to Japan	Document review	Unchahar #3	→							4
			Stay	Vindhyachar	Vindhyachar	Vindhyachar				Delhi	Unchahar	Unchahar							
	5	Wed	Activity	Vindhyachar to Varanasi (car) Varanasi to Delhi 9W-724 (14:40)	→	→				Document review	Unchahar to Lucknow (car) Lucknow to Delhi 6E-341 (13:00)	→							5
			Stay	Delhi	Delhi	Delhi				Delhi	Delhi	Delhi							
	6	Thu	Activity	Meeting with CenPEEP	→	→				Meeting with CenPEEP	→	→							6
			Stay	Delhi	Delhi	Delhi				Delhi	Delhi	Delhi							
	7	Fri	Activity	Spare day Delhi to Japan	→	→				Spare day Delhi to Japan	→	→							7
			Stay																

Table 4.5-1 #3 Site Work Schedule

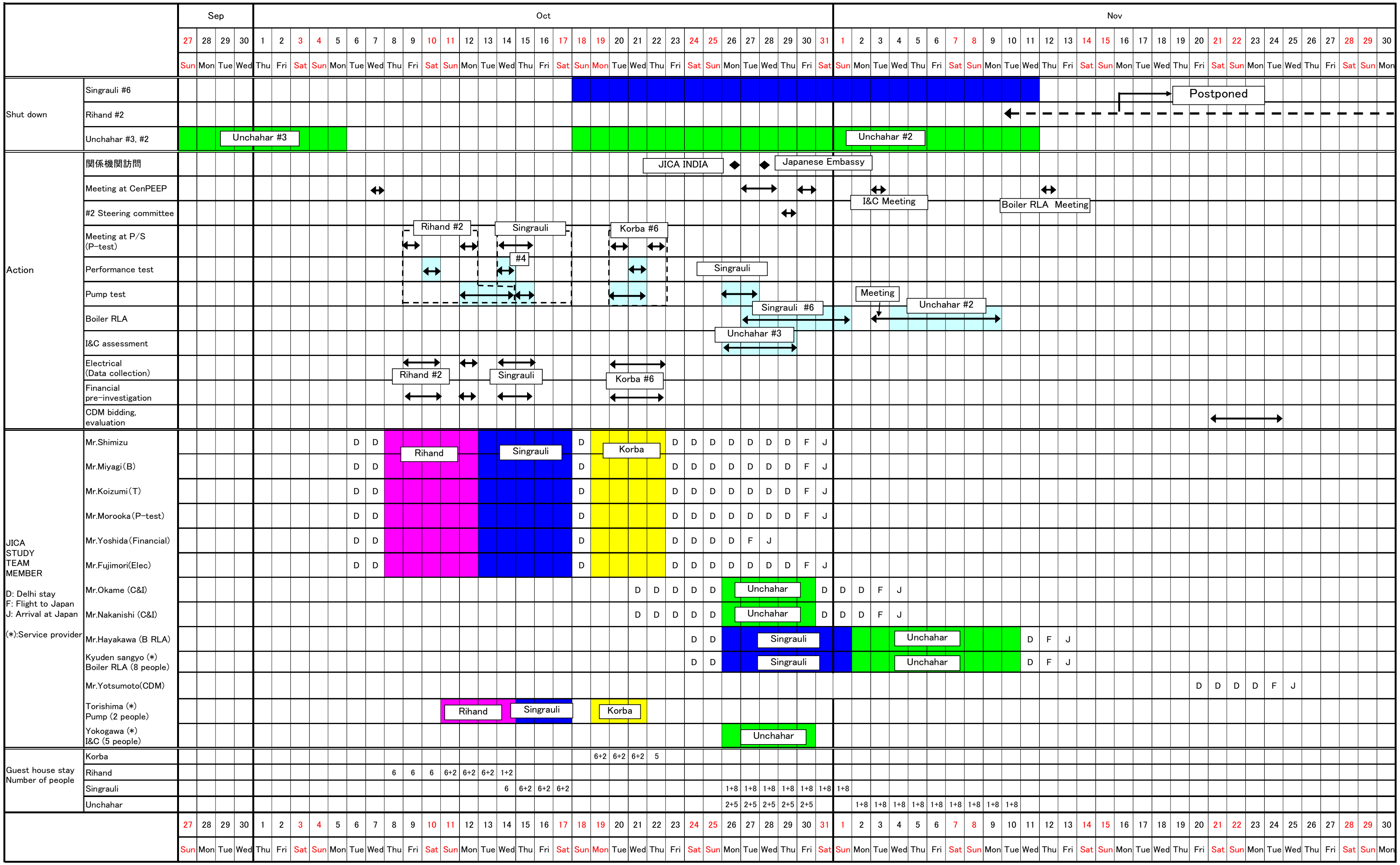


Table 4.6-1 #4 Site Work Schedule

	Item	Feb																																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2	3	4	5	6	7	8	9	10	Remarks
		Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	
Main Sch.	**Japan to Delhi**																☆																							
	Workshop																																							
	Seminar																																							
	#3 Steering committee																																							
	Delhi to Japan																															☆	☆							
Meeting with CenPEEP																																								
Meeting with JICA & Embassy																																								
Seminar	Attachment 4 & Information Request Matters (Separate meeting as for Workshop)																																							
Workshop	Diagnosis of boiler problem																																							
	Combustion simulation																																							
	Boiler RLA																																							
	AH performance improvement																																							
	Seal fin replacement																																							
	Condenser assessment																																							
Separate Meeting (Boiler, Turbine, Electrical, C&I, Performance, O&M)	Pump assessment																																							
	Control system assessment																																							
	BFPT parameter assessment																																							
	Generator assessment																																							
	Transformer assessment																																							
	Analysis of present performance and performance decrease & Improvement of plant performance and application																																							
	Review and improvement of past and present O & M procedure																																							
	Financial analysis																																							
	Preparation of CDM application (pending)																																							
JICA STUDY TEAM MEMBER	Mr.Shimizu																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J						
	Mr.Miyagi(B)																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J						
	Mr.Koizumi(T)																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J						
	Mr..Hayakawa (B RLA)																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J							
D: Delhi stay	Mr.Fujimori(Elec)																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J							
F: Flight to Japan	Mr.Nakanishi (C&I)																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J							
J: Arrival at Japan	Mr.Yoshida(Financial)																D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	F	J							

Table 4.7-1 #5 Site Work Schedule

		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon
Shut down	Korba #4																								
Action	Turbine RLA (Korba #4)					Kick-off										Piping assessment		Turbine RLA / Steam Path Audit							
	Meeting at CenPEEP							CDM																	
	#3 Worlk shop (Financial,CDM)																								
	CDM Contract																								
JICA STUDY TEAM MEMBER	Mr.Shimizu																								
	Mr.Miyagi(B)																								
	Mr.Koizumi(T)		D		Korba			F	J						D					Korba				D	D
	Mr.Morooka(P-test)																								
	Mr.Fujimori(Elec)																								
	Mr.Nakanishi (C&I)																								
	Mr.Hayakawa (B RLA)																								
	Mr.Yoshida(Financial)																								
	Mr.Yotsumoto(CDM)				D	D	D	F	J																
	Alstom Japan*					Korba												Korba							
	NASL*																								
Guest house stay Number of people (+ XX : Number of service provider)	Korba																								
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon

		June																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed
Shut down	Korba #4																														
Action	Turbine RLA (Korba #4)																Piping assessment														
	Meeting at CenPEEP				CDM									Guide line/ Manual			5th VISIT / Wrap-up				Wrap-up of Work shop										
	#3 Worlk shop (Financial,CDM)																														
	CDM Contract																														
JICA STUDY TEAM MEMBER	Mr.Shimizu													D	D	D	D	D	F	J											
	Mr.Miyagi(B)													D	D	D	D	D	F	J											
	Mr.Koizumi(T)	D	D	D	F	J								D	D	D	D	D	F	J											
	Mr.Morooka(P-test)													D	D	D	F	J													
	Mr.Fujimori(Elec)													D	D	D	F	J													
	Mr.Nakanishi (C&I)													D	D	D	F	J													
	Mr.Hayakawa (B RLA)													D	D	D	F	J													
	Mr.Yoshida(Financial)													D	D	D	D	D	F	J											
	Mr.Yotsumoto(CDM)															D	D	D	F	J											
	Alstom Japan*																														
	NASL*																														
Guest house stay Number of people (+ XX : Number of service provider)	Korba																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed

JICA STUDY TEAM MEMBER
D: Delhi stay
F: Flight to Japan
J: Arrival at Japan
(*):Service provider

Table 4.8-1 #6 Site Work Schedule

Item		26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Remakes
								September																														
		Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	
Main Sch.																																						
	Preparation Works																																					
	a) Final Draft Report (including Guideline/Manual)	∇	Report send by e-mail to NTPC																																			
	Japan to Delhi											☆	☆																									
	#2 Seminar																																					
	#5 Workshop																																					
	#4 Steering committee																																					
	Delhi to Japan																							☆	☆													
Meeting with CenPEEP																																						
Meeting with JICA & Japan Embassy																																						
#2 Seminar																																						
	Guideline and Manual																																					
#5 Workshop																																						
Separate Meeting (Boiler, Turbine, Electrical, C&I, Performance, O&M, CDM, Finance)	Guideline and Manual																																					
	Combustion simulation																																					
	Turbine RLA, SPA																																					
	Transformer assessment																																					
	CDM																																					
	Finance																																					
JICA STUDY TEAM MEMBER D: Delhi stay F: Flight to Japan J: Arrival at Japan	Mr.Shimizu											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Miyagi(B)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Koizumi(T)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Morooka(P-test)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr..Hayakawa (B RLA)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Fujimori(Elec)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Nakanishi (C&I)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Yotsumoto (CDM)											D	D	D	D	D	D	D	D	D	D	D	D	F	J													
	Mr.Yoshida(Financial)												D	D	D	D	D	D	D	D	F	J																

CHAPTER 5

SELECTION OF CANDIDATE UNITS AND STUDY SCOPE

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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. All the survey sheets are attached in Clause 8.3. 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 eight 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
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*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	○	– (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

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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.

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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	○(#6)	– (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
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5.2 Present Operation Condition of the Selected Units

(1) Korba #6 (500 MW, 1989)

The total of 2,100 MW power output of Korba power station, consists of three 200 MW units and three 500 MW units, has the biggest power output in Chhattisgarh, and now #7 of extension unit (500 MW) is under construction. Because of constant power shortage in India, all of the units are operated at nearly MCR condition. The power station performance during recent one year was high; Plant load factor of 96.21%, Availability of 93.47% and Load factor of 102.9% were achieved.

Current problems of #6 are as follows:

- HP & IP Turbine efficiency - low
- Turbine Unaccounted Loss is high.
- Feed water, MS & Ext steam Flow validation
- Air Pre-Heater leakages - high
- Unbalance of flue gas temp (SAPH & PAPH)
- Boiler tube Leakages
- Obsolete (Spares C&I & Elect)

As for periodical inspection, boiler inspection is carried out once per year, turbine inspection is carried out once per five or six years and generator disassembly inspection is carried out once per six years.

#6 Turbine RLA was carried out by BHEL (OEM), for HP turbine in 2000, for IP/LP turbine in 2003, and remaining life of 15,000 hours was reported. Boiler RLA was carried out by Darmax B&W in 2002, and remaining life of 10 years was reported.

Renovation of Instrument and Control system of #6 is planned in the near future, and bidding was scheduled in June 2009.

There are two condenser cooling water system, one is closed cycle using forced draft type cooling tower for dry season and the other is one through system for rainy season.

(2) Singrauli #4 (200 MW, 1983)

The total of 2,000 MW power output of Singrauli power station consists of five 200 MW units and two 500 MW units. Same as other units in NTPC power station, #4 is operated at 210 MW, which is nearly MCR of the unit. The power station performance during recent one year was high; Plant load factor of 90.7% and Availability of 89.1% were achieved.

Current plant problems of #4 are as follows:

- High RH spray flow

- Air Pre-Heater leakages

As for periodical inspection, boiler inspection is carried out once per two years, turbine inspection is carried out once per four years and generator disassembly inspection is carried out once per three years.

#4 Turbine RLA was carried out by ABB India (present Alstom India), but precise Remaining life was not reported. Boiler RLA was also carried out by CPRI (Central Power Research Institute), and same as turbine, precise remaining life was not reported.

Replacement of IP and LP rotors is planned at next overhaul, because 25 years passed since start of its commercial operation.

First boiler chemical cleaning after 25 years operation since start of its commercial operation is planned at next overhaul.

Instrument and Control system, except for burner management system and turbine governing system, was renovated to ABB DCS system in 2006.

Cooling water system for condensers is one through system, and cooling water is taken from Rihand reservoir, and is returned to Rihand reservoir. On the way of return line to Rihand reservoir, there is branch connection to Vindhyachal power station for make up of cooling tower.

(3) Rihand #2 (500 MW, 1989)

The total of 2,000 MW power output of Rihand power station consists of four 500 MW units. Now extension of power station, stage III, two units of 500 MW, is under way. Same as other units in NTPC power station, all of the units are operated at around 520 to 530 MW, which is nearly MCR condition. The power station performance during recent one year was high; Plant load factor of 97% and Availability of 96% were achieved.

Current plant problems of #2 are as follows:

- High RH spray flow
- High Air Pre-Heater outlet gas temperature

As for periodical inspection, boiler inspection is carried out once per two years, turbine inspection is carried out once per five or six years and generator disassembly inspection is carried out once per four to six years.

#2 Turbine RLA has not carried out. Boiler RLA was carried out by CPRI.

First boiler chemical cleaning after 20 years operation since start of its commercial operation is planned at next overhaul.

Renovation of Instrument and Control system to DCS, except for burner management system and turbine governing system, is scheduled at next overhaul.

Cooling water is taken from Rihand reservoir through underground tunnel. Stage I cooling water system is one through system and Stage II cooling water system is closed cycle using cooling tower. Make up water of cooling tower is taken from cooling water return line of Stage I.

(4) Vindhyachal #7 (500 MW, 1999)

The Vindhyachal power station is the largest power station in India, as big as total of 3,260 MW power output, consists of six 210 MW units and four 500 MW units. Because of constant power shortage in India, all of the units are operated at nearly MCR condition. The power station performance during recent one year was high; Plant load factor of 93.15% and Availability of 92.18% were achieved..

Current serious problems of #7 boiler is “Low MS/HRH temp.” This problem started from initial operation stage. Though heating surface modification was carried out two times, this problem was not solved.

(5) Unchahar #3 (210 MW, 1999)

The total output of 1,050 MW Unchahar power station consists of five 210 MW units. Because of constant power shortage in India, all of the units are operated at 220 MW at nearly MCR condition. This power station was constructed by State electricity board, and was taken over by NTPC in 1992. The power station performance during recent one year was high; Plant load factor of 93.43% was achieved..

This power station does not have any serious problem.

Different from the other four power stations, this power station does not have its own dedicated coal mine, and they are utilizing three kinds of different domestic coal, two kinds of import coal from Indonesia and Australia.

Renovation of Instrument and Control system is not planned.

