5) Efficiency Improvement Ratios with the Adoption of Facility Modifications and Review of Maintenance

It is necessary detail study to adopt the modification mentioned in 1), 2) and 3) due to the structure of the existing air heater. The improvements mentioned in 1), 2), 3) and 4) will be adopted considering cost of modification. By adopting the modifications mentioned 1) or 2) and 3), it can be expected that the AH air leakage ratios will become equal to the design value.

a) Adoption of SDU

Air leakage ratio of SDU design value: 9.0%

b) Adoption of Floating Radial Seals (FRS) and carbon circum seal (CCS):

Air leakage ratio of FRS and CCS design value: 7.0%

c) Adoption of Floating Radial Seals (FRS):

Air leakage ratio of FRS design value: 9.0%

6.5 Turbine RLA

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

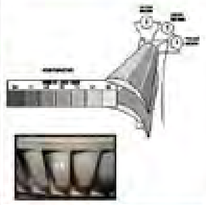
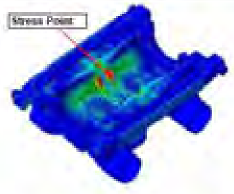
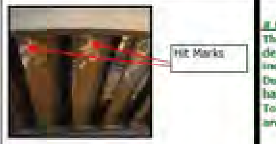
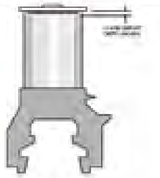
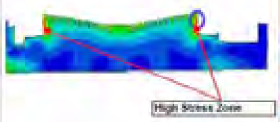
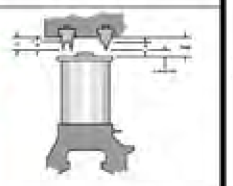
1) Turbine RLA
2) Steam path audit
3) Main piping assessment (Main steam, Hot reheat, Cold reheat and Feed water piping)

Major findings and recommendations are shown in the attached summary.

OVERALL EXECUTIVE SUMMARY OF THE PROJECT (1/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

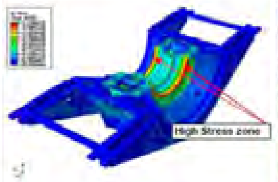
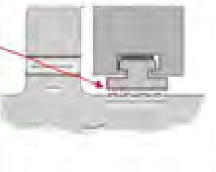
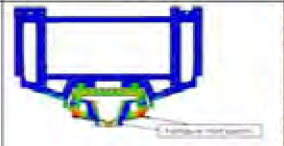
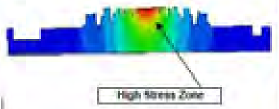
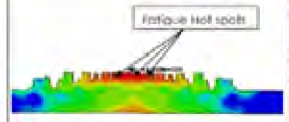
Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

			Findings from Destructive Test (DT) / Non-Destructive Test (NDT)		Findings from Steam Path Audit (SPA)		Remaining Life & Other Findings				Conclusions	Recommendations
Sl No		Component	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Larson Miller Parameters (LMP)	In-situ Metallography (IM)	Finite Element Analysis (FEA)			
1	IP Turbine	IP Inner & Outer Casing	# Visual observations reveal that the Casing and Stationary blades have no significant damage. Some sealing fins are found in damaged condition, which were repaired during the Overhaul. # MPI, DPT & UT of Journal & Coupling Area has not revealed any defect. # Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry. # Microstructural degradation level is II-L. The expended creep life fraction is 0.181. Hardness value of casing is observed in the range of 160-172 BHN at the steam entry side, & 190-200 BHN at the steam exit side.		# Surface Roughness: The opening audit loss due to surface roughness was 3350.3 kW and an increase in heat rate 50.86 kJ/kWh and in closing loss was 1756.9 kW and heat rate was 26.63 kJ/kWh. Total of 1593.4 kW and 24.23 kJ/kWh are recovered.		Not considered.	Based on Microstructural degradation of II-L & the degree of Life expended comes to be 0.12 thus confirming the damage level-1 with expended creep life fraction as 0.181 which proves that the 18% of the life is over of the component.	Observations: # IP Inner casing is highly stressed (530 MPa: Peak transient stress) near the inlet and first stage as shown in the figure. # The FE-SAFE analysis shows the probability of crack initiation in IP casing assembly from the inlet and first stage, over a period of time.		1) NDT/DT showed that the IP turbine assembly is in good condition. No significant defect was observed. 2) Major losses are observed in Surface Roughness of rotating & stationary blades. The followings stages showed the maximum losses: IP Gen side, Stage - 14 : Power loss = 266.9 kW IP Tur side, Stage - 14: Power loss = 266.9 kW 3) FEA results show that stresses are within safe limit of the material. Creep & Fatigue analysis predicted some hot spots, which are most prone to crack initiate, over a period of time. The same analyses need to be periodically carried out during overhauls. 4) From the observations/results of DT/NDT, SPA, FE simulations and fatigue computations, it can be concluded that the life of the rotor is evaluated to be minimum of 16 years, & casing is >20 years, subject to the recommended O&M practice. (it doesn't consider life time for blades and other loose items)	1) Stressed locations as marked in the figures, need to be checked during the inspection/Overhauls and microstructure analysis should also be carried out so as to ascertain the material degradation and damage level. 2) Emphasis is to be given during the overhauling activities to clean the blades surfaces to minimize the surface losses as loss contribution of surface roughness is maximum in steam path components. 3) Although the conclusion of remaining life is found to be 16 years for rotor & 22 years for casing, we recommend to carry out further RLA of the component in 5 years/Overhauls to evaluate the deterioration level.
					# Interstage Packing: The opening audit loss due to interstage packing was -7.7 kW and an increase in heat rate -0.11 kJ/kWh and in closing loss was -138.3 kW and heat rate was -2.09 kJ/kWh. Total of 130.6 kW and 1.98 kJ/kWh are recovered.				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 22 years.			
2	IP Turbine	IP Rotor	# Visual observations reveal that the IP rotor has no significant damage. Coupling holes and coupling bolts are also in good condition. # MPI, DPT & UT of Journal & Coupling Area has not revealed any defect. # Microstructural degradation is II-L and the expended creep life fraction is 0.181. Hardness value of rotor is found to be 204 to 210 BHN at the steam entry side and 221 to 223 BHN at the steam exit side. # Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry.		# Cover Deposits: The opening audit loss due to cover deposits was 106.7 kW and an increase in heat rate 2.03 kJ/kWh. Due to the blasting cover deposit have been removed. Total of 106.7 kW and 2.03 kJ/kWh are recovered.		Not considered.	Based on Microstructural degradation of II-L & the degree of Life expended comes to be 0.12 thus confirming the damage level.1 with expended creep life fraction as 0.181 which proves that the 18% of the life is over of the component.	Observations: IP rotor is stressed (at 360 Map- peak transient stress) near the inlet and last stage. Inlet becomes critical because of higher temperature and pressure of steam.			
					# Tip Spill Strips: The opening audit loss due to tip spill strips was -210.2 kW and an increase in heat rate -3.10 kJ/kWh and in closing loss was -104.3 kW and heat rate was -1.50 kJ/kWh. Total of -105.9 kW and -1.6 kJ/kWh are recovered				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 16 years.	 The analysis shows the probability of crack initiation in IP shaft from the steam inlet location and first stage, over a period of time. (Figure shows the details)		
					# End packing: The opening audit loss due to End packing was 64.2 kW and an increase in heat rate 0.97 kJ/kWh and in closing loss was 26.2 kW and heat rate was 0.40 kJ/kWh. Total of 38.0 kW and 0.57 kJ/kWh are recovered.							
3	IP Turbine	Fasteners	# No significant indications observed in the Visual observations & DPT. # Results of DT of one stud of outer casing showed that the actual & the predicted Charpy Value are matching.		NA		NA		NA		It can be concluded that the condition is normal.	NA
		Bearing No. 03	No significant indication was observed in Visual observations. In DPT, Minor loose bonding observed on the edge portion, the same was checked during the UT and found within acceptable limits.		NA		NA		NA		Based on the VI, DPT & UT, Bearing No. 03 is acceptable for operation for the next five years.	It is recommended to recheck the bearing in every overhauls, especially the babbit bonding.

OVERALL EXECUTIVE SUMMARY OF THE PROJECT (2/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

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

			Findings from Destructive Test (DT) / Non-Destructive Test (NDT)		Findings from Steam Path Audit (SPA)		Remaining Life & Other Findings				Conclusions	Recommendations
Sl No		Component	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Key Observations/ Findings/ condition assessment	Reference Location/Sketch	Larson Miller Parameters (LMP)	In-situ Metallography (IM)	Finite Element Analysis (FEA)			
4	LP Turbine	LP Casing	# Visual observations reveal that the inner-outer casing, erosion has been observed on the weld area as marked in the figures. Stationary blades have no significant damage. Sealing fins are found in good condition. # MPI, DPT & UT of parting plane area has not revealed any significant defect. # No measurable deposits found, indicating good water chemistry.	Erosion observed on weld area inside the inner support plate.  Erosion observed on weld area inside the inner casing.	# Surface Roughness:- The opening audit loss due to surface roughness was 3505.0 kW and an increase in heat rate 54.45 kJ/kWh and in closing loss was 1140.9 kW and heat rate was 17.28 kJ/kWh. Total of 2444.1 kW and 37.17 kJ/kWh are recovered.		Not considered.	Not Considered (due to low temp. zone)	In LP casing assembly, Inner casing shows the stress of 256MPa (Peak transient stress) near the third stage of the turbine.		1) NDT testing & FE analysis results show that stress is within safe limit of the material. 2) Major losses are observed in Surface Roughness of rotating & stationary blades. The followings stages showed the maximum losses: LP Gen side, Stage - 2 : Power loss = 486.2 kW LP Tur side, Stage - 2: Power loss = 487.2 kW 3) Fatigue analysis predicted some hot spots, which are most prone to crack initiation over a period of time. 4) From observations of DT/NDT, SPA, FE simulations and fatigue computations, it can be concluded that the life of the casing is enough more than >20 years, subject to following recommended O&M practice. (It doesn't consider life time for blades and other loose items)	1) Stressed locations as marked in the figures, need to be checked during the inspection/Overhauls and microstructure analysis should also be carried out. 2) Based on explicit observations in various locations i.e. blade root area , leading edge , trailing edge and blade surface of LP turbine rotor, no immediate action is required. However the last stage moving blades of both sides needs to be replaced in the next overhaul.
					# Interstage Packing:- The opening audit loss due to Interstage packing was 245.3 kW and an increase in heat rate 3.71 kJ/kWh and in closing loss was 212.5 kW and heat rate was 3.21 kJ/kWh. Total of 32.8 kW and 0.50 kJ/kWh are recovered				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 113 years.	 For LP casing cracks may initiate from the 3rd stage as shown in the figure.		
5	LP Turbine	LP Rotor	# Erosion observed on the steam exit side of the last stages i.e. TS-6 & GS-6 of blades. # Minor erosion observed on blades of second last stages i.e. TS-5 & GS-5. # Minor pitting is also observed on the blades of stages TS-3 & GS-3. # Erosion observed on leading edge of some of the blades during eddy current inspection. # Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry. # No errosion in balancing weights observed. # There is no significant drop observed in NFT measurements of last 3 stages free standing blades, with respect to design value. # The microstructural degradation level is I-L and the expended creep life fraction is less than 0.181. # Hardness value of rotor is found to be 268 to 278 BHN at the inlet side and 261 to 271 BHN at the collar region (exit side).		# End Packing:- The opening audit loss due to end packing was 2.3 kW and an increase in heat rate 0.03 kJ/kWh and in closing loss was -3.2 kW and heat rate was -0.05 kJ/kWh. Total of 5.5 kW and 0.08 kJ/kWh are recovered.		Not considered.	Based on Microstructural degradation of I-L the expended creep life fraction comes to be less than 0.1, thus confirming the damage level-0, which proves that approx. only 10% of the life is consumed of the component. The component is normal in condition and can be in operation for many more years.	In LP rotor high stress (360 MPa) is observed near the inlet. This is due to higher pressure and temperature of steam at inlet.		In the light of the inspection and analysis made in different stages and critical locations of LP turbine rotor, the following conclusions are derived: 1) Overall condition of the LP rotor moving blades is found to be satisfactory. 2) Erosion observed on leading edge of some of the blades during eddy current inspection. 3) NFT of free standing blades of last three stages shows that the natural frequency is within the acceptable limits. 4) From observations of DT/NDT, SPA, FE simulations and fatigue computations, it can be concluded that the life of the rotor is enough more than 20 years, subject to following recommended O&M practice. (It doesn't consider life time for blades and other loose items)	
					# Tip Spill Strip:- The opening audit loss due to end packing was 161.3 kW and an increase in heat rate 2.44 kJ/kWh and in closing loss was 122.5 kW and heat rate was 1.85 kJ/kWh. Total of 38.8 kW and 0.59 kJ/kWh are recovered.				Conclusions: From the above Analysis and based on Miner's Rule Remaining life = 47 years.	 The analysis shows the probability of crack initiation in LP shaft from the steam inlet location and first stage, over a period of time.		
6	LP Turbine	Fasteners	No significant indications observed in the Visual observations & MPI.		NA		NA		NA		Based on the VI & MPI it is concluded that the condition is normal.	NA
		Bearing No. 04	No significant indication was observed in Visual observations & DPT. UT testing revealed the indications are within acceptable limits.		NA		NA		NA		Based on the VI, DPT & UT, Bearing No. 04 is acceptable for operation for the next five years.	It is recommended to recheck the bearing in every overhauls, especially the babbit bonding.

OVERALL EXECUTIVE SUMMARY OF THE PROJECT (3/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

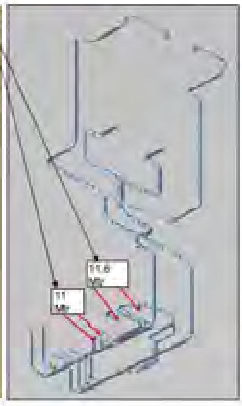
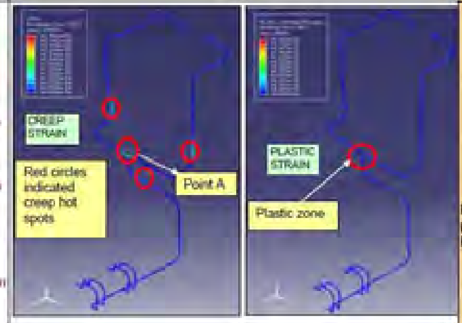
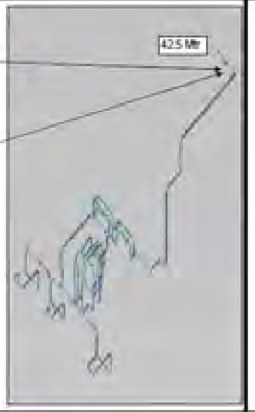
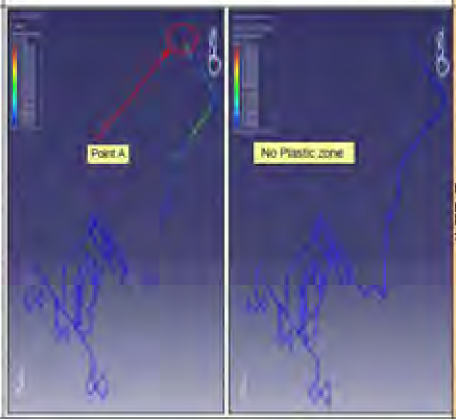
Findings & Recommendations of Turbines & Piping of NTPC-Korba Unit No 4, 500 MW.

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

OVERALL EXECUTIVE SUMMARY OF THE PROJECT (4/4)

OVERALL EXECUTIVE SUMMARY OF THE PROJECT

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

		Findings from Destructive Test (DT) / Non-Destructive Test (NDT)	CAESAR II / Hot & Cold Walk Down Findings			Remaining Life & Other Findings				Conclusions	Recommendations
Sl No	Component	Key Observations/ Findings/ condition assessment	Key Observations/ Findings/ condition assessment	Reference Location/Sketch		Larson Miller Parameters (LMP)	In-situ Metallography (IM)	Finite Element Analysis (FEA)				
1	MS -CRH -HPBP	Visual observations do not show any surface damage. During MPI and UT no significant defect was observed. Partial Bainite and Pearlite Degradation were observed in MS pipe lines. The spherodisation level (diffusion degradation) observed is II-L to IV L. No creep cavities have been observed.	1) The maximum risk node points having highest stress components are marked with elevation. 2) In pipe support No.MST-18,the hanger scale is damaged. 3) In HPBP-02 the spring is topped out. In HPBP-18 the spring casing is missing. 4) Hanger no CRH-17 has no load on the spring. 5) Hanger no CRH-20 is found missing.	Code Stress Ratio (%): 58.5 @Node 2140 Code Stress: 66.9132 MPa Allowable: 114.453 MPa (Sustained Load)		Remaining Life of Piping System based LMP is: For MS Line = 5.91 yrs. For CRH line is > 20 years. For HPBP line is > 20 years.	Based on Microstructural degradation of IIL to IVL & the degree of life expended come to be 0.45 thus confirming the damage level-2 with expended creep life fraction as 0.442, which proves that the 44% of the life is over of the component.	Conclusions: From the above Analysis and based on Miner's Rule, Remaining life is 21 years.	1)Maximum Stress due thermo mechanical load is 168 Map (localized Point A) ,average stress value is 60 to 70 MPa which is within allowable limit.& strain observed is 0.00112.(Elastic Strain 0.001 + Plastic Strain 0.00012) 2)Maximum Permanent Deformation after 25 Yrs of open due to Creep is 88 mm (Point B) 3) Displacement (plastic) of following hangers over a period of 25 years is more than 60 mm. a) MST 044, b) HPB 012, c) CRH 030, d) CRH 032		I) Evaluated Remaining Life through FEA & IM is >20 years (Lower amongst the two). II) Evaluated Remaining Life through LMP is 5.91 years. The wide difference between the evaluated remaining life as above is due to a conservative approach taken in LMP methodology. A safety factor of 1.25 upon operating pressure is taken - to cover the probability of variation in operation, undue stresses due to change in loading pattern & spent life of the pipe. It may be noted that probability of failure is generally located in the hot spot zone as identified in FEA analysis. However evaluated life changes drastically to 25 yrs if 10 % safety factor is taken or in other words if pressure does not rise above design pressure. Based upon above result, we conclude that the expected remaining life could be prolonged up to 20 years under strict compliance of the following: 1) Operating pressure will not exceed design pressure 2) Corrective action of resetting the hangers and supports are taken 3) Close monotiring of weak zones are carried out as recommended. Please note that CRH & HPBP line is evaluated that the remaining life is >20 years.	It is suggested that the critical locations identified be subjected to the following tests in every annual overhauling, mandatory at next annual overhauling: 1. In situ Metallography (IM) to know the material degradation level. 2. Thickness Survey. 3. Online line monitoring systems using the installation of the High temperature strain gauges at identified hot spot locations & thus the real time strain data will be acquired and used for further life estimations. 4. EMAT - Electromagnetic acoustic transducer test / high frequency (20MHz) small diameter probe UT, can be implemented to check the state of steam side surface corrosion. / pitting of the main steam pipe in the critical locations. 5. Indicated hangers required to be corrected.
2	HRH - LPBP	Visual observations do not show any surface damage. During MPI and UT no significant defect was observed. Partial bainite and pearlite degradation was observed in HRH pipe lines. The spherodisation level (diffusional degradation) observed is II-L to III L . No creep cavities have been observed.	1)The maximum risk node points having highest stress components are marked with elevation. 2) A horizontal restraint provided between LPBH13 and LPBPH-14 is in dismantled condition. Bolts to be tightened.	Code Stress Ratio (%): 71.6 @Node 275 Code Stress: 33.5433 MPa Allowable: 46.7189 MPa (Sustained Load) Code Stress Ratio (%): 82.9 @Node 8005 Code Stress: 152.8681 MPa Allowable: 184.3418 MPa (Expansion Load)		Remaining Life of Piping System based on LMP is: For HRH > 20 years. For LPBP >20 years.	Based on Microstructural degradation of II-L to III-L & the degree of life expended come to be 0.45 thus confirming the damage level-2 with expended creep life fraction as 0.442, which proves that the 44% of the life is over of the component.	Conclusions: From the above Analysis and based on Miner's Rule, Remaining life = 13.6 years.	1)Maximum Stress due thermo mechanical load is 102 Mpa (localised Point A) ,average stress value is 50 to 70 MPa which is within allowable limit.& strain observed is 0.00818.(Elastic Strain 0.00712 + Pastic Strain 0.00106) 2)Maximum Permanent Deformation after 25 Yrs of open due to Creep is 100 mm (Point A) 3) Displacement (plastic)of HRH hangers over a period of 25 years is less than 5 mm.		Based on the overall analysis, the condition of piping system is satisfactory. Remaining life is evaluated to 13.6 years.	Run-Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service. Repair / Replace: Indicated hangers required to be corrected.
3	BFD	Visual observations do not show any surface damage. During MPI and UT no significant defect was observed.	1)The maximum risk node points having highest stress components are marked with elevation.. 2) Spring supports below the Feed control station at about 20 M elevation are not accessible for hanger measurements. However, visual inspection in this region shows no damages.	Code Stress Ratio (%): 35.6 @Node 1175 Code Stress: 49.1261 MPa Allowable: 137.8951 MPa (Sustained) Code Stress Ratio (%): 13.1 @Node 1195 Code Stress: 38.8209 MPa Allowable: 296.8034 MPa (Expansion)		Not considered	Not considered	Remaining Life of Piping System based on FEA is > 20 Years.	1)Maximum Stress due thermo mechanical load is 142 Map (localized Point A) ,average stress value is 60 to 70 MPa which is within allowable limit.& strain observed is 0.00066.(Elastic Strain 0.00066 + Plastic Strain 0.0)		Based on the overall analysis, the condition of piping system is satisfactory. Remaining life may be concluded > 20 years.	Run-Component fit for further operation and re-inspection of the component is recommended after 5 years of further operation to monitor the extent and trend in service induced damage and assess its fitness for further service.

6.6 Condenser Leak Buster

(1) Summary

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

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

Table 6.6-1 Summery of Test Result

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

6.7 Pump Assessment

(1) Summary

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

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

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

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

1) Korba Turbine driven BFP (6B)

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

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

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

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

2) Rihand Motor driven BFP (2B)

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

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

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

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

3) Rihand CWP (2B)

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

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

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

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

4) Singrauli Stage I CWP (09)

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

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

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

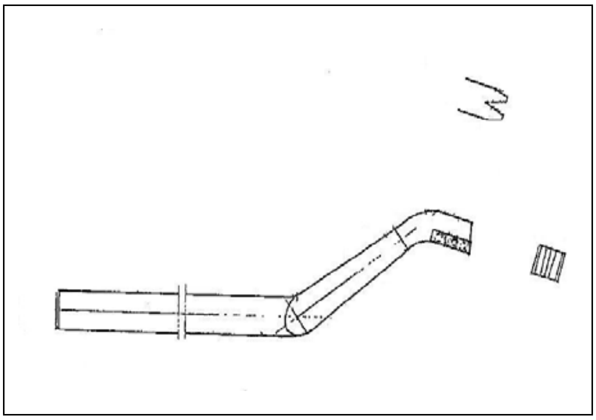
It is recommended to conduct pump test for the same pump every two years, and to carry out the test for other pumps.

6.8 Seal Fin Replacement

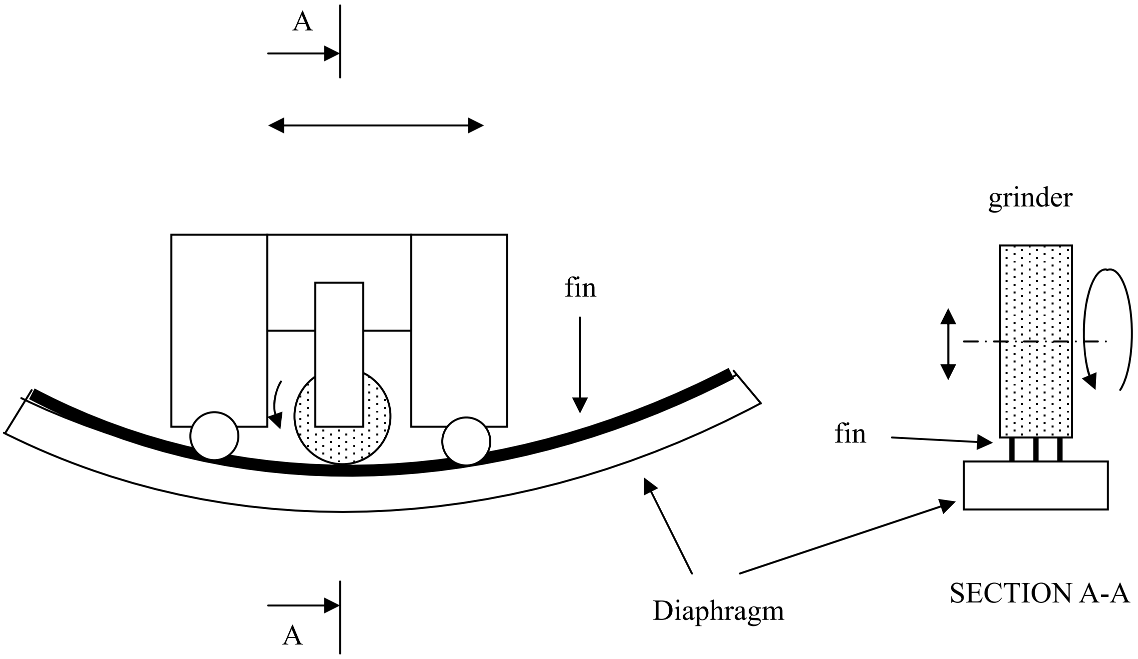
This item was newly requested by NTPC during the first field work to witness during turbine overhaul, and to provide advice by expert in order to share Japanese practice of this work at site. However, due to various constraints, since JICA-ST could not accept NTPC's request, JICA-ST requested NTPC to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

<u>Seal Fin Maintenance Procedure</u>

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



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


A
grinder
fin
fin
Diaphragm
SECTION A-A
A

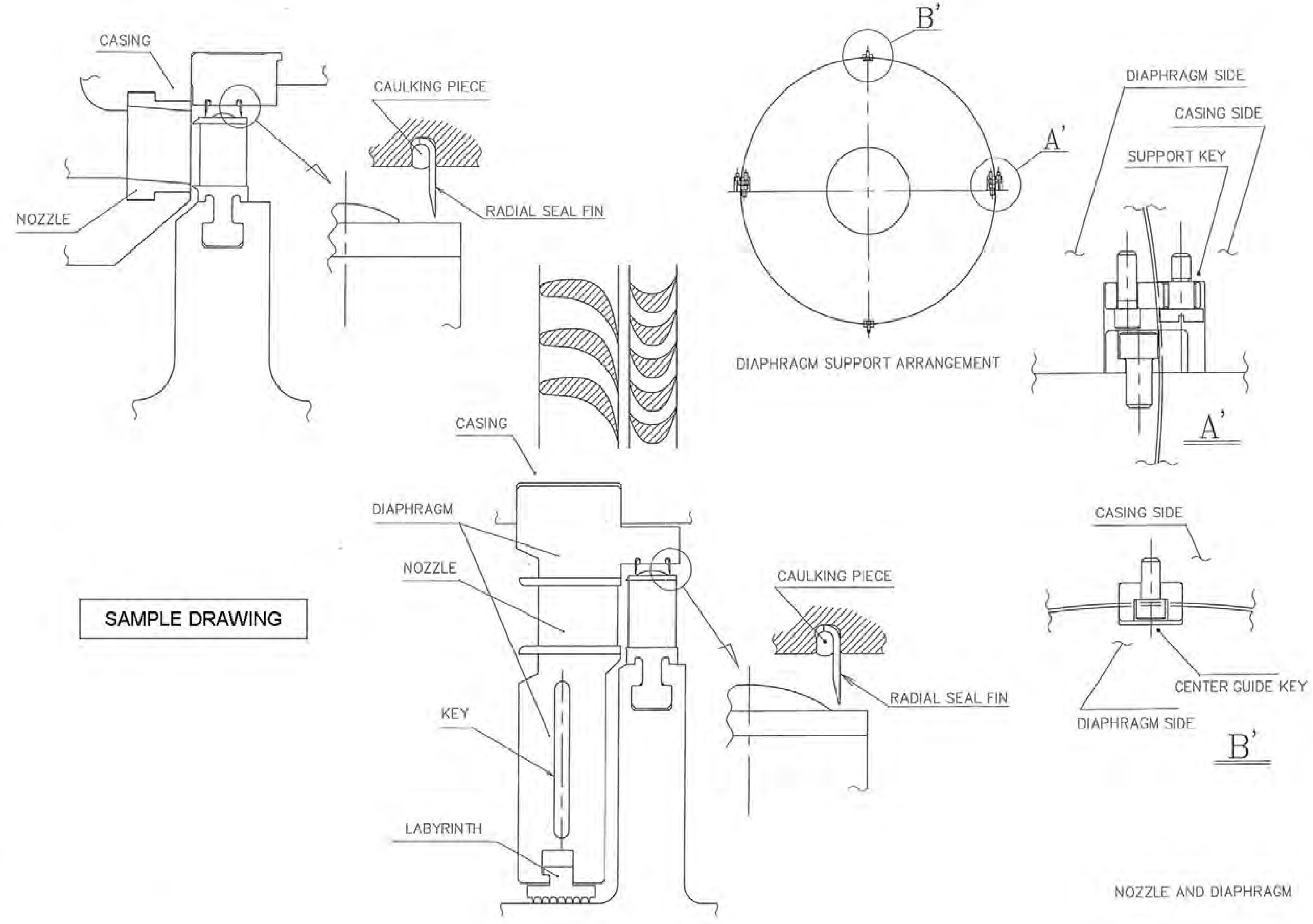


Fig. 6.8-1 Sample Drawing

6.9 Control System Assessment

6.9.1 Overview

(1) Objectives

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

(2) Units to be Assessed

Unchahar #3

(3) Schedule

October 26 to 29, 2009 (4 days)

(4) Team

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

6.9.2 Details

Investigation of the power station facilities (central control room, C&I laboratory room, on-site instruments, etc.)

- Collection of operation data
- Hearing held with control-related engineers and operators
- Variable load test for checking controllability, etc.

6.9.3 Evaluation

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

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

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

6.9.4 Improvement Proposals and Effects

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

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

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

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

6.10 BFP Turbine Parameter Assessment

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

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

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

5) Then, assuming either or both of turbine inner efficiency decrease and pump efficiency decrease, balance point is gotten.

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

(1) Vindhyachal #7

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

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

(2) Rihand #3

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

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

(3) Korba #6

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

6.11 Generator Assessment

6.11.1 Target Generator for Assessment and the Procedure

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

Table 6.11-1 Generators for Assessment

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

In general, stator coil insulation deteriorates faster than other generator parts, such as rotor coil insulation and rotors. Therefore, Study team assesses these generators focusing on their stator coil insulation.

In general, the specifications of stator coil insulation of existing generator are as follows. And the units for the assessment have the same type generator:

- Insulation: Mica
- Resin: Epoxy
- Resin process: VPI (Vacuum Pressure Impregnation)

The following data is required for generator assessment if their stator coil insulation has the above-mentioned specifications:

1) Insulation resistance test (IR test)
2) Polarization index test (PI test) (Lots of historical test data are required for the RLA)
3) Tanδ test (Lots of historical test data are required for the RLA)
4) AC voltage/current test (Step-voltage test) (Lots of historical test data are required for the RLA)
5) Partial discharge test (corona test) (Lots of historical test data are required for the RLA)

Study team analyzed the results of the tests carried out by NTPC and evaluated them according to the Indian and Japanese evaluation criteria to conduct the current condition assessment and RLA.

As for the procedures of current condition assessment and RLA.

When Study team visited these power stations as #2 Field work in late July 2009 and obtained part of the data needed to assess the generators from NTPC. Study team carries out generator assessments after obtaining the additional data needed for the assessment from NTPC and so on and setting the preconditions for the assessment in #3 Field work.

By the way, the followings are strongly required for the assessment
- The data submitted from NTPC are reliable.
- The data are sufficient for the assessment.

6.11.2 Korba#6 Generator Assessment

(1) Outlines

Korba#6 has carried out the IR test and PI test as the insulation assessment of generator stator coil. If any cooling water remains inside the stator coil, the obtained insulation resistance value will be extremely low, making the tests meaningless. Korba#6 has carried out the tests with cooling water remaining inside the generator stator, which means that the tests were meaningless. Korba#6 has carried out the tests with cooling water remaining inside the generator stator, which means that the tests were meaningless. The test results are shown in Table 6.11-2.

When the generator stator insulation is assessed, it is important to use the appropriate procedures. Therefore, Study team recommends that NTPC carry out the tests in the condition that the stator cooling water is properly drained and dried out, and get reliable the test data.

Table 6.11-2 IR Test and PI Test Results

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

Three phases are measured at the same time.
IR(): Insulation resistance test record

6.11.3 Rihand#2 Generator Assessment

(1) Outlines

Rihand#2 has carried out the IR test, PI test and Tanδ test as the insulation assessment of generator stator coil. Cooling water is properly drained and dried out for the assessment. The test results are shown in Table 6.11-3. Some variations are observed in the data of the PI test for RLA, and it is impossible to grasp the deterioration trend now. Therefore, the Study team recommends that NTPC continue to carry out the insulation diagnosis so as to grasp the deterioration trend.

Table 6.11-3 IR Test and PI Test Results

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

6.11.4 Singrauli#4 Generator Assessment

(1) Outlines

Singrauli#4 has carried out the IR test, PI test, Tanδ test, and partial discharge test as the insulation assessment of generator stator coil. Cooling water is properly drained and dried out for the assessment. As for partial discharge test, maximum quantity of electric discharge (Qmax) is the assessment indicator in Japanese power plant, but not in Singrauli#4. Study team could not conduct the assessment by partial discharge test because there is not sufficient explanation about it from Singrauli#4. The results of the IR test, PI test, and Tanδ test are shown in Table 6.11-4.

The test results show that the R-phase and Y-phase are deteriorating, but when the dryness of the generator stator is low, the PI values tend to decrease. Therefore, it is hard to simply say that these phases are deteriorating. However, it is highly likely that these phases are actually deteriorating. Study team recommends that NTPC continue to carry out the insulation diagnosis in all the phases, including B-phase, to grasp their deterioration trend. As for the Tanδ test, technically the Tanδ value increases as the test voltage increases, but the test result shows that the Tanδ value in the Y-phase decreased. Study team recommends that Singrauli#4 check whether the data is strange technically, confirm the reliability with the testers and obtain the appropriate test results.

Table 6.11-4 Current Status Assessment and RLA

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

*1: Possibly due to variations in the stator dryness

6.12 Generator Transformer Assessment

6.12.1 Target Transformers for Assessment and the Procedure

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

Table 6.12-1 Units for Transformer Assessment

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

*1: Originally, Study team planned to assess the GT of Singrauli#4, but the GT of Singraul#4 is of an open type. This means that CO+CO_2 analysis, which is one of the RLA methods, cannot be applied to it. Therefore, Study team assessed Singrauli#6 instead of Singrauli#4.

*2: Two of the three GTs have been replaced recently, and there is no need for the assessment. The other transformer is assessed.

*3: OFAF: Oil-forced air-forced type
OFWF: Oil-forced water-forced type

The transformers were assessed in the following ways:

(1) Current Status Assessment

Current condition assessment requires the following test data and analysis data conducted in recent years:

1) Insulation resistance test (IR test)
2) Dissolved gas analysis (DGA)
3) CO+CO_2 analysis
4) Furfural analysis

(2) Remaining Life Assessment (RLA)

In general, transformer coil insulating paper deteriorates faster than other transformer parts such as iron cores and press board. Therefore, Study team carried out the assessment with a focus on the transformer coil insulating paper.

The RLA was carried out in the following ways:

Based on the results of the following tests conducted by NTPC, the RLA was carried out for the GTs:

1) CO+CO_2 analysis (Lots of historical test data are required for the RLA)
2) Furfural analysis (Lots of historical test data are required for the RLA)

Study team analyzes and evaluates the results of these tests which NTPC carried out according to Japanese evaluation criteria, and carries out the current condition assessment and the RLA.

Study team visited these power stations as #2 Field work in late July 2009 and obtained part of the data needed to assess the GTs from NTPC. Study team carries out GT assessments after obtaining the additional data needed for the assessment from NTPC and so on and setting the preconditions for the assessment in #3 Field work.

By the way, the followings are strongly required for the assessment

- The data submitted from NTPC are reliable.
- The data are sufficient for the assessment.

In addition, as for CO+CO_2 analysis and furfural analysis, NTPC's transformers are assessed by the Japanese assessment method. The Japanese assessment method uses the criteria established based on the results of assessing the transformers manufactured in Japan. The structures and specifications of Japanese transformers may differ from those of NTPC's transformers, meaning that it is highly likely that the assessment results may differ from the actual condition.

Moreover, CO+CO_2 assessment and furfural assessment are originally carried out to estimate the average degree of polymerization (Ave. DP) of insulating paper in an indirect manner. In Japan, these assessments are carried out to roughly estimate the remaining life of insulating paper, not to guarantee the remaining life of insulating paper.

6.12.2 Korba #6 GT Assessment

(1) Outlines

Korba#6 has carried out the IR test and DGA as the current condition assessment. In addition, the furfural analysis has been carried out in recent years, but the CO+CO_2 analysis has not been carried out. However, it is possible to carry out the CO+CO_2 analysis using the DGA data. The assessment results are shown in Table 6.12-2.

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

	Phase	Test record	Evaluation	Remark/standard
Current condition assessment				
IR test	R	3500 MΩ	Good	Smallest value among the values measured between High Voltage–Ground, Low Voltage–Ground, and High Voltage–Low Voltage JP ≥ 80 MΩ
	Y	3500 MΩ	Good	
	B	3250 MΩ	Good	
Dissolved gas analysis	R	–	Good	
	Y	–	Good	
	B	–	Good	
CO+CO$_2$ analysis	R	0.4305 mL/g	Caution	Caution ≥ 0.2 mL/g Danger ≥ 2.0 mL/g
	Y	0.5082 mL/g	Caution	
	B	0.5943 mL/g	Caution	
Furfural analysis	R	0.00389 mg/g	Caution	Caution ≥ 0.0015 mg/g Danger ≥ 0.015 mg/g
	Y	0.00467 mg/g	Caution	
	B	0.00312 mg/g	Caution	
RLA		**Operation years**	**Year**	
CO+CO$_2$ analysis	R	53.7	Sep.-2042	Up to the average service life[*1]
	Y	45.5	Jul.-2034	
	B	38.9	Dec.-2027	
Furfural analysis	R	44.5	Jul.-2033	Up to the average service life[*2]
	Y	37.1	Feb.-2026	
	B	55.7	Aug.-2044	

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

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

6.12.3 Rihand#2 GT Assessment

(1) Overview

Rihand#2 has carried out the IR test and DGA as the current condition assessment. In addition, the furfural analysis has been carried out in recent years, but the CO+CO$_2$ analysis has not been carried out. However, it is possible to carry out the CO+CO$_2$ analysis using the DGA data. The assessment results are shown in Table 6.12-3.

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

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

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

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

6.12.4 Singrauli#6 (R-Phase) GT Assessment

(1) Outlines

Singrauli #6 has carried out the IR test and DGA as the current condition assessment. In addition, furfural analysis has been carried out in recent years. $CO+CO_2$ analysis has not been introduced. However, it is possible to carry out the $CO+CO_2$ analysis using the DGA data. The assessment results are shown in Table 6.12-4.

Generally in Japan, the service lives of GTs are 40 to 50 years. Compared to this figure, the remaining life of the GTs of Singrauli #6 is very short. It is likely that the insulating paper has deteriorated. The reasons are as follows:

- Singrauli #6R GT quality might be a little bit low because the 6Y GT and the 6B GT already broke due to the insulation breakdown troubles, even if they had operated for a short term relatively.
- Singrauli #6R GT has operated with high PLF and over load like other NTPC GTs due to the shortage of power supply. That has made the temperature of the transformer coil and the insulation paper high and the insulation paper deteriorates fast by the high temperature.

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

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

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

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

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

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

(1) Outlines

The assessment results are shown in Table 6.12-5

As for the CO+CO_2 analysis, parts of the test data were technically inconsistent and abnormal. Therefore, Study team conducted the assessment using reliable data only. As the result of that, the assessment result became the same as the previous one Study Team conducted.