Note:

$$\text{Plant Load factor} = \frac{\text{Cumulative output per year (MWh)}}{\text{Rated output (MW)} \times \text{24 hrs} \times \text{365 days}} \times 100(\%)$$

$$\text{Load factor} = \frac{\text{Cumulative output per year (MWh)}}{\text{Rated output (MW)} \times \text{Actual running hours per year}} \times 100(\%)$$

$$\text{Availability} = \frac{\text{Actual running hours per year}}{\text{24 hrs} \times \text{365 days}} \times 100(\%)$$

CHAPTER 6

STUDY RESULT AND RECOMMENDATION

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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

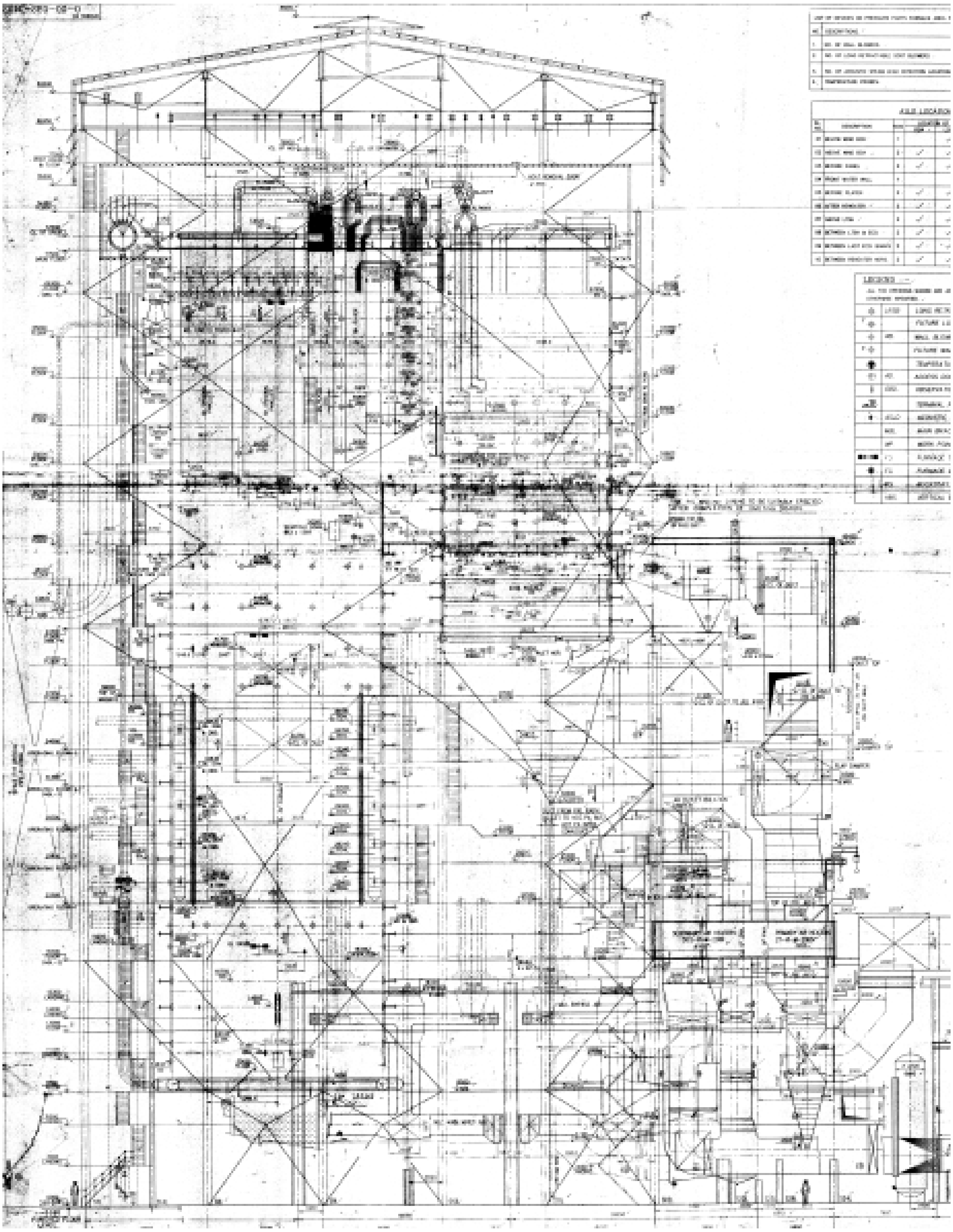


Fig. 6.1-1 Boiler Side View

2) Fuel Property Assessment

The following tables show the properties of fuel coal.

Table 6.1-1 Design Coal Analysis Data

No.	Item	Unit	Design	Remarks
1	Coal Proximate Analysis			
	- Moisture	%	20.5	
	- Ash	%	30	
	- Volatile Matter	%	23	
	- Fixed carbon	%	26.5	
	- GCV	Kcal/kg	3,700	
2	Coal Ultimate Analysis (by Calculation)			
	- Carbon	%	39.35	
	- Hydrogen	%	2.33	
	- Nitrogen	%	0.79	
	- Sulfur	%	0.3	
	- Oxygen	%	6.73	
	- Moisture	%	20.5	
	- Ash	%	30	

Table 6.1-2 Design Coal Ash Analysis Data

No.	Item	Unit	Design	Remarks
1	SiO_2	%	62.7	
2	Al_2O_3	%	24	
3	Fe_2O_3	%	6.5	
4	TiO_2	%	1.82	
5	P_2O_5	%	0.4	
6	SO_3	%	0.55	
7	CaO	%	1.3	
8	MgO	%	1.75	
9	Na_2O	%	--	
10	K_2O	%	0.98	
11	Ash Fusion Temp.	°C	>1,400	

The fuel property evaluation shows that the coal has characteristic of low calorific value and high ash content. The ash has no significant slagging and fouling potential characteristic in the boiler, however erosion may occur by the amount of ash according to following calculation results. The comparison table of this design coal and imported coal utilized in Japan is shown for reference.

➢ Slagging

$$\text{Slagging index} = \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2} \times S$$

Criteria	Slagging index
Low	below 0.6
Medium	0.6 to 2.0
High	2.0 to 2.6
Severe	Over 2.6

➢ Fouling potential

Criteria	$Na_2O + K_2O$
Low	Less than 3.5
Medium	3.5 - 5.0
High	Over 5.0

➢ Erosion Index

$$\text{Erosion index} = \frac{\text{Ash in Coal} \times (SiO_2 + 0.8 \times Fe_2O_3 + 1.35 \times Al_2O_3)}{100}$$

Criteria	Erosion Index
Low	<15.0
Medium	<25.0
High	>25.0

Table 6.1-3 Comparison Table Vindhyachal Design Coal and Imported Coal in Japan

Item	Vindhyachal Design Coal (India Domestic Coal)	Imported Coal in Japan
Slagging	0.04: Low	0.03: Low
Fouling potential	0.98: Low	3.4: Low
Erosion Index	31: High	17: Medium

(2) Boiler Operation Status

The main steam temperature and reheat steam temperature are lower than the design values. Therefore, Study team analyzed the current status of the boiler focusing on the heat absorption ratio of the furnace. The following table shows the calculated design absorption ratio (heat output/heat input × 100) at rated output of 500 MW based on the design values before modification.

Table 6.1-4 Design Heat Recovery Rate

No.	Item		Flow Rate (t/h)	Temp. (°C)	Pressure (kg/cm^2)	Heat Output (kcal/h) (Calculated)	Heat Absorption ratio (%) (Calculated)
1	Economizer	in	1501.8	253	192.8	1.21×10^8	10.8
		out	1501.8	318			
2	Furnace	in	1501.8	318		3.77×10^8	33.8
		out	1501.8	360	188.5		
3	LTSH	in	1501.8	364		1.20×10^8	10.8
		out	1501.8	393	184.7		
4	SH Spray		0				—
5	Division Panel	in	1501.8	393		1.23×10^8	11.1
		out	1501.8	466			
6	Platen	in	1501.8	466		0.82×10^8	7.4
		out	1501.8	540	176.2		
7	RH Spray		0				—
8	Reheater	in	1338.3	336	43.1	1.55×10^8	13.9
		out	1338.3	540	41.4		
9	Total					9.78×10^8	87.8

The following table shows the furnace heat absorption ratios and other related values calculated based on the obtained data.