As for the furfural analysis, the remaining life was assessed to be shorter than the previous one because this test data slightly increased compared to the previous one. Study Team recommends NTPC continue to conduct furfural analysis periodically so that NTPC can grasp the deterioration trend.

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

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

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

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

6.13 Analysis of Current Performance and Performance Degradation

6.13.1 General

In the 2nd field work, Study team submitted the general performance test procedures shown to NTPC, and discussed the differences in procedures they have with NTPC. The following shows the major differences.

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

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

[frequency of test]

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

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

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

[frequency of test]

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

The performance tests were carried out in the 3rd field work (October 2009) with Korba Unit 6, Singrauli Unit 4, and Rihand Unit 2.

Analysis was made after the performance tests.

(3) Differences in the Implementation of the Performance Tests

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

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

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

➢ Test implementation team

In accordance with Study team’s procedure, the performance tests are carried out by specialized service providers. According to NTPC’s procedure, the performance tests, including those for measuring instruments, are carried out by NTPC itself.

➢ Test preparation

On the day before the performance tests, the power station operation data used for the performance tests are checked and, if any problems/discrepancies are found, they are calibrated. When Study team selected one power station and checked the data displayed in the central control room before the performance tests, Study team found some inappropriate values. Study team also found some inappropriate values when the team checked the performance test data sent from NTPC.

➢ Test implementation

In accordance with Study team’s procedure, those involved in the performance tests are informed 30 minutes before the performance test is carried out and they have a ten minute briefing to confirm the test procedure before starting the performance test.

In order to ensure that the test data is recorded in a timely manner, those involved are informed of the recording times via a paging system.

➢ Boiler gas outlet composition measurement

The gas composition analyzer is calibrated with a standard gas on the day of the performance tests.

NTPC uses a portable gas composition analyzer. According to NTPC, this is because the performance tests are carried out frequently, and the performance of the portable analyzer is almost equivalent to that of the desktop analyzer.

In accordance with Study team's procedure, the performance tests are carried out with a portable gas composition analyzer. In addition, gas compositions are measured several times using different measurement methods (Orsat method and simplified gas analyzer) to verify the readings of the gas composition analyzer.

NTPC uses the Orsat method to measure the gas composition in the performance tests, but does not use a dust removal bin (a bin to remove dust from gas to sample gas only).

- Sampling

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

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

Fig. 6.13-1 Coal Sampling Plastic Bag

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

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

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

Fig. 6.13-2 Fly Ash Extraction Valve for Sampling

Fig. 6.13-3 Fly Ash Sampling Storage Bin

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

6.14.1 Current Conditions of Thermal Power Station Operations

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

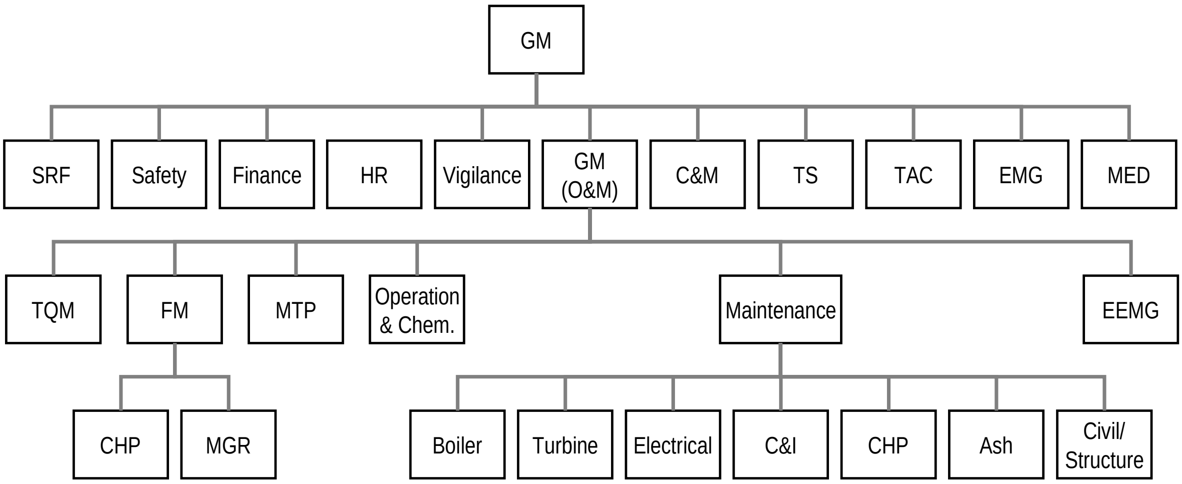
6.14.2 Current Conditions of Operation

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

6.14.3 Outline of a Power Station Management System

(1) Management system

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



Abbreviations

C&M:	Contract and Materials (Purchasing)	MGR:	Merry Go-around
CHP:	Coal Handling Plant	MTP:	Maintenance Planning
EEMG:	Energy and Efficiency Management	SRF:	Special Repair Facilities (Workshop)
EMG:	Environment Management Group	TAC:	Township Administration
FM:	Fuel Management	TQM:	Total Quality Management
HR:	Human Resources	TS:	Technical Services
MED:	Medical		

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

This management system is considered to be better in terms of office work, such as budgeting and purchasing, than that of Japanese power utilities. Operation and maintenance at these power stations are basically the same as those in Japan.

NTPC utilizes PLF and other indexes to encourage competition among NTPC power stations, and motivates employees by giving an award to the power station that achieves the highest PLF in the year.

(2) Operating system

1) Operating personnel

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

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

2) Load operation

Individual power stations determine the next day's power generation load schedules in units of 15 minutes while considering their equipment conditions. They apply for their feasible power generation load (MW) schedules to the Regional Dispatch Center in various locations (east, west, south, north and central regions) by faxing the load schedules, and confirm resultant power supply commands on the Internet at Regional Center websites.

3) Operating personnel training system

Operating personnel and maintenance personnel receive required training at the Employee Development Center (EDC) which manages training in each power station. The EDC which located at the Korba Power Station has 200MW and 500MW operation simulators for trainees from each power station. Operating personnel receive training in the following steps:

- Training for university graduates (engineers)
  6-month lecture of power plant and 6-month OJT (including 1-month training with simulators)
- Training for college and high-school graduates
  6-month lecture of power plant and 6-month OJT

In addition, the EDC at the Korba Power Station invites overseas power generation engineers to provide training using the plant operation simulators.

(3) Maintenance System

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

If a major control device malfunctions during plant operation, it is likely to quickly affect power generation and requires prompt restoration. Due to power station location, terrain and other problems, it takes too long time to dispatch manufacturer's supervisor in order to restore such devices. For this reason, the power stations storage most of spare parts to enable internal restoration.

1) Daily maintenance

The power stations divide preventive maintenance into the following four types, A, B, C and E, and determine the priority for repair works as following criteria

A: Non-emergency troubles that can be handled by analyzing equipment defects and malfunctions and checking spares and other parts
B: Troubles that will interfere with power generation within 72 hours to one week if equipment defects and malfunctions are not dealt with
C: Troubles that do not affect power generation, load factor and plant efficiency
E: Troubles that greatly affect personal safety and major equipment

The power stations conduct daily maintenance to prevent failures, malfunctions and other problems detected during plant operation by using almost the same procedures as those used in Japanese power stations. Last year NTPC introduced the Computerized Maintenance Management System (CMMS) as one module of Enterprise Resource Planning (ERP) System (provided by SAP), and utilizes it for maintenance management. Maintenance is conducted in the following steps:

a. A failure or malfunction is detected.
b. The Maintenance Group is notified of the failure or malfunction through a maintenance work order
c. The Maintenance Group ascertains the cause(s), makes a maintenance plan and consults relevant departments in the power station to determine the time at which to execute the maintenance.
d. The Operation Group permits the maintenance during operation.
e. Maintenance is conducted.

Like Japanese power stations, these power stations sometimes entrust maintenance work to specialized manufacturers/service providers depending on the details of the work.

The power stations also conduct vibration analyses of rotating machines, thermal analyses using thermography and analyses of lubrication oils for preventive maintenance (PdM). For pulverizes they apply operating hour based maintenance.

The power stations conduct dissolved gas analysis (DGA) and insulating oil analysis of the generator transformers at the following frequency which is determined based on the results of the previous analysis according to the NTPC manual.

> Every 6 months conduct DGA when the previous analysis was normal condition and
> every 3 months when the analyzed value exceeds in the previous analysis.

Recently NTPC has introduced the furfural analyses and insulating paper sampling analyses to gain understanding of the current conditions and remaining life of the generator transformers, and has specified the inspection frequencies and evaluation criteria in the NTPC manual. Furfural analyses are conducted at the following frequencies:

First : After 5 years of operation
Second : After 10 years of operation
Third : After 15 years of operation
Fourth : After 20 years of operation
Fifth : After 25 years of operation
Sixth and later : Every year

The Research & Development (R & D) Analysis Department at the NTPC headquarters conducts DGA and furfural analyses of after sampling oil.

C&I instruments are periodically calibrated to maintain their accuracies and are managed by using the CMMS including the calibration results of the instruments. C&I instruments are calibrated at labs accredited by the Department of Science & Technology, India under ISO/IEC 17025 to assure the accuracy of the calibrated measuring instruments.

To maintain the functions of instrumentation equipment as preventive maintenance, operating personnel use check lists to ascertain indicator recording states and conduct patrols to check instrumentation equipment during plant operation.

They also conduct weekly, monthly, seasonal and other periodical inspections of gas analyzers and instrumentation equipment that may change characteristics in a relatively short period of time.

If any failure or malfunction occurs, the power stations take prompt action, such as replacement with spares parts in stock, to prevent interruption of power generation. They also analyze the causes of the trouble, take countermeasures, and share the information with other NTPC power stations as necessary.

2) Periodic inspections

- Frequency of periodic inspections

  The India Boiler Regulations (IBR) requires boilers to be inspected every year, but there is no regulation on periodic inspections of turbines. Therefore, turbines are inspected based on manufacturer recommended intervals. It is possible to extend the periodic inspection frequency for boilers by applying to the Central Electricity Authority of India. Every NTPC power station is making efforts to extend the periodic inspection interval to 1.5 to 2 years due to shortage of electricity power supply. They conduct periodic inspections on turbines every four to six years. They determine periodic inspection frequencies and adjust intervals separately for high-, medium- and low-pressure turbines in consideration of the need for repair, rather than inspecting all turbines at the same time. They conduct internal inspections of generators every three to six years to minimize plant shutdowns in consideration of inspection frequencies recommended by generator manufacturers and turbine inspection timings.

- Periodic inspection procedures and methods
  - It takes two years to renew large-scale equipment (from order to delivery). Preparations are started two years before the next periodic inspection in consideration of the details of the periodic inspection plan.
  - Procurement of materials is scheduled so that materials arrive at the power station six months before the periodic inspection.
  - Boiler manufacturer supervisors are not always asked to attend the periodic inspections of boilers. Sometimes maintenance service providers are entrusted to perform periodic inspections and work on boilers through competitive bidding exercise. In such cases, those who have worked as supervisors in BHEL, a boiler manufacturer, are assigned to give technical instructions to maintenance providers. For the periodic inspection of turbine, supervisors from the turbine manufacturers of BHEL or OEM are asked to give technical instructions.
  - NTPC-qualified welders are assigned for welding work on high-temperature or high-pressure pipes. They conduct the welding work according to the welding procedures established by the NTPC.
  - Due to the shortage of power supply, periodic inspections and repair works are conducted 24 hours a day to minimize shutdown period.
  - 24-hour inspections are conducted to inspect the reduced wall thicknesses of heat transfer tubes due to ash erosion caused by the high ash content of Indian coal, replace (several thousand) short tubes due to reduced wall thicknesses as needed, and check by gamma rays

during and after welding. Whereas Japanese power stations conduct inspections of picked-up tubes at several intervals of pitch, the NTPC power stations inspect all tubes in areas of interest and sometimes they need to inspect tens of thousands of tubes.

- Each power station determines the frequencies of internal generator inspections and stator coil insulation diagnoses because NTPC has no standard manual about them.

Korba#6 :	Conducts an insulation resistance test (IR test) and a polarization index test (PI test) every year.
Rihand#2 :	Conducts an IR test and a PI test every five years (every 40,000 hours of operation).
Singrauli#4:	Conducts IR test, a PI test, a Tanδ test and a partial discharge test every three years. (In Japan, power generator manufactures conduct stator coil insulation diagnoses every ten years)

- They conduct periodic inspections of C&I devices including overhauls of control valves and other instrumentation equipment, checks for wear and damage in various parts, and replacement of consumables, such as gaskets and seal packing. They also replace fuses, relays, timers, electrolytic capacitors, diaphragms and other parts which have short remaining service lives according to the relevant schedules. They also megger cables as well as check and additionally tighten terminals.
- To determine what to do in the next periodic inspection, the Maintenance Planning Group rolls plans and the Maintenance Group determines the details of work. Two kinds of plans, five-year mid-term plans and 10-year long-term plans are subject to rolling.
- Remaining life assessment
  The remaining service lives of boilers are assessed in every 5 years, mainly by inspecting welds on boiler pipes and tubes with reduced wall thicknesses. The remaining service lives of turbines are diagnosed in consideration of the years in operation.

3) Long-term maintenance plans and equipment renewal plans

The Maintenance Planning Group determines the times for maintenance and renewal of major equipment in long-term maintenance plans and equipment renewal plans in consideration of the conditions of equipment maintenance as well as operating hours and remaining life assessment. Renewal of large-scale equipment requires the approval of the Central Electricity Authority.

The power stations are making efforts to improve the performance of all their equipment and reduce the failure rate for higher reliability by introducing paperless recorders, replacing oxygen analyzers with the zirconia type, and introducing the 2-out-of-3 logic for renewal of measurement control equipment that has deteriorated due to age.

4) Management of spare parts

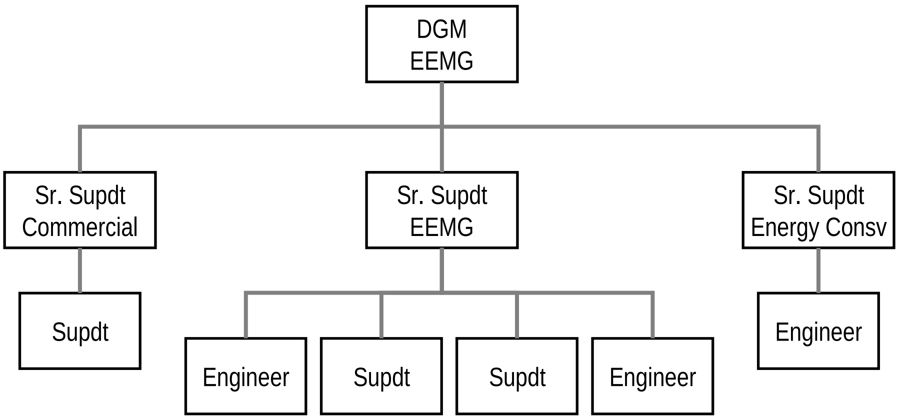
Spare parts is efficiently managed by utilizing the spare parts management system (a part of the ERP system) with classification items and material codes that have been standardized throughout NTPC. This allows spare parts to be shared throughout the entire company and confirmation of the stock of spares in all the power stations. In an emergency, one power station can obtain spares from other power stations. Expensive spares are stored as common spares among neighboring power stations with minimum quantities.

Spares are mainly selected based on OEM spare lists and past station experience in consideration of the procurement lead time.

(4) Efficiency Management System

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

The EEMG is organized as follows:



Abbreviations
Consv : Conservation
Supdt : Superintendent

Fig. 6.14-2 Typical Organization of EEMG

Table 6.14-1 shows the daily efficiency management factors. The EEMG keeps a daily operation data, they checks them and prepare the daily operation report regarding the efficiency of the power station.

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

Power station performance tests are conducted at the following frequencies:

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

Coal and ash required for calculations in performance tests are sampled by the Operation Group (in charge of chemical analysis) and analyzed in the chemical laboratories in the power stations.

Table 6.14-1 Format of the Daily Plant Report for Efficiency

	Description	**Unit**	**Unit No.**	**Description**	**Unit**	**Unit No.**
A	Generation	MU		Make-up Water	MT	
	Plant Load Factor	%		Make-up Water	%	
	Run Hours	Hrs.		HR Coal	Kcal/Kwh	
	Availability Factor	%		HR Oil	Kcal/Kwh	
	Partial Loading	%		Unit Heat Rate	Kcal/Kwh	
	Coal Cons.	MT		Load at 8 AM	MW	
	Sp. Coal Cons.	Kg/Kwh		Max. Load	MW	
	Oil Cons.	KL		Min. Load	MW	
	Sp. Oil Cons.	ML/Kwh		MVAR Max.	Mvar	
	GCV Coal	Kcal/Kwh		MVAR Min.	Mvar	
	GCB Oil	Kcal/Lit				
	Aux. Power	MU				
	Aux. Power	%				

B Partial Loss due to

Grid Restriction	MU		Shut Down	MU	
Grid Disturbance	MU		Coal Quality	MU	
ABT/High Freq.	MU		Coal Shortage	MU	
Equipment	MU		Others/Coml Const	MU	
Startup/Stab	MU		Excess Gen	MU	

C Generation Loss due to

No. of Outage	No.		Grid	MU	
Planned S/C	MU		Comml Const	MU	
Forced S/D	MU		Coal	MU	

D	Bus Voltage Max.	KV				Total
	Bus Voltage Min	KV		Coal Received	MT	
	Grid Freq. Max	Hz.		Usable Coal Stock	MT	
	Grid Freq. Min	Hz.		HFO Stock	KL	
	Declared Cap	MU		Forebay Level	M	
	Schedule Gen	MU				
	Actual Gen	MU				

E Remarks

The EEMG also prepares analysis reports regarding unit trip caused by equipment accidents, etc. Table 6.14-2 shows the format of the report. The Group collects data about unit trip and a problem reported from relevant groups, analyzes the causes of tripping, and summarizes the results in reports. Unit trip analysis reports are submitted to the Operation Service Department in the NTPC headquarters for information sharing among the power stations.

Table 6.14-2 Format of the Unit Trip Analysis Report

Unit No. : Outage No. :
Report No. : Outage Code :

01	**Date of Tripping**	:	
02	**Time of Tripping**	:	
03	**Status before Unit Tripping**	:	
	Unit Load	:	
	Mills in Service	:	
	No. of Oil Guns i/s	:	
	No. of BFPs	:	
	No. of IDs	:	
	No. of FDs	:	
	No. of Pas	:	
	No. of CC Pumps	:	
	No. of CW Pumps	:	
	Any other information	:	
04	**First Up Protection Acted**	:	
05	**Similar Occurrence in Last Two Years**	:	
06	**Other Relays Protection Acted**	:	
07	**Supporting Documents (SOE/PTL/Alarm Logs)**	:	
08	**Any Operation Done prior to Tripping**	:	
09	**Analysis of Tripping**	:	
10	**Root Cause of Tripping**	:	
11	**Remedial Measures Taken**	:	
12	**Time & Date of**		
	Boiler Light Up	:	
	Unit Synchronization	:	
13	**Date of Completion of Last Over-haul / Type of Overhaul**	:	
14	**Constraints during Restoration**	:	
15	**Recommendation / Action Plan**	:	
16	**Any Specific Learning / Feed Back**	:	

S.No.	Recommendation	Action Plan	Responsibility	Target Date / Schedule

17 Signature / Date

HOD (EEMG) HOD(Operation) HOD (Electrical) HOD (C&I)

AGM (O&M)

GM

(5) Power Station Management systems

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

1) ISO9001, ISO14001 and OHSAS 18001

The candidate power stations introduced ISO9001 and ISO14000 systems and have started activities for quality control and environmental management. Study team confirmed on computer screens that they systematically organized written instructions and procedures according to the ISO9001 system. They also introduced OHSAS 18001 (occupational health and safety management system) and have started activities to reduce the potential risks of occupational accidents in the power stations.

2) 5 S's (Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization), and Shitsuke (discipline))

NTPC introduced the 5 S’s system from Japan and has started company-wide activities in the 5 S target areas. Each organizational section quantifies states of its 5 S’s activities and the best performance section is awarded internally. This system is also applied to each power station and the power station with the best performance is awarded company-wide as an excellent 5 S’s organization.

3) Know-how sharing system

Equipment accidents that occurred in the power stations and technical improvements are posted on the ERP system to share technical know-how throughout the company. Details of the workshops of this JICA study have already been made available not only to the candidate units, but also to other power stations.

4) Work improvement suggestion system

NTPC established a suggestion system to evaluate suggestions from power stations, and gives awards for excellent suggestions and posts them in the know-how sharing system.

The following table shows a comparison between the management systems adopted by NTPC and systems generally adopted by Japanese electric utilities.

Table 6.14-3 Comparison Table for Power Station Management system

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

As can be seen from this table, NTPC established and utilizes management systems similar to those applied to Japanese electric utilities.

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

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

(6) Contents of Written Operation and Maintenance Instructions and Procedures

Study team reviewed the Local Management Instructions (LMI) regarding the following five operation and maintenance items provided by NTPC according to our request in comparison with operating and maintenance procedures in Japan.

1) Chemical control of the Water/Steam Circuits of Drum Type Boilers
2) The Safety Operation and Maintenance of a Pulverizer Fuel Plant
3) Long Term Storage of Power Plant and Equipment: General Consideration and Preservation
4) Prevent and control Boiler Tube Failures (Boiler Dept.)
5) Reporting arrangement in the event of a serious incident (Op. Dept.)

1) Water quality control of drum boilers

This is the written instruction about the water quality of drum boilers. It describes the need to control the water quality of drum boilers and the parameters to be controlled. Detailed control standards and target values are determined by individual power stations depending on equipment they have. Control items are similar to those in Japan. Study team could not confirm the detailed instructions because they were not available, but we estimate from the LMI that the power stations prepare management instructions at the same level.

2) Response to a pulverized coal explosion

This is the written instruction about actions to be taken in the event of a pulverized coal explosion and spontaneous ignition in coal bunkers. It describes countermeasures for areas where pulverized coal explosion could occur (inside furnaces, mills and coal feed pipes, and outside furnaces) and actions to be taken in case of spontaneous ignition. The content is at the same level as actions to be taken in case of accidents (pulverized coal explosion) in Japan.

3) Spares control

This is the written instruction about storage and control of spares. It classifies storage places into four types, outdoor, partially-indoor, indoor, and indoor (dry and dustproof environment), and it classifies the spares to be kept in each type of environment. It describes the spare control method, which is at the same level as that in Japan.

4) Investigation of causes of boiler tube leaks

This document provides the guidelines about techniques of investigating causes of boiler tube leaks. It describes procedures for identification of tube leak points and confirmation of operating states and analysis of the leak tube metals to clarify causes and procedures for retention of a record of countermeasures (actions) taken against leak points. These procedures are similar to those in Japan.

5) Accident report instructions

This describes the instruction about reporting in case of emergency. It classifies accidents into Categories 1 and 2 and specifies when to make an initial report (for example, one hour) after an accident occurs, to provide information about safety, environmental pollution, operation, strikes, factors outside the power station (for example, strikes in coal mines) and who is responsible for the accident. The content is similar to those of reports in Japan. Study team assume that each power station has established instructions that contain the contact information of the relevant departments and contact persons to which accidents need to be notified.

6.14.4 Power Generation Equipment Operating States in Each Power Station

Listed below are the operating states of the candidate units for the past three years.

(1) Korba #6

1) Operating states

a) Operation reliability

Item	Unit	2006–2007	2007–2008	2008–2009
Generation	MU	3682.200	4220.530	4115.310
Load factor	%	84.07	96.1	93.96

b) Main unplanned outages

Year	Item	Duration of Outage (day)
2006–2007	ECONOMISER TUBE LEAKAGE	1.7
	REHEATER TUBE LEAKAGE (58 MTR RHS NEAR SB 119)	2.1
	SCW TUBE LEAKAGE	0.7
2007–2008	ECONOMISER TUBE LEAKAGE	2.1
	SCW & LTSH TUBE LEAKAGE	2.0
	PLATEN SUPER HEATER TUBE LEAKAGE	1.0
2008–2009	PLATEN SUPER HEATER TUBE LEAKAGE	1.1

(2) Rihand #2

1) Operating states

a) Operation reliability

Item	Unit	2006–2007	2007–2008	2008–2009
Generation	MU	4126.877	4173.972	4361.960
Load factor	%	94.22	95.036	99.59

b) Main unplanned outages

Year	Item	Duration of Outage (day)
2006–2007	No major unplanned shutdowns due to trouble	---
2007–2008	No major unplanned shutdowns due to trouble	---
2008–2009	LTSH tube Leakage. LTSH INLET HDR-14 TUBE NO. 6A,6B,7	1.4
	Tube leakage in RH. REHEATER II STAGE FIRST PANEL FROM LHS.	1.3
	Tube leakage in 2nd pass. 1)LTSH INLET HDR 14,TUBE 9B,10A,10B,10C,11B,11C. 2) WATER WALL, CORNER D,RHS WALL, (7TH TUBE TRANSITION)	2.5
	Bottom Ring Hdr leakage. 4 C-corner manhole gasket leakage	1.3
	LTSH tube Lkg. + Boiler Misc works.	2.7

(3) Singrauli #4

1) Operating states

a) Operation reliability

Item	Unit	2006–2007	2007–2008	2008–2009
Generation	MU	1529.220	1692.602	1777.500
Load factor	%	87.28	96.35	101.46

b) Main unplanned outages

Year	Item	Duration of Outage (day)
2006–2007	Tube Leakage	2
	Low vacuum	1
	Due to excit. System/6.6 kV Bus problem/132 kV system problem	5
	DDCMIS commissioning	2
2007–2008	Excit. System	2
	DDCMIS stabilization	1
	APH problem	1
2008–2009	Tube Leakage	3
	Generator Aux-Elect.trippings	2
	Others	1

6.14.5 Issues and Countermeasures about Operation of Power Generation Equipment

(1) Evaluation of current states

Study team researched operation and maintenance in the candidate units and found that they introduced and utilize management systems similar to those in Japanese electric utilities. For example, they have already introduced a spares control system that is more advanced than that used in

Japanese electric utilities. They have the ability to quickly build scaffolding inside boiler furnaces for periodic inspections. Japanese electric utilities should emulate these advantages.

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

(2) Suggestions for improvement

1) Patrols

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

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

a) Patrol kit

As shown in Fig. 6.14-3, wear a helmet, gloves and protective shoes for safety and carry a flashlight and a Listing rod required for inspection during patrols.

b) Use of a hearing bar

To detect abnormal noises from motors or other rotating machines at an early stage, check for noise from bearings and other parts by putting a hearing bar tip on the external surface of the part as shown in Fig. 6.14-4.

c) Marking on indicators

As shown in Fig. 6.14-5, visualize the values in normal operation by marking them on indicators to allow workers to easily recognize abnormal values.

d) Check for seat leaks by using thermo-labels

To detect seat leaks of safety valves and other parts at an early stage, apply thermo-labels as shown in Fig. 6.14-6 to allow workers to easily recognize seat leaks by changes in the label color.

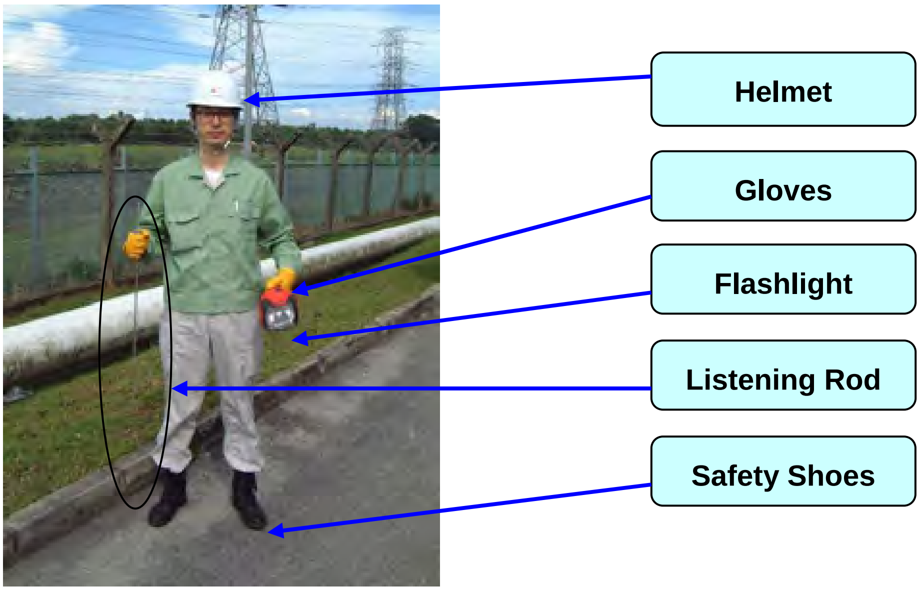


Fig. 6.14-3 Typical Patrol Kit

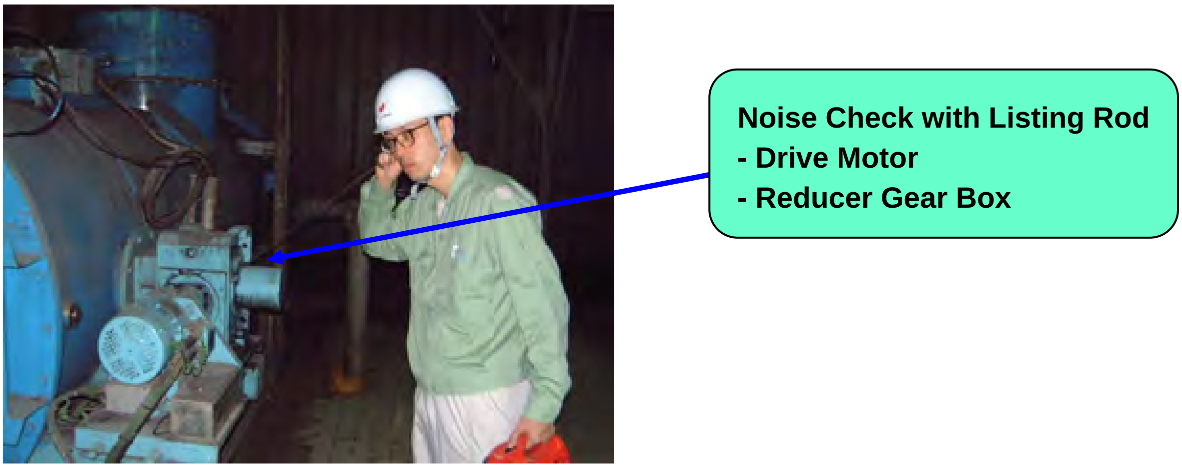


Fig. 6.14-4 Noise Inspection with Listing Rod

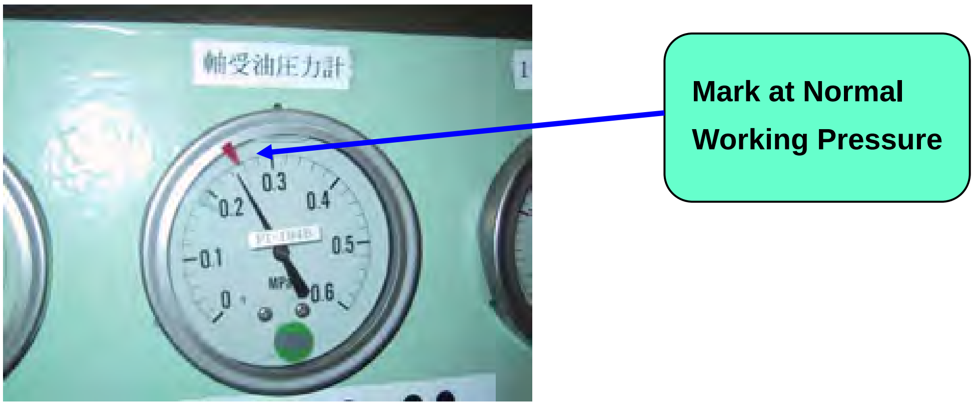
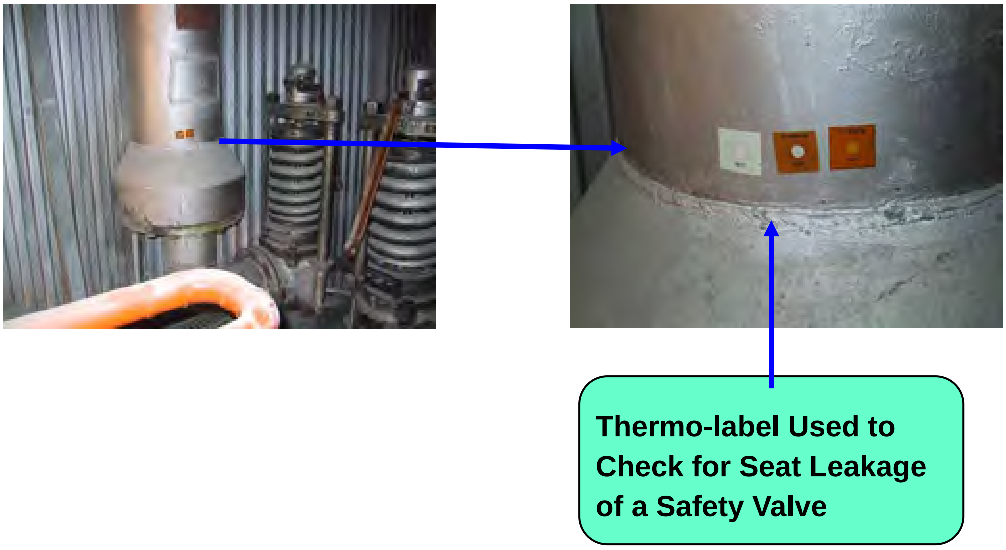


Fig. 6.14-5 Indication of Normal Working Value



Thermo-label Used to Check for Seat Leakage of a Safety Valve

Fig. 6.14-6 Thermo-label

2) Safety management

a) General safety management

Pictures with the slogan of safety first are posted on walls in several areas in the power stations. However, there are only a few local operators and workers who wear safety shoes and other safety gear when doing their work. It is advisable to thoroughly educate all employees from managers to workers about the importance of safety and reemphasize the necessity of putting on safety gear for them. Japanese power stations are making efforts to get workers to perform their duties with a consciousness of safety by, for example, assigning safety managers of power stations and subcontractors, providing safety education to all employees from managers to workers using safety manuals when they join power stations, holding KY (Kiken-Yochi, or danger prediction) meetings before starting work every morning, and holding safety manager meetings to check for intricate works among subcontractors. Power station staff conducts periodic safety patrols to check for unsafe construction or actions in on-site work. If they find any unsafe work, they immediately point it out and request prompt improvement. For your reference, a safety patrol check sheet used in Japanese power station is shown below.

Table 6.14-4 Safety Patrol Check Sheet

Check Sheet about Patrol for Safety (Night patrols and joint patrols by two or more sections)

Date of patrol	
Scope of patrol	
Conducted by	

Focus points	Check points	Result	Request for action	Result of action
- Working area - Sign - Passage	Check that working areas are properly marked off and indicated as such. (Looseness, sagging, doorway, etc.)			
	Check that passages are secured for general traffic. (Detours, passage width, and height of 1.8 m or higher)			
	Check that sufficient temporary passages are provided. (Gradient shall not exceed 30 degrees, and non-slip measures and handrails of 90 cm or longer shall be provided for passages with gradients of 15 degrees or more.)			
	Check that an acceptable number of appropriate signs are posted in easy-to-see directions and positions.			
- Work floor - Opening - Scaffolding	Check that work at a height of 2 m or more is done properly. (Work floors, handrails, lighting and ladder, steps, etc for access)			
	Check that ladders have fall prevention measures. (Fixing, slip prevention and angle holding fittings)			
	Check that scaffoldings are built properly. (Load indication, scaffolding plates with a width of 20 cm, a thickness of 3.5 cm and a length of 6 m or more, and work floors with a width of 40 cm or more, clearance of 3 cm or less and handrails of 90 cm or more)			
	Check that openings are properly fenced and have caution signs.			
	Check that scaffoldings have indications of the maximum load, the name of the person responsible for building the scaffoldings, the name of construction and other required information in easy-to-see positions (near stairways).			
Prevention of electric shock	Check that welders, power distribution boards and other electric devices are inspected at the start of work using check sheets.			
	Check that power distribution boards and electric machines and tools are used properly (usage and stickers for indicating completion of inspection).			
	Check that cables and wires are installed properly. (Indication of destination, protection of charged parts, damage, routing, rain prevention, etc.)			
	Check that grounding wires are installed properly.			
Work involving oxygen deficiency and other risks	Check that closed spaces and areas involving an oxygen deficiency risk are properly marked off and have signs.			
- Order - Arrangement - Cleaning - Clothes	Check that work areas are in good order (marking-off methods, construction tags, work tags and others).			
	Check that work spaces are in good order. (Space is secured, tools are in good order and there is no oil leak or protrusion.)			
	Check that the required tools are provided for the proper disposal of waste, such as trash cans and used rag cans.			
	Check that workers wear clothes suitable for their work. (Safety hard hats, safety shoes and various protective gear.)			
- Smoking - Fire prevention	Check that there is no problem with smoking areas (places, indications, ash trays, fire extinguishers, buckets, curing and others).			
	Check that gas cylinders are installed properly (fall prevention, caps for transport, charge indication, etc.).			
	Check that there are measures for protecting equipment and facilities from falling sparks during welding or cutting and check that there is no flammable material in the vicinity.			
	Check that fire extinguishers are provided at intervals of 20 m or less by walking distance when using the boiler main building periodic inspection floor.			
Other findings				

b) Danger signs

"Danger" and "Keep out" signs should be posted in areas where there is a risk of accident, such as steam leaks from high-temperature or high-pressure pipes, to prevent secondary accidents. There are no such signs at the candidate station where they had the above leakages.

c) Regulation of entry and exit of closed spaces

Japanese power stations regulate those who enter and exit closed spaces such as boiler furnaces, boiler steam drums and other for inspection purposes, by checking the oxygen concentration and the entry and exit management boards (see Fig. 6.14-7). This is mainly intended to prevent those who enter closed spaces from being oxygen-deficiency disease or from becoming trapped. Similar management were executed by concerned Study team members/service provider personnel during diagnoses of the remaining life assessment of boilers in Singrauli and Unchahar. However, NTPC did not control the entry and exit of closed spaces using entry and exit management boards or other tools. (When NTPC trainees received on-site training in Japanese thermal power plants for the NTPC counterpart training project, they commented that they were not using such a management system.)

Fig. 6.14-7 Entry and Exit Management Board

3) Housecleaning

As it stands, field housecleaning around equipment is implemented with using compressed air to blow ash away, but the ash merely accumulates on other areas. This is not cleaning. Vacuum cleaners, and as needed, vacuum cleaning pipes should be installed for housecleaning around equipment, particularly boilers and air heaters. Extension hoses should be attached to the installed pipes for approach to equipment. It's also proposed to utilize temporarily vacuum cleaning vehicles until cleaning equipment is installed.

4) Operation and maintenance of electric equipment

a) Countermeasures against unit tripping due to trouble with electric equipment

Unit tripping due to electric equipment trouble occurs once every few years in NTPC power stations. (Japanese power stations rarely have unit tripping due to electric equipment trouble.) The causes of unit tripping are listed below.

i) Short circuit of switchboards due to the entry of lizards, mice or other small animals
ii) Open upstream circuit breakers due to accidents of downstream electric equipment (wrong performance of protection relays)
iii) Trouble spreading from defective transmission line systems

Study team suggest the following measures for improvement:

- ➢ Sealing cable tray/ducts in places where they penetrate buildings
  Seal cable tray/ducts in places where they penetrate buildings to prevent fire from spreading to cables and to prevent small animals from entering.
- ➢ Sealing electric panel cable inlets
  Seal cable inlets of electric boards to prevent fire from spreading to cables and to prevent small animals from entering.
- ➢ Measures to prevent wrong performance of protection relays (measures to be taken during construction (commissioning))
  Open upstream circuit breakers due to accidents of downstream electric equipment (wrong performance of protective relays) may be attributable to the improper settings of protection relays. It is necessary to set protective relays in consideration of errors in relay performance.

b) Management of switchboards

Study team found some switchboards with their doors left open. When dust sticks to electric equipment, it may cause the insulation to deteriorate, the malfunction of relays and other problems. To prevent such problems, Study team suggests the following measures:

- ➢ Promptly repair electric board doors and install electric boards with gaskets and other means of dust proofing, particularly in dusty places.
- ➢ Make and observe an internal rule to close electric board doors without fail

c) Management of oil-immersed transformers

Oil-immersed transformers contain seal mechanism to prevent the oil from deterioration by oxidizing. Transformers used in Japanese power stations have excellent seals so that the quality of the insulating oil rarely deteriorates. Those transformers require almost no treatment of the insulating oil, including replacement, cleaning and degassing. Many oil-immersed transformers used in the NTPC power stations have insufficient seals (probably due to product quality), which cause premature deterioration of insulating oil quality and thus require frequent insulating oil treatment.