Table 6.1-5 Heat Recovery Rate

No.	Item	Unit	Design	Dated: 02.2001	Dated: 04.2004	Dated: 01.2005	Dated: 06.2009	Dated: 12.2009
1	Load	MW	500	502	484	513	518	506
2	Furnace	%	33.8	33.2*	34.7*	30.6*	29.3*	30.1*
3	HP Turbine Inlet Temp.	C	537	515	526.9	536.7	523.9	533.7
4	SH Spray	t/h	0	0	0	130	56	24.3
5	RH Spray	t/h	0	1.2	11.2	27	38	13.6
6	Fuel Heat input/MW	Kcal/kg/MWh	2.23×10^6	2.42×10^6	2.33×10^6	2.47×10^6	2.61×10^6	2.58×10^6
7	HPH (6A, 6B)	in service	6A, 6B	6A	6A, 6B	6B	NA	NA

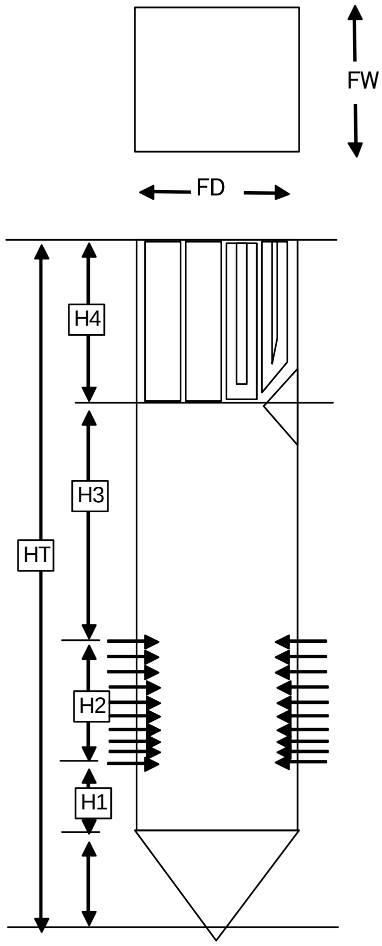
Note: * Calculated by Study Team. Assumption figure was utilized.
HPH: High Pressure Feed Water Heater

(3) 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 2.6 m interval on same type of boiler in Japan and 48 panels with 0.4 m 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.

Table 6.1-6 Boiler Furnace Dimension Comparison Table

No.	Item	Unit	Same type of Boiler in Japan	Vindhyachal Unit 7
1	Rated Output	MW	500	500
2	Boiler High (HT)	m	56	63
3	Bottom of SH Panel to roof (H4)	m	14	16
4	Top Burner level to Bottom of SH Panel (H3)	m	17	18
5	Burner Zone (H2) Burner	m	10 (6 stages)	13 (10 stages)
6	Hopper Bent to bottom of burner (H1)	m	3	5
7	Hopper bend to Bottom of SH Panel (HH (H1-H3))	m	30	36
8	Furnace width (FW)	m	16	19
9	Furnace depth (FD)	m	15	16
10	Furnace Area	m^2	229	303
11	Furnace Volume	m^3	10,700	16,424
12	1st SH Panel (Dev SH)	No.	6	48
13	Panel Pitch (No./FW)	m	2.6	0.40
14	2nd SH Panel (Platen SH)	No.	28	25
15	Panel Pitch(No./FW)	m	0.57	0.76
16	Coal Calorific value	kcal/kg	6600	3700
17	Ash	%	16.6	30



(4) 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. 6.1-2 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.

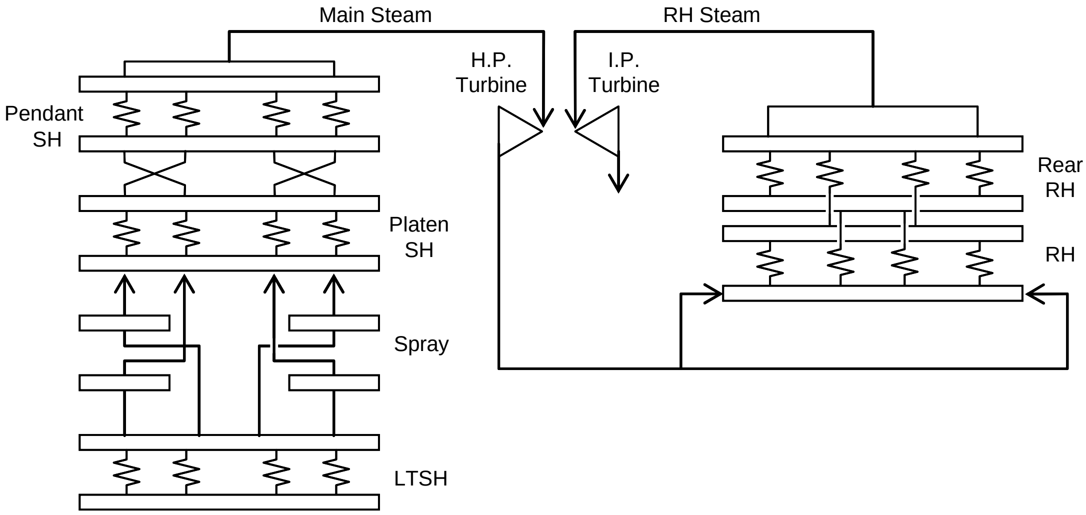


Fig. 6.1-2 Outline of Steam Flow Diagram (Same type of Boiler in Japan)

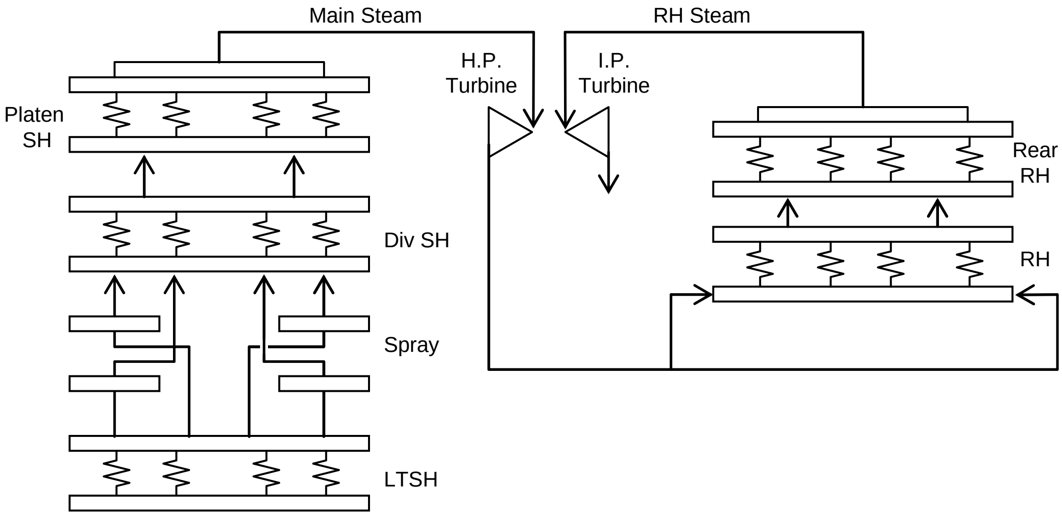


Fig. 6.1-3 Out line of Steam Flow Diagram (Vindhyachal Unit 7)

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 Outline of the Combustion Simulation and the Subject in this Project

The pulverized coal combustion simulator was based on the entrained flow coal gasifire model “RESORT”, which was developed in a national project of Japan. The solution obtained from “RESORT” corresponds to one of the commercially available structured type fluid dynamics code “FLUENT V4”. The gasification model “RESORT” was modified to analyze the coal combustion boiler. In this project, the pulverized coal combustion simulation was done by using the modified “RESORT". Fig. 6.2-1 shows a part of this simulation result.

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

The subject in this project is to evaluate some idea for improving the main steam temperature, the RH temperature and those right and left temperature differences by using the pulverized coal combustion simulation. The combustion simulation was used to evaluate some idea of the improvement.