To avoid these problems, it is necessary to procure highly-reliable equipment from qualified manufacturers at the construction stage. Equipment should only be procured from manufacturers that provide sufficient after-sales services.

d) Insulation management of water-cooled generator stators

To ascertain and evaluate the insulation performance of water-cooled generator stators, it is necessary to drain stator cooling water completely and dry stators. Korba#6 has carried out the tests with cooling water remaining inside the generator stator, which means that the tests were meaningless. When the generator stator insulation is assessed, it is important to use the appropriate procedures. Therefore, it is required that NTPC carries out the tests in the condition that the stator cooling water is properly drained and dried out, and get reliable the test data.

5) Management of control panels

Study team found many control boards with doors left open in control panel rooms. If panels are left open, dust and foreign matter directly enters the panels and tends to cause control cards to fail. Study team heard that the doors were left open because the fans in the panels were out of order. However, there are too many control panels with doors open. It is necessary to review the fan replacement frequency and reduce their failures. It is also a good idea to adopt new type fans that can be replaced even during operation.

6.14.6 Provided Reports and Instructions

JICA ST submitted the following operation and maintenance reports and instructions during the research period:

1) Typical Activity chart for Overhauls
2) Major specification and construction drawing of debris filters in Japan
3) Techniques for boiler tube cleaning after cutting (before welding)
4) Information about intelligent soot blowing systems

5) Spray control valves – advancements for zero passing (water leakage). Specification and CV curve (example) and RH spray valves in Japan.
6) Enclosure specifications for noise reduction
7) Boiler fast cooling procedure
8) Information of online condition monitoring for transformers
9) Information about generator condition monitoring and diagnostics
10) Test procedures for boiler and turbine performance tests
11) Test procedures for AH tests
12) Monthly efficiency management table format
13) Sample of a Japanese performance test report
14) Honing based on Alumina blasting specifications and procedures
15) AH basket water washing procedure
16) Boiler RLA procedure
17) Japanese Boiler RLA system
18) Stator coil cooling water quality management and criteria
19) Japanese periodical inspection item list for generators
20) Japanese periodical inspection item list for generator transformers
21) How to analyze the $CO+CO_2$ RLA method and Furfural RLA method
22) Troubleshooting and information sharing (Electrical trouble)
23) Stator coil cooling water quality management and criteria
24) Japanese periodical inspection item list for generators
25) Japanese periodical inspection item list for main transformers
26) How to analyze the $CO+CO_2$ RLA method and Furfural RLA method
27) Troubleshooting and information sharing (Electrical trouble)
28) Japanese insulation diagnosis criteria for electrical machines
29) Sample of typical Japanese insulation diagnosis of generator stator coils

6.15 Economic and Financial Analysis

6.15.1 Concept

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

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

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

6.15.2 Scope

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

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

Table 6.15-1 Current items for Financial Analysis

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

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

6.15.3 Method

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

6.15.3.1 Assumption

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

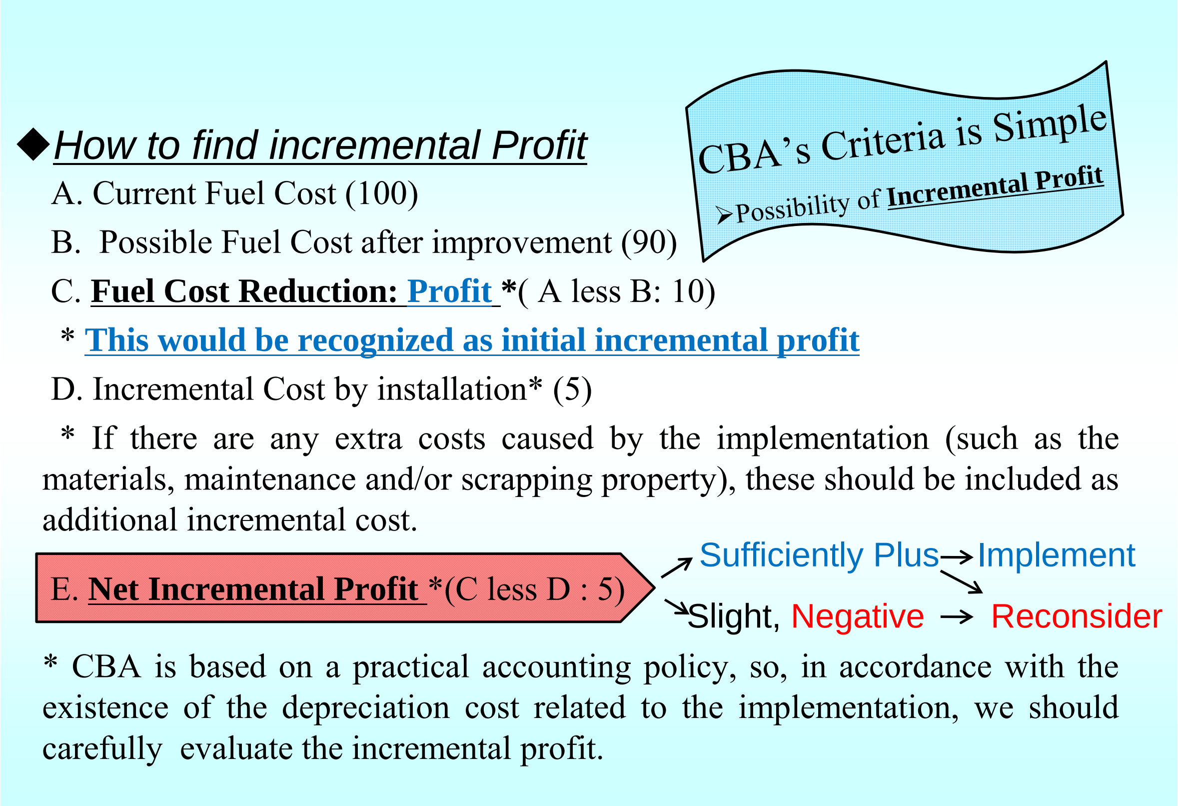
Please understand the possibility that different conclusions of financial assessment may be reached in the future based on assumptions at the time of preparation for each actual implementation to be planned by NTPC because the assumption will be directly affected by the differences of Prices, logistics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

6.15.3.2 Cost Benefit Analysis

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

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

(1) Image of CBA Method



◆ ***How to find incremental Profit***

A. Current Fuel Cost (100)

B. Possible Fuel Cost after improvement (90)

C. **Fuel Cost Reduction:** **Profit** *(A less B: 10)

* **This would be recognized as initial incremental profit**

D. Incremental Cost by installation* (5)

* If there are any extra costs caused by the implementation (such as the materials, maintenance and/or scrapping property), these should be included as additional incremental cost.

E. **Net Incremental Profit** *(C less D : 5)

↗ Sufficiently Plus → Implement

↘ Slight, Negative → Reconsider

* CBA is based on a practical accounting policy, so, in accordance with the existence of the depreciation cost related to the implementation, we should carefully evaluate the incremental profit.

CBA's Criteria is Simple

➢ Possibility of **Incremental Profit**

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

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

(2) CBA Practice

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

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

= X (kWh) × Y (kg/kWh) × Z (Rs./kg)

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

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

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

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

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

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

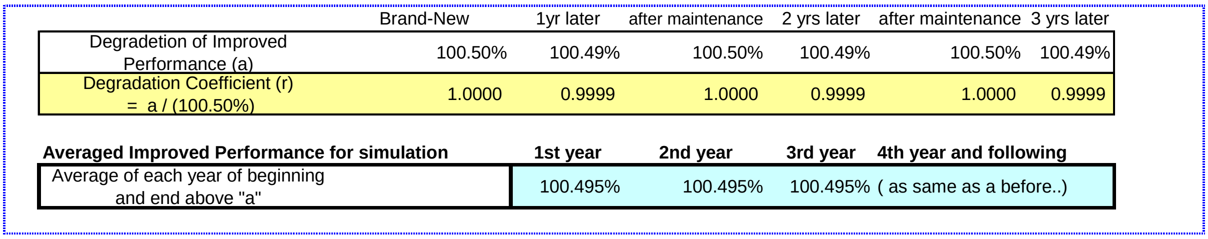
*1: This figure was calculated by Capacity and annually-averaged PLF of the power plant
*2: Due to completion of depreciation on the end of year 4

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

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

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

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



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

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

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

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

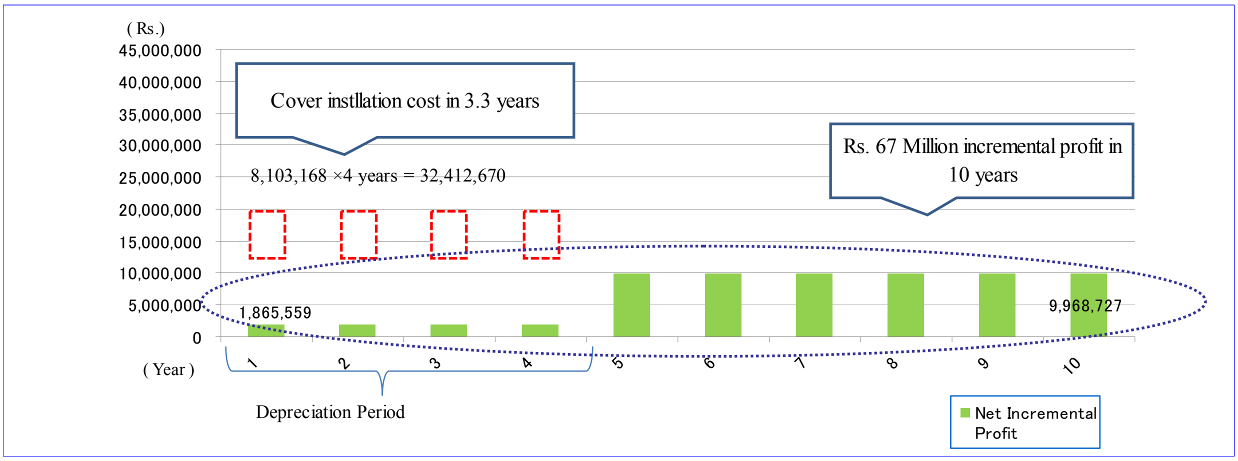


Fig. 6.15-4 Anticipated long term incremental profit with the concept of degradation

6.15.3.3 Sensitivity Analysis

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

(1) Sensitivity Analysis Practice

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

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

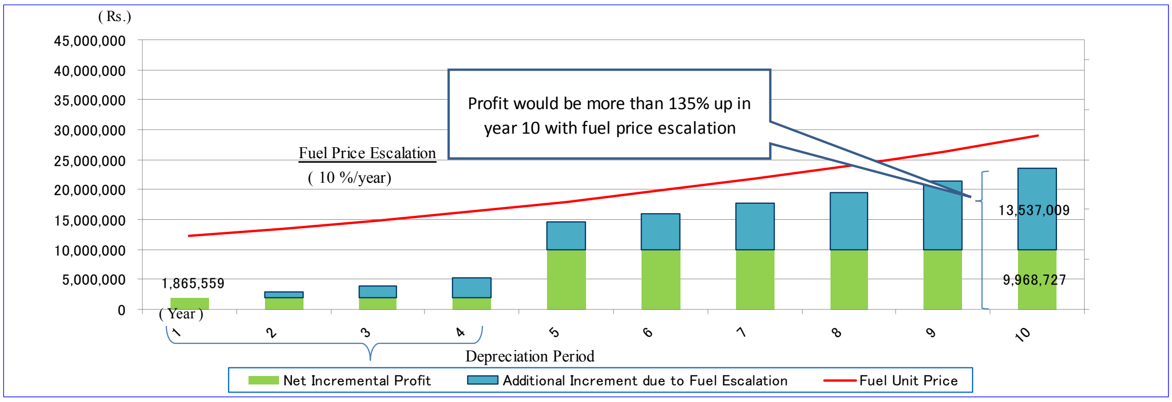


Fig. 6.15-5 Anticipated additional incremental profit due to fuel price escalation

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

6.15.3.4 DCF approach

- **NPV**

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

- **IRR**

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

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

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

- **BCR**

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

- **Cost of Capital**

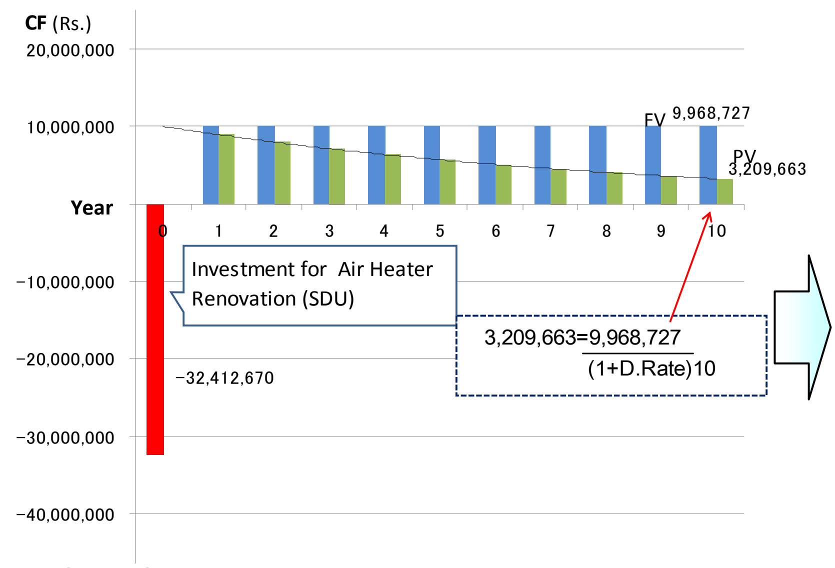
The cost of capital is the cost of a company's finance (e.g. interest on debt and dividend on stock). As a result of discussions about the expected cost of capital in the near future with CenPEEP, following NTPC’s suggestion, **we have set the cost of capital as 12% for the following DCF Approach analysis**.

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

(1) DCF Approach in Practice

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

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



Findings by DCF Approach

- Sum of the present values (PVs) is Rs. 56.3Mil (A)
  (As a nominal, Rs.99.7Mil in 10 years.)
- **NPV is Rs. 23.9Mil**
  (=A-Rs.32.4Mil for Investment)
- IRR is 28.2% (high rate of return)
- BCR is 1.7(good investment value)
- PO is 3.3 years (short recovery)

Air Heater Seal Renovation (by SDU)

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

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

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

6.15.3.5 Conclusion - the Economic and Financial Analysis

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

However, because business resources, especially cash for capital expenditure are limited, we should conduct financial management with the concept of the leverage effect (i.e. Cost Benefit Analysis in comparison with the magnitude of each implementation cost). On the other hand, from the perspective of the business environment, there seem to be uncertainties that increase rapidly with time, which means that on a case-by-case basis, we should chose options with short recovery times, in comparison with others, even if these are less profitable.

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

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

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

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

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

Color stands for the level of recommendation by Financial view point (reference purpose)	🟦 Excellent	(Huge return(NPV) and the rapid recovery of the installation cost would be expected)
	🟩 Good	(Sufficient return(NPV) and the short time recovery of the installation cost would be expected)
	🟨 Not recommended	(Huge installation and/or accompanying cost in comparison with a incremental profit)

6.15.4 Environmental Value Added Analysis

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

Formula

Formula

$$\underline{CO_2\ \text{Emission/Unit}}\ (\text{kg -}CO_2/\text{kWh}) =$$

$$\text{Fuel Consumption Rate(kg / kWh)} \times \text{Carbon Content of Fuel (\%)} \times \text{Relative Atomic Weight (44/12)}$$

$$\underset{(\text{kg-}CO_2)}{\underline{CO_2\ \text{Emission}}} = \underset{(\text{kg-}CO_2/\text{kWh})}{CO_2\ \text{Emission/Unit}} \times \underset{(\text{kWh})}{\text{Generation}}$$

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

Cost Benefit for Emission Reduction (CBER)

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

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

$$\underline{\textbf{Cost benefit for Emission reduction} = \textbf{Investment} / CO_2\ \textbf{Reduction}}$$

6.15.4.1 Conclusion - Environmental Value Added Analysis

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

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

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

6.16 Application of CDM

NTPC has high expectations of the application of CDM based on the results of efficiency improvements made through this study. We present specific and accurate information on climate change and global warming. We committed the work of preparation of PDD (Project Design Document) for the application of CDM to an experienced consultant. We noted summary of CDM and prepared PDD Draft here in this clause.

6.16.1 Outline of CDM

(1) The Kyoto Protocol

The Kyoto Protocol, which was adopted at the COP3 of the UNFCCC held in December 1997, came into force in February 2005. In order to assist the Parties to achieve their GHG emission reduction targets, the protocol defines three innovative "flexibility mechanisms" including CDM to lower the overall costs to meet the targets.

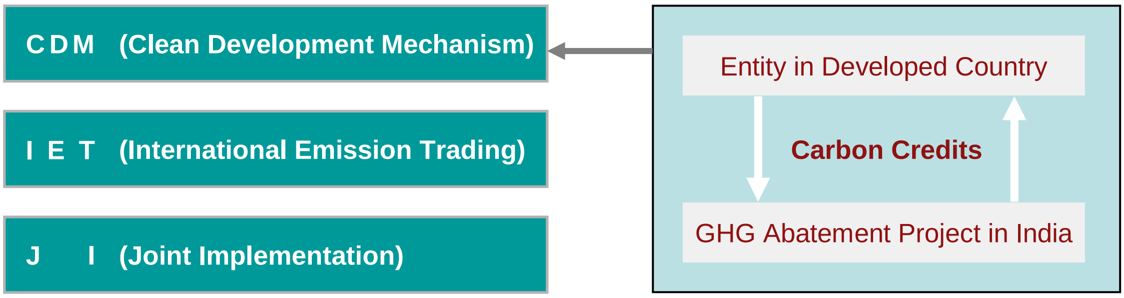


Fig. 6.16-1 Kyoto Mechanism

(2) Outline of the CDM

CDM is a mechanism that is based on the provision of Article 12 of the Kyoto Protocol. It is a scheme for GHG emission reduction through cooperation between developed countries (Annex I Parties to UNFCCC, which are committed to certain GHG emission reduction targets under the Kyoto Protocol, and developing countries (non- Annex I Parties), which do not have any commitments to reduce GHG emissions. The purpose of CDM is to assist to accomplish the GHG emission reduction targets of Annex I Parties (investing countries) under the Kyoto Protocol, as well as to contribute to sustainable development of non- Annex I Parties (host countries). Under the CDM, Annex I Parties implement projects resulting in reduction of GHG emission within the territories of non- Annex I Parties. Annex I Parties are able to acquire the credits (CERs: Certified Emission Reductions) which result from the projects. Non- Annex I Parties will benefit (economic, social, environmental and technological) from CDM projects.

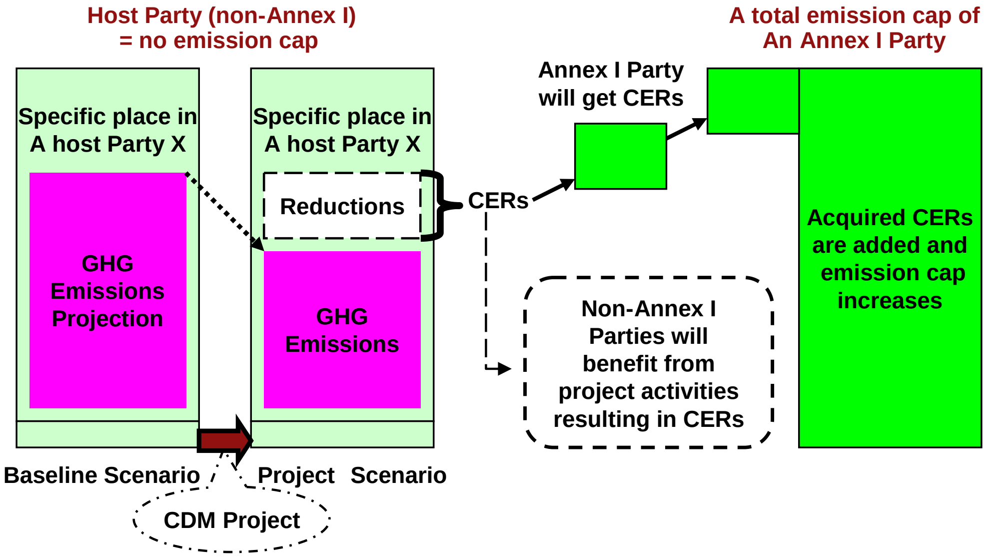
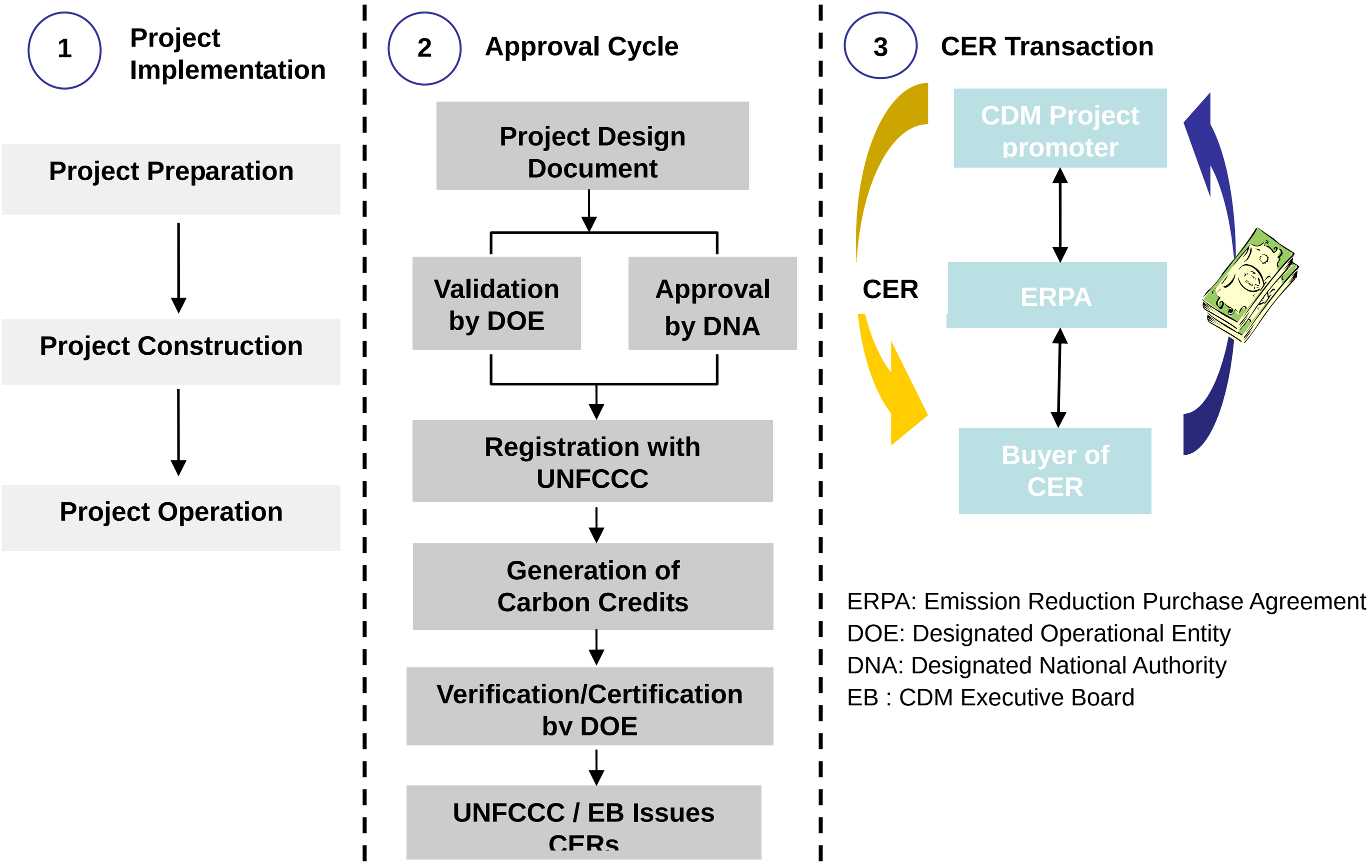


Fig. 6.16-2 Outline of the CDM

(3) CDM Project Cycle

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



ERPA: Emission Reduction Purchase Agreement
DOE: Designated Operational Entity
DNA: Designated National Authority
EB : CDM Executive Board

Fig. 6.16-3 CDM Project Cycle

(4) Preparation of PDD

Project participants shall prepare PDD contained information on project activity, the approved baseline methodology applied to project activity, duration of the project activity / crediting period, Environmental impacts and Stakeholders' comments, and shall submit PDD for validation and registration. Project participants shall observe five (5) provisions including submission in English language to the EB, using original CDM-PDD template and so on in order to prepare PDD.

Table 6.16-1 Item of CDM–PDD (version 3.2)

SECTION A	General description of project activity
SECTION B	Application of a baseline and monitoring methodology
SECTION C	Duration of the project activity / crediting period
SECTION D	Environmental impacts
SECTION E	Stakeholders' comments
Annex 1	Contact information on participants in the proposed Small Scale project activity
Annex 2	Information regarding public funding
Annex 3	Baseline information
Annex 4	Monitoring Information

(5) Selection of Methodology

Project participants, when preparing PDD, shall select whether adaptation of approved Methodology or development of new Methodology. Appropriate selection of any Methodologies governs success of smooth procedures for PDD. Large Scale project and Small Scale project have Approved Methodologies registered by EB respectively.

1) Large Scale Approved Methodologies

Large Scale Approved Methodologies applicable to energy efficiency improvement measures for rehabilitation and retrofitting of existing power plants are AM0061 and AM0062.

Table 6.16-2 Large Scale Approved Methodologies applicable to existing Thermal Power Station

Approved Methodologies No.	AM0061	AM0062
Area	Energy Industry	Energy Industry
Key word	Energy efficiency improvement, Energy saving	Energy saving, Energy efficiency
Scope	Power Plant	Power Plant (Turbine)
Title of Methodologies – Version No.	Methodology for rehabilitation and/or energy improvement in existing power plants – Version0.2.1	Energy efficiency improvements of a power plant through retrofitting turbines – Version01.1

2) Small Scale Methodologies

On the other hand, project participants may select Small Scale Methodologies according to scale of project activity. Three types of Small Scale Methodologies (AMS-I, II and III) are currently registered by EB as follows.

Table 6.16-3 Methodologies of Small Scale CDM

Meth. No.	Scope
AMS–I A~E	Renewable energy project activities within a maximum out put capacity of 15 MW (or an appropriate equivalent)
AMS–II A~J	Improvement in energy efficiency which reduce energy consumption on the supply and/or demand side, shall be limited to those with a maximum output of 60 GWh per year
AMS–III A~Z AA~AH	Emission reductions of less than or equal to 60 kt CO_2 equivalent annually

6.16.2 Implementation of preparation of PDD Draft

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

1) Title of the Study

“PREPARATION OF PDD Draft” FOR THE STUDY ON ENHANCING EFFICIENCY OF OPERATING THERMAL POWER PLANTS IN NTPC-INDIA

2) The Contractor

Ernst & Young Pvt. Ltd.

3) Period of Execution and Scope of the Work

Table 6.16-4 Period of Execution and Scope of the Work

Fiscal year	Period of Execution	Scope of the Work
2009	From December 2009 and February 12, 2010	- Collection of necessary data and information - Selection of AM - Making plan and policy for the preparation of PDD Draft
2010	May 2010 and September 2010	- Preparation of PDD Draft - Planning of schedule of preparatory works for CDM procedure for submission and approval

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

We reported Findings and Recommendation on efficiency improvement measures for the target units (Singrauli #4, Korba #6 and Rihand #2) during the fourth field work in February/March 2010, and they were agreed with by NTPC. We recommended those units and measures by taking realized possibility and scale of emission reductions into consideration. The improvement measures for the three thermal power generation units initially included turbine seal fin replacement. However, it was confirmed that turbine seal fin replacement was a regular maintenance activity and housekeeping measures which could not satisfy applicability of CDM. Hence improvement measures for Singrauli #4 and Korba #6 were limited only to Air heater performance improvement.

Further the improvement measures for Rihand #2 was changed to BFP performance improvement in stead of turbine seal fin replacement through the discussion with NTPC.

Table 6.16-5 Finalized thermal power generation unit and energy efficiency improvement measures

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

(3) Application of Small Scale Methodology

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

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

6.16.3 Summary of PDD Draft

(1) Singrauli #4

1) Summary of Small scale project activity

a) Title of the Small Scale project activity

Air Pre-Heater performance improvement at NTPC Plant, Singrauli, Uttar Pradesh

b) Description of the Small Scale project activity

The energy efficiency measures to reduce the air leakage ratio are as follows:

1. Adoption of Floating Radial Seals (FRS)
2. Adoption of Sector Plate Drive Unit (SDU)

The project would be beneficial to the local communities in terms of socio-economic, environmental and technological well being and would hence contribute to sustainable development.

c) Project participants
Name of Party involved ((host) indicates a host party): .... India
Private and/or public entity (ies) Project participants (as applicable): .... NTPC Ltd.
Party involved wishes to be considered as project participant (Yes/No): .... No

d) Technical description of the Small Scale project activity

Location: The project activity is located at Sonebhadra District, Uttar Pradesh, India. The project activity is located between 230 50′24″ N Latitude, 820 16′12″ E Longitude & 430 m above mean sea level.

CDM Methodology: As per the 'Indicative simplified baseline and monitoring

methodologies for selected small scale CDM project activity categories', the project falls under
Sectoral scope: I - Energy Industries (renewable/non-renewable)
Main Category: Type II - Energy efficiency improvement projects
Sub Category: B - Supply side energy efficiency improvements - generation

Technology measures:

1. Adoption of Floating Radial Seals
2. Adoption of Sector Plate Drive Unit

2) Application of a baseline and monitoring methodology

a) Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity
Type - II - Energy Efficiency Improvement Projects
Title - A.M.S II B "Supply side energy efficiency improvements - generation"
Reference - A.M.S II B (Version 9, EB 33)

b) Justification of the choice of the project category
As per the methodology following applicability criteria's should be satisfied:

Table 6.16-6 Applicability Criteria and Justification as per selected methodology in Singrauli #4

Applicability Criteria as per selected methodology	Justification on how the project activity meets the applicability condition
This category comprises technologies or measures to improve the efficiency of fossil fuel generating units that supply an electricity or thermal system by reducing energy or fuel consumption.	The proposed energy efficiency measures aim at improving the efficiency of coal based electricity generation unit and thereby reducing the fossil fuel consumption.
Total energy saving should be up to the equivalent of 60 GWhe per year. A total savings of 60 GWhe is equivalent to maximal saving of 180 GWhth in the fuel input to the generation unit.	The total thermal energy savings by the project activity would be 32.18 GWh_{th}
The technologies or measures may be applied to existing stations or be part of a new facility.	The energy efficiency measures are being implemented in the existing Boiler of # 4

The above demonstrates that the project scenario meets the criteria laid out by the methodology.

c) Description of the project boundary

Project boundary encompasses the physical and geographical site of the Boiler and Air pre heaters. The project boundary which starts from the coal storage, covers the coal fired boiler system and exists till the point of heat supply to the turbine system.

d) Description of Baseline and its development

In absence of the project activity and any regulatory requirement, the most plausible baseline scenario would be to continue the generation of electricity without improving the efficiency of the boiler.

The baseline emissions are calculated as the product of the gross heat rate (kcal/kWh) in the unit, multiplied by the emission coefficient (CEA Value) of the fuel used (coal) and the expected gross electricity generation of the unit. The average gross heat rate of the three year data prior to project implementation would be used to calculate the baseline emissions.

The project emissions will be calculated as the product of the gross heat rate (kcal/kWh) in the project year y for the unit, multiplied by the emission coefficient (CEA Value) of the fuel used (coal) and the expected gross electricity generation of the unit. The emission reductions were calculated as the difference between the baseline emissions and the project emissions.

e) Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered small-scale CDM project activity (Description for demonstrating Additionality)

The project activity meets the eligibility criteria to use simplified modalities and procedure for small-scale CDM project activities as set out in paragraph 6 (c) of decision 17/CP.7. As per the decision 17/cp.7 Para 43, a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the CDM project activity.

Further referring to Appendix A to Annex B document of indicative simplified baseline and monitoring methodologies for selected small scale CDM project activity categories, project participants shall provide a qualitative explanation to show that the project activity would not have occurred anyway, at least one of the listed elements should be identified in concrete terms to show that the activity is either beyond the regulatory and policy requirement or improves compliance to the requirement by removing barrier(s).

Investment barrier: a financially more viable alternative to the project activity would have led to higher emissions;

Best practice examples include but are not limited to, the application of investment comparison analysis using a relevant financial indicator, application of a benchmark analysis or a simple cost analysis (where CDM is the only revenue stream such as end-use energy efficiency). It is recommended to use national or global accounting practices and standards for such an analysis.

Demonstrating the project IRR is lower than the benchmark rate of returns. An IRR analysis based on the opportunity cost of fuel savings and the total investment required to implement the new technological measures can be conducted. If the project IRR is below the benchmark rate of returns, the project is additional

Technological barrier has been used to demonstrate additionality for the project activity.

Technological barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions;

The use of floating radial seals and sector plate drive unit is not a common practice in the coal based power plants in India. The seals currently used are low cost, but are not reliable to reduce the air leakage ratio sustainably. The proposed energy efficiency measures are high cost and are being implemented for the first time in India. The FRS and SDU to be used in the pre heater section to maintain the air-leakage ratio at design value are a completely new technology being used for the first time in India. There is considerable amount of risk related to project activity as no historical performance data on the new technology is available. The project activity would replace an existing system which has been intensively used and is relatively low risk.

Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions;

There is no regulatory or policy requirement which would mandate the project proponent to adopt the new technology. The prevailing practice in India is to use regular seals in the pre – heater section and replace them once their performance deteriorates. NTPC is one of the most efficient power producing company in the country and follows best practices to ensure high efficiency levels are maintained throughout the plant functions. As explained earlier, the new untested technology: FRS and SDU is being implemented for the first time in the country and would lead to reduction in GHG emissions by increasing the overall efficiency of the boiler system. The performance of the prevailing practice of using regular seals is known to deteriorate over time due to which the air-leakage ratio increases. This reduces the overall efficiency of the boiler system and hence leads to higher GHG emissions.

3) Duration of the project activity/ crediting period

Expected Operational Lifetime of the Project activity : 10 years

The project activity uses a fixed crediting period of 10 years

4) Environmental impact assessment

The ministry of Environment and forests (MoEF), Government of India ,under the environment impact Assessment Notification vide S.O.1533 dated 14/10/06 has listed a set of industrial activities in Schedule of the notification for which setting up new projects or modernization /expansion will require environmental clearance and will have to conduct an Environmental Impact Assessment (EIA) study. This project activity does not require EIA to be conducted as the activity is not included in Schedule I.

The project activity is environment friendly and leads to GHG emission reduction by reducing the quantity of coal (fossil fuel) combusted in the boiler.

The project activity would not have any significant adverse environmental impacts and also it does not fall under the purview of the Environmental Impact Assessment (EIA) notification of the Ministry of Environment and Forest, Government of India. Hence EIA is not required to be undertaken by the host party.

5) Stakeholders' comments

Stakeholders have been identified on the basis of their involvement at various stages of project activity. The stakeholders identified for the project are as under:

- Local villagers and representative of village governing bodies
- Employees of NTPC
- Teachers

- Engineering trainees

NTPC organized a consultation meeting with the stakeholders on 27/07/2010 . The discussion session was held in the NTPC premises at Singrauli.

An attendance sheet of the stakeholders was prepared and various concerns and queries were invited. The queries were satisfied and the same have been listed in the PDD.

In view of various direct and indirect benefits (social, economical, and environmental), no adverse concerns were raised during the consultation with stakeholders.

(2) Korba #6

1) Summary of Small Scale project activity

a) Title of Small Scale project activity

Air Pre-Heater performance improvement at NTPC Plant, Korba #6, Chattisgarh

b) Description of Small Scale project activity

The energy efficiency measures to reduce the air leakage ratio are as follows:

1. Adoption of Floating Radial Seals (FRS)
2. Adoption of Sector Plate Drive Unit (SDU)

The project would be beneficial to the local communities in terms of socio-economic, environmental and technological well being and would hence contribute to sustainable development.

c) Project participants

Name of Party involved ((host) indicates a host party): ....India
Private and/or public entity (ies) Project participants (as applicable): ....NTPC Ltd.
Party involved wishes to be considered as project participant (Yes/No):.........No

d) Technical description of the Small Scale project activity

Location: The project activity is located at Korba District, Chattisgarh, India. The project activity is located between 22°21′0″ N Latitude, 82°40′48″ E Longitude & 304 m above mean sea level.

CDM Methodology: As per the ‘Indicative simplified baseline and monitoring methodologies for selected small scale CDM project activity categories’, the project falls under

Sectoral scope: I - Energy Industries (renewable/non-renewable)
Main Category: Type II - Energy efficiency improvement projects
Sub Category: B - Supply side energy efficiency improvements - generation

Technology measures:

1. Adoption of Floating Radial Seals
2. Adoption of Sector Plate Drive Unit

2) Application of a baseline and monitoring methodology

a) Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity

Type -II - Energy Efficiency Improvement Projects

Title - A.M.S II B “Supply side energy efficiency improvements - generation”

Reference - A.M.S II B (Version 9, EB 33)

b) Justification of the choice of the project category

As per the methodology following applicability criteria’s should be satisfied:

Table 6.16-7 Applicability Criteria and Justification as per selected methodology in Korba #6

Applicability Criteria as per selected methodology	Justification on how the project activity meets the applicability condition
This category comprises technologies or measures to improve the efficiency of fossil fuel generating units that supply an electricity or thermal system by reducing energy or fuel consumption	The proposed energy efficiency measures aim at improving the efficiency of coal based electricity generation unit and thereby reducing the fossil fuel consumption.
Total energy saving should be up to the equivalent of 60 GWhe per year. A total savings of 60 GWhe is equivalent to maximal saving of 180 GWhth in the fuel input to the generation unit	The total thermal energy savings by the project activity would be 54.12 GWh_{th}
The technologies or measures may be applied to existing stations or be part of a new facility	The energy efficiency measures are being implemented in the existing Boiler of # 6

The above demonstrates that the project scenario meets the criteria laid out by the methodology.

c) Description of project boundary

Project boundary encompasses the physical and geographical site of the Boiler and Air pre heaters. The project boundary which starts from the coal storage, covers the coal fired boiler system and exists till the point of heat supply to the turbine system

d) Description of Baseline and its development

In absence of the project activity and any regulatory requirement, the most plausible baseline scenario would be to continue the generation of electricity without improving the efficiency of the boiler.

The baseline emissions are calculated as the product of the gross heat rate (kcal/kWh) in the unit, multiplied by the emission coefficient (CEA Value) of the fuel used (coal) and the expected gross electricity generation of the unit. The average gross heat rate of the three year data prior to project implementation would be used to calculate the baseline emissions.

The project emissions will be calculated as the product of the gross heat rate (kcal/kWh) in the project year y for the unit, multiplied by the emission coefficient (CEA Value) of the fuel used (coal) and the expected gross electricity generation of the unit.

The emission reductions were calculated as the difference between the baseline emissions and the project emissions.

e) Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered small-scale CDM project activity (Description for demonstrating Additionality)

The project activity meets the eligibility criteria to use simplified modalities and procedure for small-scale CDM project activities as set out in paragraph 6 (c) of decision 17/CP.7. As per the decision 17/cp.7 Para 43, a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the CDM project activity.

Further referring to Appendix A to Annex B document of indicative simplified baseline and monitoring methodologies for selected small scale CDM project activity categories, project participants shall provide a qualitative explanation to show that the project activity would not have occurred anyway, at least one of the listed elements should be identified in concrete terms to show that the activity is either beyond the regulatory and policy requirement or improves compliance to the requirement by removing barrier(s).