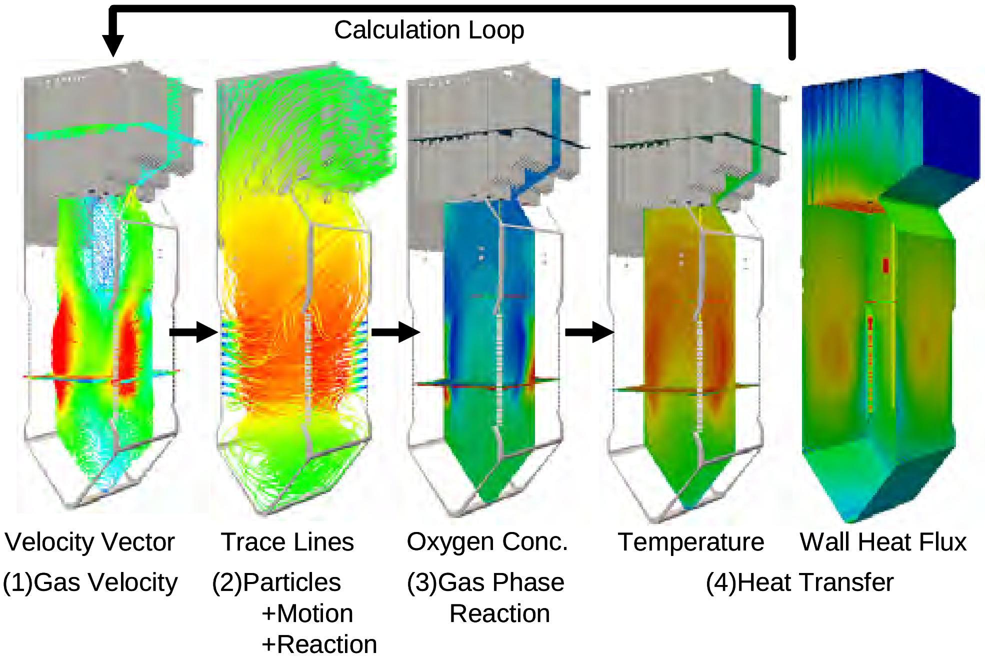


Fig. 6.2-1 Calculation Procedure of the Coal Combustion Simulation

6.2.3 The Mesh Pattern and the Simulation Cases

The mesh pattern, which was made with total 43×53×135=307,665 cells. The fine mesh was employed in near burner where the gradient was large. The elements such as super heater with a lot of numbers of the tube can not be usually calculated in the combustion simulation of the boiler furnace. The reason is that the number of cells increases, and the execution of a lot of simulations becomes difficult in the limited period. However, it is main purpose of this study Then, the mesh which is able to predict more accurate heat flux of the super heater was made. The area of the radiation sections such as Divisional Panel and Platen was matched with the actual heat transfer area as much as possible. In Heater 0-3, the three elements are evaluated especially about the effect of the configuration by having the assumption of the same area.

Base cases are the simulations to know the current status of the boiler. On the other hand, O_2=5%, GR=10%, AA=10%, AA=20%, OFA dumper=50% and the configuration change of Divisional Panel are the improvement cases. The effects of each improvement case were evaluated by comparing the heat recovery pattern with base cases.

6.2.4 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.

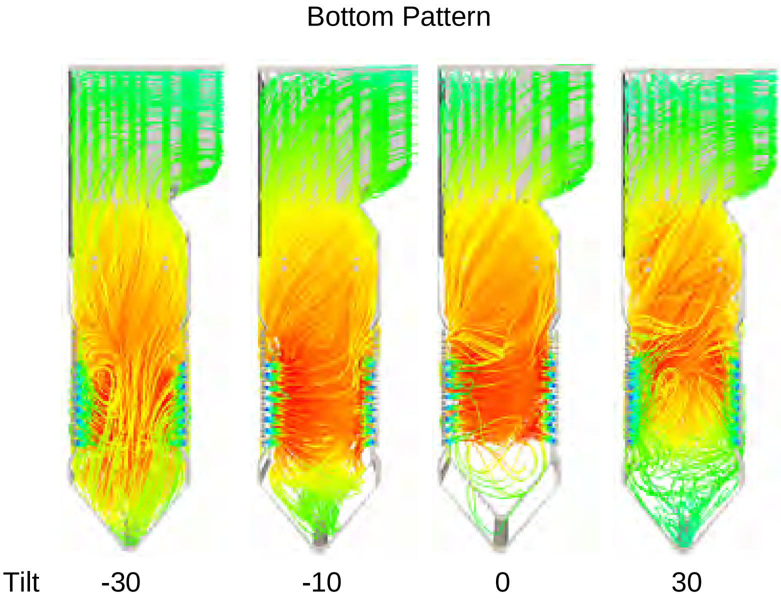


Fig. 6.2-2 Typical Flow Pattern in Tangential Fired Boiler (3)

(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

Table 6.2-1 shows the effect of this operation. 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.

Table 6.2-1 The Effect of the Oxygen Conc. & Gas Recirculation to the Heat Absorption Pattern

	Heat Recovery % (furnace)			Nose Temperature[degC]		
Operation	Base	Effect		Base	Effect	
O_2=5%	32.12	-1.98	↘	1355.98	-39.58	↘
GR=10%	32.12	-4.64	↘	1355.98	-7.87	↘
GR=20%	32.12	-8.60	↘	1355.98	-8.60	↘
	Heat Recovery % (SH)			RH_IN Temperature[degC]		
Operation	Base	Effect		Base	Effect	
O_2=5%	24.40	-1.19	↘	997.89	-2.93	→
GR=10%	24.40	-0.23	→	997.89	23.16	↗
GR=20%	24.40	-0.74	↘	997.89	32.57	↗
	Heat Recovery % (RH)					
Operation	Base	Effect				
O_2=5%	7.91	0.09	↗			
GR=10%	7.91	0.79	↗			
GR=20%	7.91	1.18	↗			

Note1:SH (Wall Heater + Div + Platen) Arrow: Red is good, Blue is bad.
Note2:RH data are reference value.

(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. 6.2-3.

- 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)

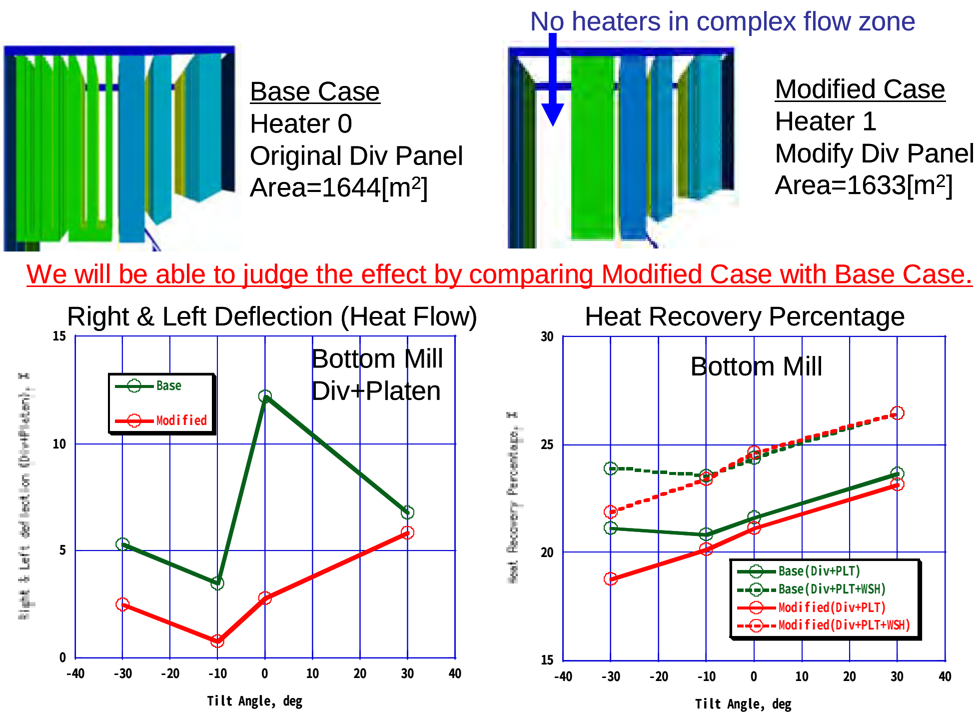


Fig. 6.2-3 Outline of the Calculation Process (5) + Evaluation of the New Idea

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.

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

In accordance with discussion result of the above combustion simulation result, NTPC requested to additional simulation for air and fuel bias cases to solve right and left steam temperature imbalance without any modification of the boiler. The result of simulation study is as follows.

(1) Review of the previous report

The important results in the previous report were summarized as follows.

1) 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 as shown in Fig. 6.2-4. However, there would be not the certainty that this condition keeps always the best condition because the other conditions of the load etc. have always been being changed.

These verification results in Unit 7 were explained from NTPC in the training for the combustion simulation which was held on this August, and it was recognized that the simulations agreed well with the test results. In the bottom mill pattern of the Tilt=-10, Right & Left deflection of the main steam temperature was almost zero. However, the steam temperature was slightly lower than that of usual. The bottom2 mill pattern of tilt=-10 which was another excellent condition was also tested. As a result, it was found that this condition can keep a usual steam temperature within allowable small Right & Left deflection. However, a better condition setting which gives higher steam temperature is hoped.

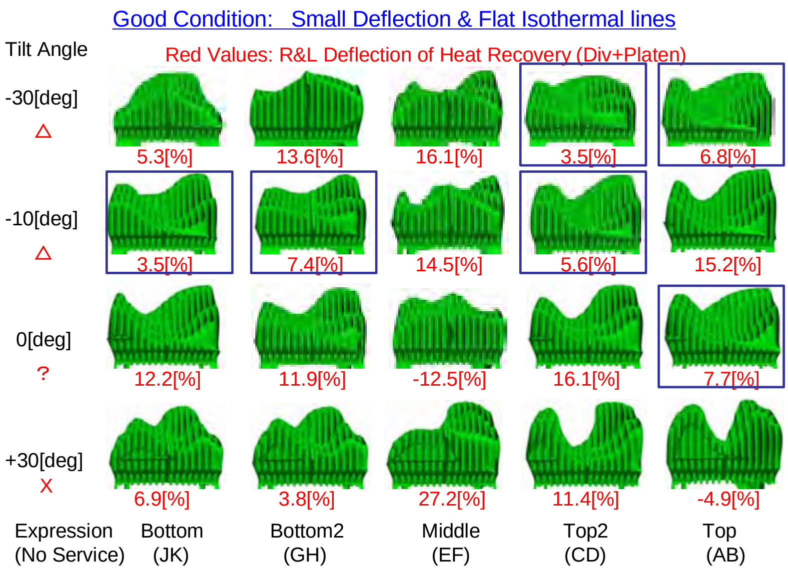


Fig. 6.2-4 Isothermal Surface = 1000 deg in SH Zone

2) Improvement with a little modification

The cross combination of the SH heaters (see in Fig. 6.2-8) 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. On the other hand, the remodeling cost would be also low.

To obtain higher main steam temperature, it would be necessary to turn the tilt from the current angle to the upper direction. At this time, the rise of the RH metal temperature which is one of the other problems would be predicted. But, this problem would be minimized by taking the condition (bottom2 or middle) which gives a small gas temperature gradient in RH zone at all tile angles.

(2) Additional Cases (Right & Left Bias condition of the Air and/or the Fuel)

There is right & left bias of air and/or fuel as a method by which right & left steam temperature difference can be improved without remodeling the boiler. The simulations were performed in the following three kinds of bias conditions.

(a) Right & Left 2nd Air Bias by changing the wind box draft.
(b) Right & Left Fuel Bias by changing the right & left primary air flow rate.
(c) 2nd Air Bias + Fuel Bias

Notes:
The operation (a) is comparatively easy, and is realistic. On the other hand, the control of the operation (b) (to obtain the quite same condition as the calculation condition) would be actually difficult. Consequently, the operation (c) would be more difficult. Here, the effects are predicted by the simulation of all conditions from (a) to (c). However, it is thought that only operation (a) would be actually realistic.

(3) Results of the 2^{nd} Air and/or Fuel Bias condition (Results of the additional cases)

Fig. 6.2-5 shows the effect of the right & left 2^{nd} 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. 6.2-6 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 2^{nd} bias to the right & left steam temperature difference was greatly different depending on the other conditions (Mill pattern and/or Tilt angle).

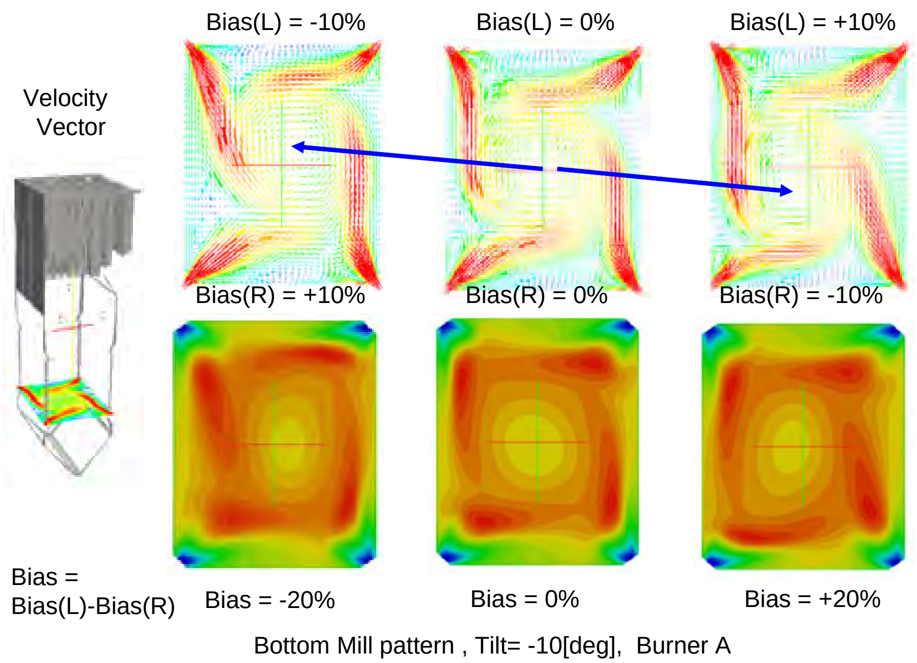


Fig. 6.2-5 Effect of the Right & Left 2nd Air Bias (1-1)