Investment barrier: a financially more viable alternative to the project activity would have led to higher emissions;

Best practice examples include but are not limited to, the application of investment comparison analysis using a relevant financial indicator, application of a benchmark analysis or a simple cost analysis (where CDM is the only revenue stream such as end-use energy efficiency). It is recommended to use national or global accounting practices and standards for such an analysis.

Demonstrating the project IRR is lower than the benchmark rate of returns. An IRR analysis based on the opportunity cost of fuel savings and the total investment required to implement the new technological measures can be conducted. If the project IRR is below the benchmark rate of returns, the project is additional.

Technological barrier has been used to demonstrate additionality for the project activity.

Technological barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions;

The use of floating radial seals and sector plate drive unit is not a common practice in the coal based power plants in India. The seals currently used are low cost, but are not reliable to reduce the air leakage ratio sustainably. The proposed energy efficiency measures are high cost and are being implemented for the first time in India. The FRS and SDU to be used in the pre heater section to maintain the air-leakage ratio at design value are a completely new technology being used for the first time in India. There is considerable amount of risk related to project activity as no historical performance data on the new technology is available. The project activity would replace an existing system which has been intensively used and is relatively low risk.

Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions;

There is no regulatory or policy requirement which would mandate the project proponent to adopt the new technology. The prevailing practice in India is to use regular seals in the pre – heater section and replace them once their performance deteriorates. NTPC is one of the most efficient power producing company in the country and follows best practices to ensure high efficiency levels are maintained throughout the plant functions. As explained earlier, the new untested technology: FRS and SDU is being implemented for the first time in the country and would lead to reduction in GHG emissions by increasing the overall efficiency of the boiler system. The performance of the prevailing practice of using regular seals is known to deteriorate over time due to which the air-leakage ratio increases. This reduces the overall efficiency of the boiler system and hence leads to higher GHG emissions.

3) Duration of the project activity/ crediting period

Expected Operational Lifetime of the Project activity: 10 years
The project activity uses a fixed crediting period of 10 years

4) Environmental impact assessment

The ministry of Environment and forests (MoEF), Government of India ,under the environment impact Assessment Notification vide S.O.1533 dated 14/10/06 has listed a set of industrial activities in Schedule of the notification for which setting up new projects or modernization /expansion will require environmental clearance and will have to conduct an Environmental Impact Assessment (EIA) study. This project activity does not require EIA to be conducted as the activity is not included in Schedule I.

The project activity is environment friendly and leads to GHG emission reduction by reducing the quantity of coal (fossil fuel) combusted in the boiler.

The project activity would not have any significant adverse environmental impacts and also it does not fall under the purview of the Environmental Impact Assessment (EIA) notification of the Ministry of Environment and Forest, Government of India. Hence EIA is not required to be undertaken by the host party.

5) Stakeholders' comments

Stakeholders have been identified on the basis of their involvement at various stages of project activity. The stakeholders identified for the project are as under:

- Local villagers and representative of village governing bodies
- Employees of NTPC
- Teachers
- Engineering trainees

NTPC organized a consultation meeting with the stakeholders on 23/07/2010. The discussion session was held in the NTPC premises at Korba.

An attendance sheet of the stakeholders was prepared and various concerns and queries were invited. The queries were satisfied and the same have been listed in the PDD.

In view of various direct and indirect benefits (social, economical, and environmental), no adverse concerns were raised during the consultation with stakeholders.

(3) Rihand #2

1) Summary of Small Scale project activity

a) Title of Small Scale project activity

Boiler feed water pump performance improvement at NTPC Plant, Rihand, Uttar Pradesh

b) Description of Small Scale project activity

The current efficiency of the boiler feed water pumps is 70.4%. The energy efficiency measures would improve the overall efficiency of the boiler feed water pump system to approximately 83% thereby reducing the electricity consumption by the boiler feed water pump system.

The project would be beneficial to the local communities in terms of socio-economic, environmental and technological well being and would hence contribute to sustainable development

c) Project participants

Name of Party involved ((host) indicates a host party): ....India

Private and/or public entity (ies)Project participants(*)(as applicable):.............NTPC Ltd.

Party involved wishes to be considered as project participant (Yes/No):...........No

d) Technical description of the Small Scale project activity

Location: The project activity is located at Rihand District, Uttar Pradesh, India. The project activity is located between 24°3′0″ N Latitude, 82°49′60″ E Longitude

CDM Methodology: As per the 'Indicative simplified baseline and monitoring methodologies for selected small scale CDM project activity categories', the project falls under

Sectoral scope:	I - Energy Industries (renewable/non-renewable)
Main Category:	Type II - Energy efficiency improvement projects
Sub Category:	B - Supply side energy efficiency improvements - generation

Technology measures: Boiler feed water pump efficiency improvement

2) Application of a baseline and monitoring methodology

a) Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity

Type - II - Energy Efficiency Improvement Projects

Title - A.M.S II B "Supply side energy efficiency improvements - generation"

Reference - A.M.S II B (Version 9, EB 33)

b) Justification of the choice of the project category

As per the methodology following applicability criteria's should be satisfied:

Table 6.16-8 Applicability Criteria and Justification as per selected methodology in Rihand #2

Applicability Criteria as per selected methodology	**Justification on how the project activity meets the applicability condition**
This category comprises technologies or measures to improve the efficiency of fossil fuel generating units that supply an electricity or thermal system by reducing energy or fuel consumption	The proposed energy efficiency measures aim at reducing the auxiliary consumption and thereby improving the efficiency of coal based electricity generation unit and thereby reducing the fossil fuel consumption.
Total energy saving should be up to the equivalent of 60 GWhe per year. A total savings of 60 GWh_e is equivalent to maximal saving of 180 GWh_{th} in the fuel input to the generation unit	The total thermal energy savings by the project activity would be 18.64 GWh_e
The technologies or measures may be applied to existing stations or be part of a new facility	The energy efficiency measures are being implemented in the existing Boiler feed water pump system of # 2

The above demonstrates that the project scenario meets the criteria laid out by the methodology.

c) Description of project boundary

Project boundary encompasses the physical and geographical site of the Boiler including boiler feed water pump systems. The project boundary which starts from the coal storage , covers the coal fired boiler system and exists till the point of heat supply to the turbine system.

d) Description of Baseline and its development

In absence of the project activity and any regulatory requirement, the most plausible baseline scenario would be to continue the generation of electricity without improving the efficiency of the boiler feed water pump system.

The baseline emissions will be calculated as the product of the total auxiliary consumption, multiplied by the emission coefficient of coal. The average auxiliary consumption of the three year data prior to project implementation would be used to calculate the baseline emissions.

The project emissions were calculated as the product of the total expected auxiliary consumption after the implementation of the proposed energy efficiency measures multiplied by the emission coefficient of coal.

The emission reductions were calculated as the difference between the baseline emissions and the project emissions.

e) Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered small-scale CDM project activity (Description for demonstrating Additionality)

The project activity meets the eligibility criteria to use simplified modalities and procedure for small-scale CDM project activities as set out in paragraph 6 (c) of decision 17/CP.7. As per the decision 17/cp.7 Para 43, a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the CDM project activity.

Further referring to Appendix A to Annex B document of indicative simplified baseline and monitoring methodologies for selected small scale CDM project activity categories, project participants shall provide a qualitative explanation to show that the project activity would not have occurred anyway, at least one of the listed elements should be identified in concrete terms to show that the activity is either beyond the regulatory and policy requirement or improves compliance to the requirement by removing barrier(s).

The additionality can be demonstrated using any or both of the following routes:

Investment barrier : a financially more viable alternative to the project activity would have led to higher emissions;

Best practice examples include but are not limited to, the application of investment comparison analysis using a relevant financial indicator, application of a benchmark analysis or a simple cost analysis (where CDM is the only revenue stream such as end-use energy efficiency). It is recommended to use national or global accounting practices and standards for such an analysis.

Demonstrating the project IRR is lower than the benchmark rate of returns. An IRR analysis based on the opportunity cost of fuel savings and the total investment required to implement the new technological measures can be conducted. If the project IRR is below the benchmark rate of returns, the project is additional

Technological barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions;

The perceived technological and operational risks for project activity have to be elaborated, and it needs to be demonstrated how CDM revenue can mitigate these risks. Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions;

It needs to be demonstrated that the project activity is not a common practice in the region and prevailing practices lead to higher GHG emissions than the project activity.

3) Duration of the project activity/ crediting period

Expected Operational Lifetime of the Project activity: XX years
The project activity uses a fixed crediting period of 10 years

4) Environmental impact assessment

The ministry of Environment and forests (MoEF), Government of India ,under the environment impact Assessment Notification vide S.O.1533 dated 14/10/06 has listed a set of industrial activities in Schedule of the notification for which setting up new projects or modernization /expansion will require environmental clearance and will have to conduct an Environmental Impact Assessment (EIA) study. This project activity does not require EIA to be conducted as the activity is not included in Schedule I.

The project activity is environment friendly and leads to GHG emission reduction by reducing the quantity of coal (fossil fuel) combusted in the boiler.

The project activity would not have any significant adverse environmental impacts and also it does not fall under the purview of the Environmental Impact Assessment (EIA) notification of the Ministry of Environment and Forest, Government of India. Hence EIA is not required to be undertaken by the host party.

5) Stakeholders' comments

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

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

(1) The way forward for the identified CDM projects is as follows:

1) CDM Documentation

a) Final Project Design Document (PDD)
b) Preparation of Project Idea Note (PIN)
c) Approx. Time Schedule: 4 weeks from the start of project- Indicative time frame for the work involved in the projects. However this would primarily depend upon a number of factors including availability of required information from NTPC.

2) Host country approval prior to request for registration

a) Preparation and submission of requisite documents and presentation at the Indian DNA.

b) Approx. time schedule: Requisite documents will be submitted within 1 week of finalization of PDD, subject to the availability of the same from NTPC/JICA. The time taken by DNA to issue the Host Country Approval (HCA) is approximately 3-4 months.

3) Validation by DOE

a) Web hosting of PDD on UNFCCC website for global stakeholder consultation.
b) Site visit by DOE to the plant
c) Preparation of Draft Validation Report including clarification, Corrective action requests (CARs), etc.
d) Issue final Validation Report after satisfactory closure of clarifications, CARs, etc. and submission of project to UNFCCC for CDM registration
e) Approx. Time Schedule: The time taken for the closure of all the issues raised in the draft validation report and issue of final validation report is approximately 8-10 months. Receipt is subject to availability of information & required documents from NTPC.

4) Registration of project with UNFCCC

Approx. Time Schedule: 4-6 months for registration (including completeness check, information and reporting check and request for registration) subject to no queries or revisions raised by EB.

Table 6.16-9 Time estimate for the Way forward

Activity	Months ----→	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CDM Documentation		▨													
Host country approval prior to request for registration			▨	▨	▨	▨									
Validation by DOE			▨	▨	▨	▨	▨	▨	▨	▨					
Registration of project with UNFCCC											▨	▨	▨	▨	▨

(2) Coordination Team

A four Member coordination team will be required from NTPC (3 at the respective plant sites and 1 at the head office) for the smooth execution of the CDM projects.

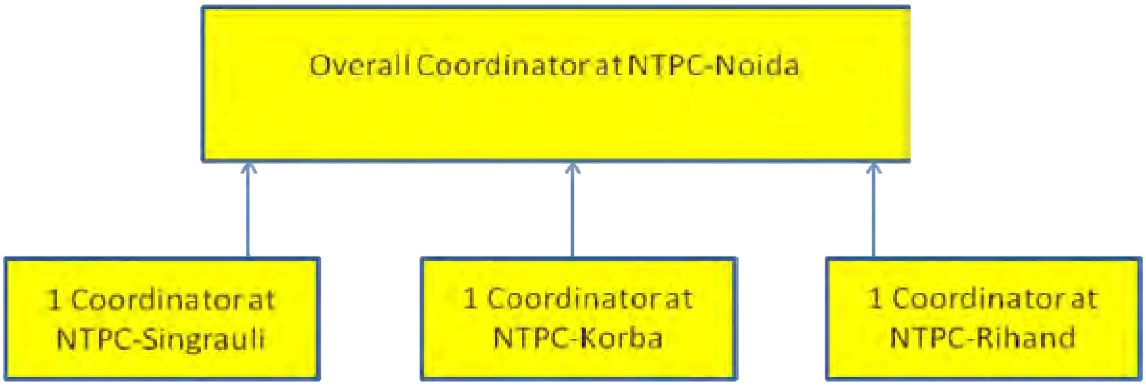


Fig. 6.16-4 Desirable Coordination Team The roles and responsibilities of the coordination team would include:

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

(3) CDM Transaction Cost

The typical costs involved in the procedures for registering a project under CDM are as follows:

1) Consultant Fee: Fixed fee and success fee (% of the CDM revenues received by the project proponent)

   Scope of Work of the consultant

   a) PDD, PCN development
   b) Facilitating Host Country Approval
   c) Facilitating Validation
   d) Facilitating Registration
   e) Preparing monitoring report, reply to queries raised by the verifier and assist in issuance and sale of carbon credits.

2) Validation Fee (one time):

   Designated Operational Entity (DOE) which are responsible for validation of projects and send request for registration to the UNFCCC. The fee charged by the validator is a one-time fee, typically ranging from 10 – 12 Lacs per CDM project.

3) UNFCCC registration fee (one time)
   a) If the CERs from a particular project are less than 15,000 CER's per annum, no registration fee is payable to UNFCCC.

b) If the CERs from a particular project are greater than 15,000 CER's per annum, the registration fee payable is as follows: 0.1 $ per CER upto 15,000 CER's and 0.2 $ per CER's beyond 15,000 CER's

4) UNFCCC Issuance fee (at every issuance)

0.1 $ per CER upto 15,000 CER's and 0.2 $ per CER's beyond 15,000 CER's (Adjustable against the registration fee)

5) Verification fee (for every verification)

The fee charged by third party verifier which verifies the monitoring report and sent request for issuance to UNFCCC. The fees payable for each verification range from 7 – 10 lacs.

(4) CDM – Indian Experience

1) The total Number

The total Number of CDM projects registered with UNFCCC is 1561. Since the establishment of the Indian DNA (MoEF) in 2003, a total of 530 projects from India have been registered by the CDM executive board as CDM projects.

2) The reasons for longer time duration for successful registration

The reasons for longer time duration for successful registration of a project under CDM with the UNFCCC are as follows:

a) Stringent guidelines and procedural requirements at UNFCCC
b) Stringent validation of the project activity by the DOE

3) Critical points

In order to successfully complete the registration of the proposed CDM project and subsequently claim CDM benefit, following critical points need to be ensured by NTPC.
Compliance with UNFCCC guidelines:

a) Prior CDM consideration of CDM

It is required to demonstrate that at the time of project approval, carbon credit revenues were a serious consideration to mitigate the financial and/or technological risks associated with the project. NTPC would be required to provide the chronology of events pertaining to the project activity with proper supporting documentation

b) Baseline Data

It is required to provide proper and reproducible documentation of the data parameters and values used to establish baseline emissions.

c) Demonstration of Additionality

- The arguments mentioned in the PDD to demonstrate additionality need to be backed up with proper supporting documentation, preferably from an independent third party.

- NTPC should construct theory of additionality with essential evidences and assessment of assumed risks in order to remove investment barrier and technological barrier of the project activity.

d) Monitoring Procedures

NTPC would have to ensure that the monitoring procedures as per UNFCCC guidelines and as detailed in the respective PDDs are strictly adhered to.

List of Abbreviations for CDM is as follows.

AM	Approved Methodology
AMS	Approved Methodology of Small Scale CDM
CDM	Clean Development Mechanism
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
PDD	Project Design Document
SSC	Small Scale CDM
UNFCCC	United Nations Framework Convention on Climate Change

6.17 Recommendation

The attached table shows recommendation plan of study items.

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

🟨 Efficiency 🟧 Reliability 🟦 Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
1	Location (State)	Chattisgarh	UP	UP	MP	UP
2	Capacity (MW)	500	#4 200MW #6 500MW	500	500	210
3	Turbine Make	KWU	#4 LMZ #6 KWU	#2 GEC	KWU	KWU
4	Boiler Make	BHEL	BHEL	#2 ICL	BHEL	BHEL
5	Overhaul Scope	B+IP+LP	#4: B+HP+(IP)+LP #6: B+LP	#2 B+IP+LP	B	#3 B+HP+IP #2 B+LP
6	Age	#4 1987, #6 1989	#4 1983, #6 1986	#2 1989, #3 2004	1999	#3 1999, #2 1989
7	Shut down period	#4: 9 May – 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 front and rear Division SH or between front and rear Division SH and Platen SH. - To increase SH and RH steam temperature, remove front Division SH, and add the same heating surface to rear Division SH by modification of rear Division SH. In addition, apply wall SH at left and right sides of furnace where Division SH is located. Removal of front Division SH is also effective for mitigation of temperature imbalance.	—

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

🟨 Efficiency 🟧 Reliability 🟦 Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
10	Boiler RLA	—	**#6** **RESULT** - As a whole, creep damage was not remarkable with no creep void and creep strain observed in each evaluated component. - Residual life of desuperheater was estimated to be 100,000, which was minimum among tested boiler pressure parts and headers. - Residual life of main steam pipe was estimated to be 21,000 hours. - Thickness decrease by erosion and attrition were observed in water wall tubes and SH tubes respectively. **RECOMMENDATION** - Implement RLA including outer diameter measurement and replica for main steam pipe again before reaching 21,000 hours, and preferably periodically later on. - Alternative standard criteria for tube replacement such as tsr (Thickness Shell Required) can be considered. In Japan boiler tube replacement is based on calculations of tsr which is a function of allowable stress, design pressure & design OD. NTPC can also consider the use of such criteria in consultation with OEM rather than the method of thickness decrease ratio from design thickness. - Conduct RLA focusing or emhasizing 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	**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 (FRS). - 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 (FRS). - Collect the historical data such as AH inlet/outlet air/gas temperature and soot blowing operation from just after periodical inspections in order to evaluate AH heating element heat transfer condition for improvement of low temperature efficiency of AH. - Furthermore, for better O&M, review the current field activities of periodic inspections for AH by utilizing supervisors from licenser of OEM.	—	—	—

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

🟨 Efficiency 🟧 Reliability 🟦 Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
12	Turbine RLA	**#4** **RESULT** - The unit is generally in good conditions. - No significant defect is observed in turbine and piping. - Remaining life of IP rotor is estimated to be 16 years. Remaining life of IP casing, LP rotor, LP casing is estimated to be more than 20 years. - Remaining life of MS piping is estimated to be more than 20 years, and HRH piping to be 13.6 years. - According to Steam Path Audit, 90% of losses of turbine (output & heatrate) 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	**BFP-6B** **RESULT** - Pump efficiency is decreased from the design value. **RECOMMENDATION** - Refurbish inner parts of the pump after economic evaluation. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	**CWP Stage-I 09** **RESULT** - Pump efficiency is decreased from the design value. **RECOMMENDATION** - Refurbish inner parts of the pump after economic evaluation. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	**#2** **BFP-2B** **RESULT** - Pump efficiency is decreased from the design value. **RECOMMENDATION** - Refurbish inner parts of the pump. - Conduct pump test for the same pump every two years, and to carry out the test for other pumps. **CWP-2B** **RESULT** - Pump is considered to be in acceptable condition. **RECOMMENDATION** - Conduct pump test for the same pump every two years, and to carry out the test for other pumps.	—	—

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

🟨 Efficiency 🟧 Reliability 🟦 Remaining life

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

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

🟨 Efficiency 🟧 Reliability 🟦 Remaining life

No.	Plant name	Korba #6 (#4)	Singrauli #4 (#6)	Rihand #2 (#3)	Vindhyachal #7	Unchahar #3(#2)
18	Analysis of present performance and performance decrease	**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 (corrected) is increased from design value. - HP turbine efficiency is decreased from design value. **RECOMMENDATION** - Replace HP & 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 efficiency whether they have been gradually decreased or were originally lower than design values. - Measure extraction steam pressure and temperature at turbine end. - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	**#4** **1.Boiler efficiency** **RESULT** - Boiler efficiency is decreased from design value. - AH outlet gas temperature is lower than design value. - AH outlet air temperature of Primary AH and Secondary AH outlets are lower than design value. It is estimated that heat exchange performance is decreased. - Air leakage is higher than design value. **RECOMMENDATION** - Improve temperature efficiency (refer to AH performance improvement). - Improve AH seal performance (refer to AH performance improvement). **2.Turbine heat rate** **RESULT** - Turbine heat rate (corrected) is increased from design value. - HP turbine efficiency is decreased from design value. **RECOMMENDATION** - Replace HP & 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 efficiency whether they have been gradually decreased or were originally lower than design values. - Measure extraction steam pressure and temperature at turbine end. - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	**#2** **1.Boiler efficiency** **RESULT** - Boiler efficiency is decreased from design value. - Average gas temperature (after gas flow correction) of Primary AH and Secondary AH outlets is higher than design outlet gas temperature. The average secondary air preheaters inlet exhaust gas temperature is higher than design value. - Air leak is higher than design value (assumption). - Unit is operated under slightly higher O_2 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 O_2 value at economizer outlet during operation to realize better boiler efficiency. **2.Turbine heat rate** **RESULT** - Turbine heat rate (corrected) 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 IP efficiency whether they have been gradually decreased or were originally lower than design values. - Measure extraction steam pressure and temperature at turbine end. - Investigate seal welding of partition plate - Take trend of tube side ΔP across FW heater and if ΔP increases more than 50% compared with design value, clean tubes by high pressure water jet	—	—
19	Review and improvement of past and present O & M procedure	**RESULT** - Picked-up five O&M procedures are properly edited as manuals. - Some recommendations were found through monitoring of operation including field patrol activities in order to improve technical and safety performance further. **RECOMMENDATION** **Safety Aspect** - Wear suitable safety gear (working clothes, helmet, gloves, safety shoes, flash light). - Encourage safety mind further through safety education. - Implement safety monitoring patrol and hold KY (Kiken-Yochi, danger prediction) meeting. - Indicate dangerous condition clearly to persons around intricate works in the same area. - Manage the entry and exit status into and from closed space by applying "In and Out Status Board". - Carry out field housecleaning by vacuum cleaner instead of air blow. - Enhance application of 5S(Seiri (organization), Seiton (neatness), Seiso (cleaning), Seiketsu (standardization), and Shitsuke (discipline)) especially in local field. **Improvement of Patrol** - Use suitable detection gear (flash light, listening rod). - Use listening rod to detect abnormal noise of rotating machines. - Put marks to local gauges to show normal working values. - Put thermo label to effectively detect steam leak from safety valve seat.			—	—

CHAPTER 7

TRAINING PROGRAM

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

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

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

Study team prepared 3 kinds of training plans in Japan for counterpart members based on the results of JICA S/W (JICA investigation report of pre-evaluation for this project), the results of kick-off meeting and the coordination with NTPC by e-mails.