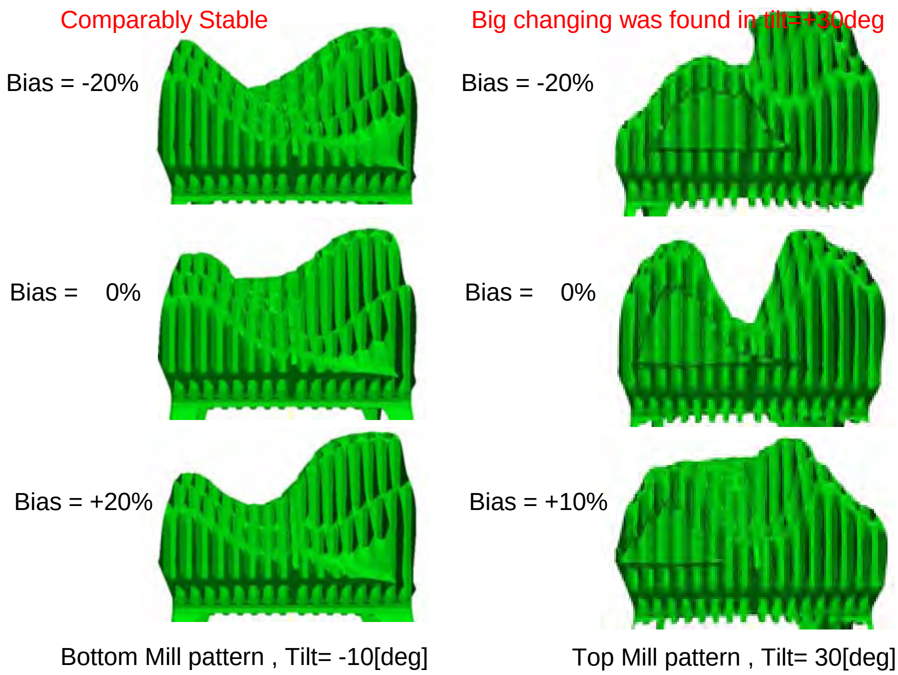


Fig. 6.2-6 Isothermal Surface = 1000 deg in SH Zine by Changing 2nd Air Bias

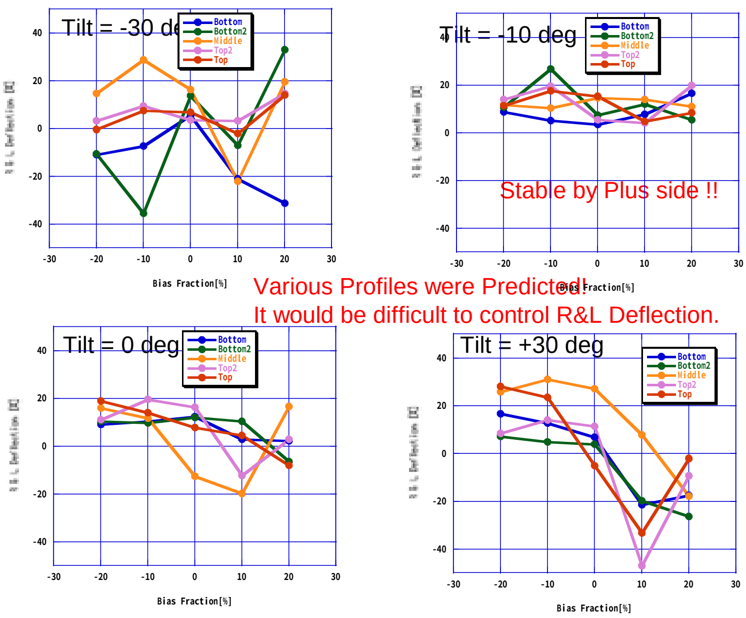
1) The effect of the 2nd Air bias to the Right & Left steam temperature deflection

In Fig. 6.2-7 and Table 6.2-2, 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.

But of course, it is possible to find out the good conditions locally. The interested regions were also shown in Table 6.2-2, and these regions were selected from the area of 0 or more tilt angel. Green frames are the conditions which have already been verified. The blue regions have the possibility, which would reduce the right & left deflection. The orange region would also have the possibility. But this region is a challenging, because it is a big tilt angle or the conditions have a big temperature gradient in RH zone.

Fig. 6.2-8 shows the super heater cross combination patterns, which are very effective to the reduction of the right & left deflection. Fig. 6.2-9 shows the effect of the 2nd air bias to the right & left deflection in each combination. 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.



Plus value = Left (high), Minus value = Right (high)

Fig. 6.2-7 Effect of 2nd Air Bias on the R&L Deflection

Table 6.2-2 Effect of 2n Air Bias on the R&L Deflection

Plus value = Left (high), Minus value = Right (high)

Evaluation Item		R&L Deflection of Heat Recovery (Division Panel + Platen)				
Pattern	Tilt	Straight -20	Straight -10	Straight 0	Straight 10	Straight 20
Bottom (JK)	-30	-11.09	-7.26	5.32	-21.13	-31.15
	-10	8.86	5.04	3.48	7.58	16.57
	0	9.12	10.44	12.19	2.73	2.12
	30	16.60	12.54	6.81	-21.47	-17.45
Bottom2 (GH)	-30	-10.56	-35.46	13.56	-6.97	32.81
	-10	10.51	26.68	7.37	11.90	5.54
	0	10.19	9.57	11.84	10.41	-6.33
	30	6.92	4.69	3.79	-19.69	-26.42
Middle (EF)	-30	14.77	28.75	16.10	-22.15	19.48
	-10	11.68	10.28	14.51	13.93	11.04
	0	15.81	11.52	-12.53	-19.81	16.65
	30	25.65	31.01	27.20	7.83	-17.76
Top2 (CD)	-30	3.11	9.21	3.45	3.29	14.61
	-10	14.00	19.51	5.57	3.98	19.86
	0	11.01	19.53	16.13	-12.36	2.90
	30	8.34	13.91	11.36	-46.92	-9.20
Top (AB)	-30	-0.50	7.53	6.78	-2.13	13.82
	-10	11.28	17.70	15.16	4.79	8.44
	0	18.98	13.82	7.66	4.53	-7.87
	30	28.00	23.44	-4.92	-33.22	-2.01
AverageABS(df%)		12.35	15.90	10.29	13.84	14.10
Max(ABS(df%))		28.00	35.46	27.20	46.92	32.81
MIN(ABS(df%))		0.50	4.69	3.45	2.13	2.01

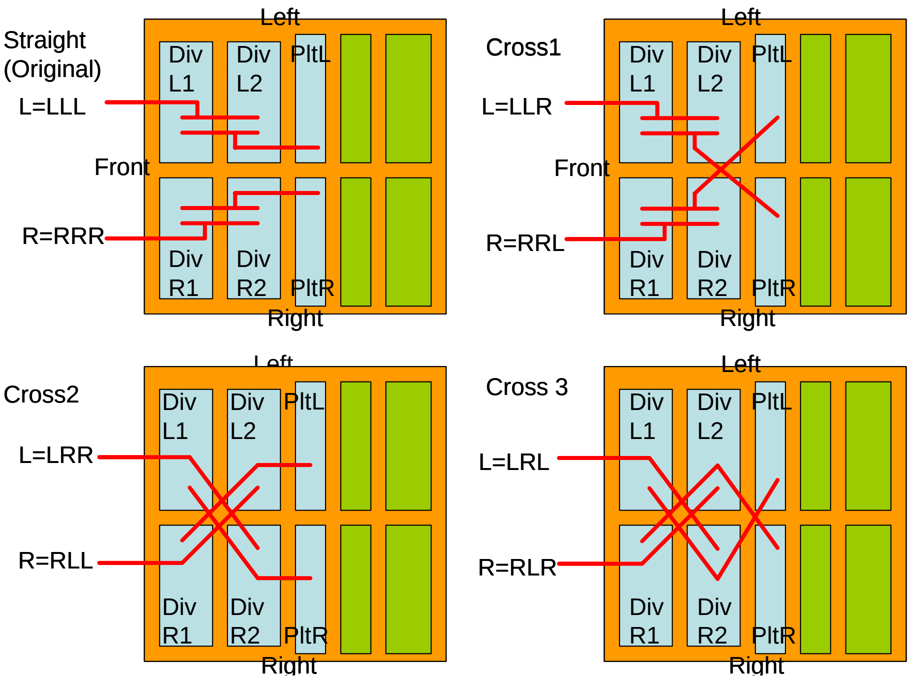


Fig. 6.2-8 Improvement of the R&L Deflection by Changing the Heater Combination (1)

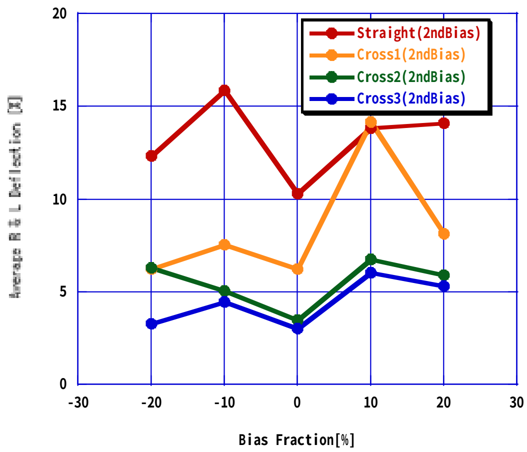


Fig. 6.2-9 Effect of the Heater Combination on the R&L Deflection under the Bias Condition

2) The effect of the other operations

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

(4) Recommendation

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 Section 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 were determined through discussions among Study team, the staff from Kyuden Sangyo and NTPC in the 2nd field work. The preliminary study did not cover Unchahar Unit 2, and therefore, the parts to be inspected and inspection items for Unchahar Unit 2 were determined through discussions among Study team, the staff from Kyuden Sangyo and NTPC before the start of the boiler remaining life assessment. The boiler remaining life assessment results for each unit are summarized in Table 6.3-1 and Table 6.3-2.

Each inspection for boiler remaining life assessment was carried out with demonstration. NTPC strongly desired to acquire the techniques to be able to conduct SUS scale deposition inspection, TOFD inspection and replica inspection which was carried out by taking the replicas back to Japan. Therefore, Study team proposed providing training on advanced non-destructive inspection techniques in Japan in the next 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

  There are differences in the boiler tube thickness management method between NTPC and Japan. NTPC uses the thickness reduction ratio in relation to the design thickness as a criterion. Study team introduced to NTPC that the thickness shell required (tsr) as a criterion, calculated based on the allowable stress of the material, can be applicable as in Japan.

- Differences of boiler remaining life assessment between Japan and NTPC

  There are differences in the scope and inspection items of boiler remaining life assessment between Japan and NTPC. The boiler remaining life assessment in NTPC covers every high temperature part for inspections which include items classified as precise inspections in Japan, while the boiler remaining assessment 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 based on 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 sootblower 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

There are two primary air heaters and two secondary air heaters making up two lines: A line and B line. This study will be conducted with the primary air heaters where significant air leakage occurs. The primary air heaters of Korba #6 are Ljungstrom type heaters and use a vertical Bi-sector heat exchanger. The following shows a systematic diagram of an air heater.

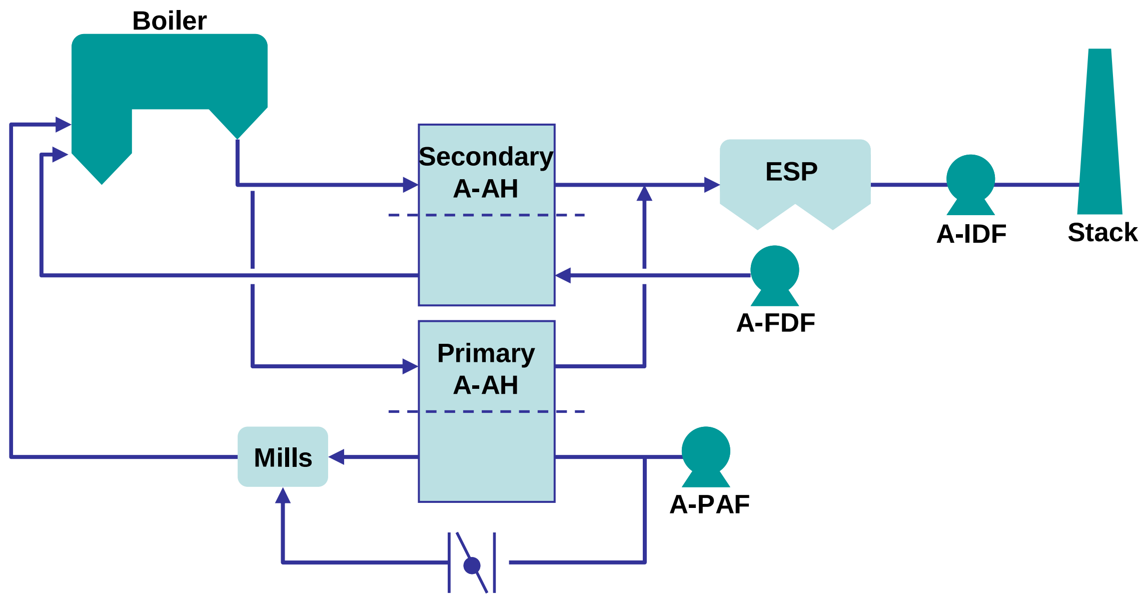


Fig. 6.4-1 AH Air and Gas Flow Diagram

Primary air heater specifications

- Type: Ljungstrom type air heater 27.0-VI-2050 (M)
- Air heater elements: High-and mid-temperature areas: Double undulated (DU) shape
  Low-temperature area: Notched flat (NF) shape

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(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):

$$m = \frac{21 - 0.062 \times (O_2)_{INL}}{21 - (O_2)_{INL}}$$

Constant: 0.062

- AH air leakage ratio:

$$\varepsilon = \frac{(O_2)_{OUTL} - (O_2)_{INL}}{21 - (O_2)_{OUTL}} \times 90$$

- AH air side temperature efficiency: $\eta_A = \frac{t_{A2} - t_{A1}}{t_{G1} - t_{A1}} \times 100$

- Corrected AH outlet gas temperature: $t_{G2'} = t_{G2} + \frac{\varepsilon}{100} \times 0.941 \times (t_{G2} - t_{A1})$

$$\frac{\text{average air specific heat}}{\text{average gas specific heat}} = \frac{Cpa}{Cpg} = 0.941$$

- Corrected gas temperature efficiency: $\eta_{G'} = \frac{t_{G1} - t_{G2'}}{t_{G1} - t_{A1}} \times 100$

- AH average temperature efficiency: $\eta = \frac{\eta_A + \eta_G}{2}$

- AH cold end metal temp.: $t_{dew} = \frac{t_{G2} + t_{A1}}{2}$

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

The air heaters of Singrauli Unit 4 are Ljungstrom type heaters and use a vertical Tri-sector heat exchanger. There are two air heaters making up two lines: A line and B line. The following shows a systematic diagram of an air heater. The air heater elements have a double undulated (DU) shape for high and mid temperature, and a notched flat (NF) shape for low temperature.

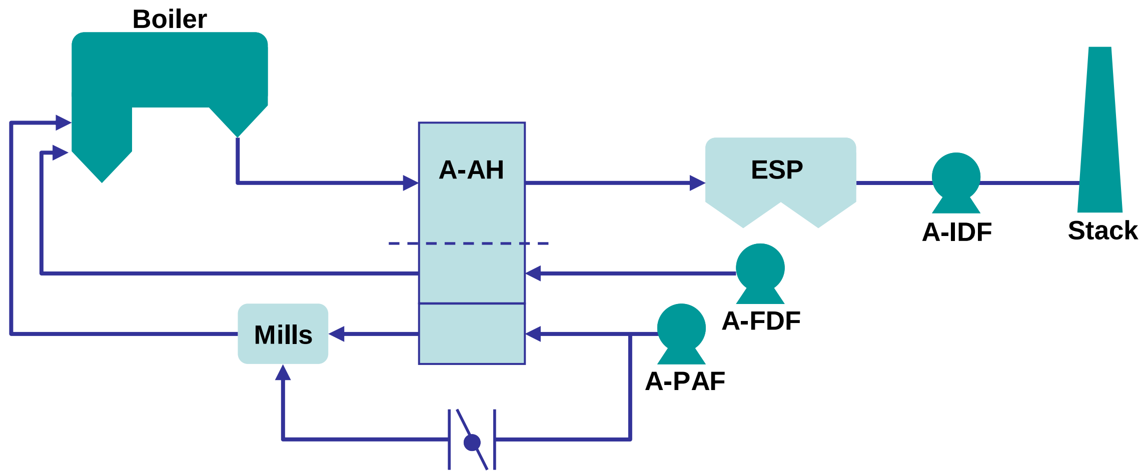

Fig. 6.4-2 AH Air and Gas Flow Diagram

Air heater specifications

- Type: Ljungstrom type air heater 27.0-VI-2050 (T)
- Air heater elements: High-and mid-temperature areas: Double undulated (DU) shape
  Low-temperature areas: Notched flat (NF) shape

(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 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.