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

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

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

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

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

These programs are as follows and these detailed plans are shown in Attachment-1, 2 and 3.

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

7.1.1 Periodic Inspection Training Course

The program of “Periodic Inspection Training Course” was planned as follows and implemented in June 2009. Misumi power station (1,000 MW coal-fired plant) survey was additionally implemented according to NTPC request during the training.

Table 7.1-1 Program of “Periodic Inspection Training Course”

Target

- To know the purpose of periodic inspection including its legal systems,
- To acquire the expertise concerning “inspection standards”, “process (schedule) management and process (schedule) shortening”, “quality management”, and “safety management”
- To understand them deeply through field work of inspection.

Subject	Duration (Days)	Method	Remarks
(1) Purpose of periodic inspection	1.0	Lecture	Including orientation.
(2) Flows of periodic inspection From planning to performance test of inspection work (including preparatory work and test operation)			
(3) Contents of inspection a. Inspection locations and actions based on inspection results b. Inspection implementation standards - Inspection methods for facilities affecting efficiency - Inspection activities	1.0	Lecture	
(4) Process (schedule) management/Process (schedule) shortening a. Consistency of major and partial process b. Need for schedule management meeting and test operation meeting. c. Standard inspection days/Critical path d. Methods to shorten process (schedule) (Boiler/turbine forced cooling, etc.)	1.0	Lecture	
(5) Quality management (Inspection items/Facilities to be inspected) a. Quality management system (inc. organization) b. Work system (inc. organization) (contractor, manufacturer and owner) c. Organization of operation section d. Responsibility area of inspection instructors from manufacturer e. On-site quality control - Setting and inspection of controlled area - Prevention of foreign matters - Entrance orientation f. Testing items during test operation g. Management when problem occurs	1.5	Lecture	
(6) Safety management Safety management of inspection work - Safety management system - Work supervisor - Work journal filing	0.5	Lecture	
(7) Power plant field work(*1)	4.0	Field work	2 days for boiler and 1 day for turbine and 1 day for moving day.

*1: Three days at Mizushima PS (285MW × 1 unit, 156MW × 1 unit, 340MW × 1 unit)

(Starting operation: 1961, 1963 and 1973 respectively), (The fuel of No.1 unit was shifted from coal to LNG in 2009.)

(The fuel of No.2 unit was shifted from heavy oil to coal in 1984.), (The fuel of No.3 unit was shifted from heavy oil and crude oil to LNG in 2006.)

Implementing Agency: Power Engineering and Training Services, Inc.

7.1.2 Efficiency Management Training Course

The program of “Efficiency Management Training Course” was planned as follows and implemented in October 2009 and February 2010.

Table 7.1-2 Program of “Efficiency Management Training Course”

1. Efficiency management

- To understand operation data and data processing method (performance control procedures) for maintaining and grasping plant performance
- To know the actions/solutions for improving performance
- To contribute to enhancing efficiency of operating power plant

Subject	Duration (Days)	Method	Remarks
(1) Purpose of efficiency management	1.5	Lecture	Including orientation.
(2) Methods of thermal efficiency management a. Viewpoints for performance management (Management items and standards) b. Heat input/output method/Loss method c. Input data (Fuel quantity/properties) d. Output data (net electric energy production and auxiliary power) e. Performance management program			
(3) Methods of daily management a. Management in terms of target values, management values and trends			
(4) Performance test (periodic) a. Types of performance test b. Procedures of performance testing - Procedures of performance management (daily/periodic) - Methods of data collection c. Management items by calculation d. Calculation/evaluation of plant thermal efficiency - Calculation theory of performance - Boiler efficiency - Turbine efficiency - Heater efficiency - Condenser efficiency - Loss factors	1.5	Lecture Field work	
(5) Solutions to enhance performance a. Enhancing efficiency of turbine blades b. Reducing AH leakage c. Installing variable blades for fans/pumps d. Reducing plant starting loss	1.0	Lecture	
(6) Power plant field work (*2)	2.0	Field work	

*2: One day at Shin-Onoda PS (500MW × 2 units, coal-fired super critical boiler)
(Starting operation: 1986 and 1987, respectively)
One day at Shimonoseki PS (175MW × 1 unit, coal-fired subcritical boiler and 400MW oil-fired subcritical boiler)
(Starting operation: 1967 and 1977, respectively)

Implementing Agency: Power Engineering and Training Services, Inc.

7.1.3 Facility Condition Monitoring and Diagnostic Technology Training Course

The program of "Facility Condition Monitoring and Diagnostic Technology Training Course" was planned as follows and implemented in August 2010.Upon the request of NTPC, the course of remaining life assessment technology for boiler/turbine originally planned in training program was cancelled, and instead an extra visit to Misumi power station (1,000 MW coal-fired plant) was arranged.

Table 7.1-3 Program of "Facility Condition Monitoring and Diagnostic Technology Training Course"

Target

- To acquire the monitoring actions/solutions for operation and maintenance in order to keep facilities in good condition while taking daily facility failures into account.

Subject	Duration (Days)	Method	Remarks
(1) Purpose of facility condition monitoring and diagnostic technology	0.5	Lecture	Including orientation.
(2) Maintenance management a. TBM (Time-Based Maintenance) b. CBM (Condition-Based Maintenance) c. RBM (Risk-Based Maintenance) d. Trend management of monitoring data	0.5	Lecture	
(3) Facility diagnostic technology a. Failure case study b. Non-destructive test technology	1.0	Lecture	To introduce failure cases and to explain diagnostic technology to prevent those failures.
(4) Vibration diagnosis of rotating machines a. Unbalance vibration mechanism b. Vibration measurement c. Practical training on unbalance adjustment	1.0	Lecture Practice	To focus on unbalance vibration.
(5) Operation management a. Evaluation of major warning items/values b. Frequency of daily patrol inspection and facilities to be inspected	0.5	Lecture	
(6) Condition monitoring functions of unit computers a. System outline b. Functions and Specifications, Operation dairy, performance calculating function, etc. c. Latest monitoring technology	1.5	Lecture	To explain their main functions, purposes and processing programs in Item b.
(7) Power plant field work(*3)	2.0	Field work	

*3: One day at Misumi PS (1,000MW × 1 unit, coal-fired ultra super critical boiler)
(Starting operation: 1998)
One day at Shin-Onoda PS (500MW × 2 units, coal-fired super critical boiler)
(Starting operation: 1986 and 1987, respectively)

Implementing Agency: Power Engineering and Training Services, Inc.

7.2 Boiler Residual Life Assessment Technique Training

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

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

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

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

The program of “Boiler Residual Life Assessment Technique Training Course” was planned as follows and implemented from August to September 2010.

7.2.1 Boiler Residual Life Assessment Technique Training Course

The program of “Boiler Residual Life Assessment Technique Training Course” was planned and implemented in August to September 2010 as follows.

Table 7.2-1 Program of Boiler Residual Life Assessment Technique Training Course

Targets

- To master the knowledge and skills on residual life assessment techniques of thermal power plant including advanced NDT techniques.

Subject	Duration (Days)	Method	Remarks
(1) Purpose of boiler residual life assessment technique	0.5	Lecture	Including orientation
(2) SUS scale detection technique for stainless steel tube a. Theory & practice of SUS scale detection technique for stainless steel tube	1.0	Lecture Practice	
(3) Advanced UT technique a. Theory of TOFD and PHASED ARRAY technique on pipe & header weld joints b. Practice of calibration with test block c. Practice and evaluation with thick weld joint including defects	2.0	Lecture Practice	
(4) Video image scope inspection a. Demonstration of Video image scope inspection of piping using manipulator at lab	0.5	Demonstration	
(5) Creep test a. Theory of residual life assessment by creep test b. Practice of creep test c. Case studies on residual life assessment of boiler tubes	1.5	Lecture Practice	
(6) Advanced replica and metallurgical observation technique a. Theory of replica and metallurgical observation b. Sample preparation for observation c. Practice of replica and metallurgical observation d. Practice of residual life assessment by replica and metallurgical observation	2.0	Lecture Practice	
(7) Field study of thermal power plant and research laboratory(*4)	1.0	Field Study	

*4: Half a day at Shin-Kokura PS, Kyushu Electric Power Co., Inc.
(600MW×3 units、LNG-fired super critical boiler. Starting operation: 1978, 1979 and 1983 respectively)
Half a day at Research Laboratory, Kyushu Electric Power Co., Inc.
Implementing Agency: Kyuden Sangyo co., Inc..

7.3 Boiler Combustion Simulation Training

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

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

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

The program is as follows.

7.3.1 Boiler Combustion Simulation Training Course

The program of "Boiler Combustion Simulation Training Course" was planned and implemented in August 2010 as follows.

Table 7.3-1 Program of "Boiler Combustion Simulation Training Course"

Targets
➢ To master the knowledge and skills on Boiler Combustion Simulation techniques of thermal power plant.

Subject	Duration (Days)	Method	Remarks
(1) Introduction a. Objectives of the simulation & simulation codeused for combustion b. Outline of the calculation procedure (Input data (Air flow, Emissivity, Flue gas flow, coal flow, heat transfer co-efficient, wall Temperature calculation etc.) Geometrical size of airports, Coal ports and Oil and air ports, Super heater, re-heater area etc.) (2) Geometry preparation, Mesh generation & Boundary condition setup a. Procedure of the mesh generation b. Setup procedure of gas & coal flow distribution c. Setup coal parameters in accordance with total enthalpy balance d. Setup physical constants (3) Cases and Execution Time of Simulation.	1.0	Lecture	Including orientation
(4) Simulation of base case & discussion on the result. (5) Simulation cases & Typical calculated results a. All Simulation cases (GR and Change in Oxygen % etc.) b. Typical calculated result of the tangentially fired boiler c. Adjustment of the heat transfer coefficient in preliminary stage. (6) Brief discussion on case study of furnace and other area of Boiler (7) Brief discussion on case study of implemented CFD results in different industry (8) Conclusions	1.0	Lecture	
(9) Visit to IDEMITSU KOSAN Coal and Environmental Research Institute for study of coal evaluation (10) Warp-up meeting	1.0	Lecture	

7.4 Evaluation of the Trainings

7.4.1 Evaluation of Training Programs

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

In addition to initial plan of this Program, site visit to power stations and some curriculums such as combustion adjustment were arranged and implemented from NTPC requests.
As a result of implementation program based on NTPC requests, evaluation from participants were shown that knowledge and experiences acquired from this Program would be profitable and useful at their power stations in India.
Consequently, the objective of this Training Program was satisfied and it contributed to technology transfer which was also one of the objectives of this Study.

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

(2) Boiler Residual Life Assessment Technique Training

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

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

7.4.2 Evaluation of Training Program and Implemantation

(1) Boiler Combustion Simulation Training

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

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

CHAPTER 8

ATTACHMENT

TABLE OF CONTENTS

8.1 Minutes of Meeting (MOM)

8.1.1 MoM of First Steering Committee

The Study
on
Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Minutes of Meeting
of
First Steering Committee: Review of Inception Report

JICA, JICA Study Team ,
Ministry of Power (MOP), NTPC

Pankaj Bhartiya
5/2/09.
PANKAJ BHARTIYA (AGM)

Mr. D.K.Agrawal
General Manager
NTPC Limited
India

N. Shimizu

Mr. Noriyuki Shimizu
Leader
JICA Study Team
Japan

DATE : 2^{nd}-3^{rd} February, 2009

VENUE : NTPC MCM Room, Core 6, Scope Complex, Delhi

Confirmation of Contents of Inception Report

General:

Draft Inception report of The Study on Enhancing Efficiency of Operating Power Plants' was reviewed and necessary corrections incorporated.

JICA Study Team (JICA-ST) explained outline of the Inception Report to NTPC, the study items and total schedule (Fig 4-1) and confirmed contents of report page by page.

JICA-ST pointed out that the study report will be compiled as a manual or guideline which will be submitted to JICA and/or NTPC as one of the deliverables of this study.

In response to NTPC's inquiry, JICA-ST informed that the study period is two (2) years, therefore, after the period JICA-ST will not be able to support additional clarifications.

JICA explained that NTPC should inform specific follow up works to Indian government if required, JICA will consider this matter.

Specific issues discussed are listed below:

1) Page 3, (2) "know-how"

In response to the NTPC's inquiry, JICA-ST replied that the meaning of know-how is proprietary information belonging to Service Company, therefore JICA-ST is not able to transfer such technology.

2) Page 5, Progress Report

In response to the NTPC's inquiry, JICA-ST replied that the report will be submitted as early as possible to JICA and NTPC, however Schedule date is Oct. 2009.

3) Page 6, 4) Performance Test

JICA-ST requested that performance tests will be carried out at three (3) candidate units in series to minimize transportation cost and test witness period.

NTPC explained that they will execute performance tests in association with JICA-ST expert at the three (3) units.

JICA-ST desired for a list of Offline test equipment used by CenPEEP in performance testing and an outline of the activities conducted jointly by CenPEEP and USAID.

NTPC requested that a copy of typical test procedures including input & output data used by Japanese utilities be provided.JICA-ST agreed to provide English version of test

procedures used in Japan by May'09.
Alongwith test procedure, NTPC requested JICA-ST to define the necessary data list expected for the performance testing by NTPC after the unit overhaul.

4) Page 7, 8) Operation & Maintenance

In response to the NTPC's inquiry, JICA-ST replied that the survey of O&M at power stations would be conducted by interview and discussion of the staff utilizing tables in the Inception Report.
NTPC suggested that JICA-ST should provide a copy of questionnaire to be used during interviews and additional items required in advance for timely collection of all the information.

5) Page 7, 10) Workshop

NTPC requested that duration of each workshop by JICA-ST should be two days instead of one day.JICA-ST agreed

6) Page 7, 11) Seminar

JICA desired that participants from state utilities in power sector (SEB) should also be invited to the seminars under the study.
NTPC will coordinate with SEB staff for participation in the seminars.

7) Page 7, 12) Training

NTPC requested that for counter part training in Japan the number of participants in each team should be increased to six (6) from proposed number of four (4) participants in the Inception Report. This is in order to accommodate participants from all the three candidate stations and Corporate team.

JICA responded that number of trainees are not fixed, therefore they will study NTPC request and inform the result as soon as possible.

8) Page 7, 14) CDM

JICA pointed out that NTPC has experience in CDM application for hydro and super critical boiler. JICA-ST asked NTPC to arrange a meeting with NTPC CDM section. NTPC agreed to arrange a meeting during next visit of JICA-ST.
NTPC requested that after formulation of PDD, JICA team will help in making presentation of proposal to designated authorities, if its within the study period.

9) Page 10, (4) Benefit to be provided by NTPC

NTPC and JICA-ST requested MOP for assistance of the items mentioned in (3),& (4). For exemption of customs duty, if required, and waiver of tax on income of Japanese experts during visit in India, MOP suggested that NTPC to prepare a letter and submit to MOP which will be processed for approval in accordance with the commitments/guarantees given in the mutually agreed and signed SOW. JICA-India will also provide support, if required, for this purpose.

10) Page 10, (4), 6) Securement of required budgets on the India

NTPC explained that budget for replacement/renovation of equipment requires necessary approvals of Competent Authority .

11) Page 11, 12) Custom Clearance

For the equipment to be brought on returnable basis by JICA-ST for field investigation, Custom clearance, handling, local transportation, repacking and dispatch after completion of work in India will be handled by agents appointed by JICA Study team. NTPC will provide support for the same, if required.

12) Page 11, 13) Arrangement

NTPC explained arrangement of transportation and accommodation etc. to be carried out as follows;

- Program from Delhi to nominated power station and movement between different stations(Booking detailsto be provided by NTPC
- Local Transportation: by NTPC at power stations
- Accommodation: by NTPC at power stations

13) Page 11, (5) Communication

The both parties agreed the following e-mail correspondence method;

- All communications to JICA-ST should be addressed to identified area expert and Mr. Shimizu and a copy marked to other members.
- A copy of all communication will also be sent to Resident Director, J Power in India.
- All communications to NTPC should be addressed to Mr. D.K.Agrawal, GM (CenPEEP) and copy marked to members of Counter Part team.

Both parties agreed to prepare communication table describing name, e-mail address and position.

14) Page 13, Clause 3.2.1, 2) Review of the contents of the cases of efficiency improvements of coal fired thermal power stations in Japan

NTPC requested to provide cases of efficiency improvements in Japan published in international conference, if possible.

JICA-ST agreed to look for such reports and provide to NTPC, if possible.

15) Page 14, 3) Preparation for the selection of model power station

Selection of the candidate units will be based on boiler & Turbine inspection opportunities during the study window (Oct-Dec 2009). JICA-ST requested to have opportunities of back-to-back inspection of model units in view of logistics. NTPC will review the schedule & short list five units in Kick Off II meeting, out of which three model units will be selected for Study.

JICA-ST has desired a set of _Technical & Commercial information for NTPC power stations as per the formats in Inception report. . NTPC agreed to provide the available information. JICA-ST also explained that minimum requirement for selection for unit is availability of design data

16) Page 15, c) Scope of Investigation

In response to the JICA-ST's inquiry, NTPC replied that the necessary data for selection of the candidate units will be provided by end of March 2009.

17) Page 16, b) Comprehending NTPC's efforts for efficiency improvements

In response to the JICA-ST's inquiry, NTPC replied that the list and outline of USAID activities is to be provided within two (2) weeks.

18) Page 16, (4) Kick off Meeting-2

JICA-ST suggested that Kick-off meeting-2 could be scheduled from 24th to 26th February 2009. NTPC will confirm the same.

19) Page 28, Table - 1

JICA-ST asked MOP to fulfill necessary data in the "Table -1 Check List of Questionnaires". MOP representative explained that the JICA-ST can access necessary information from the MOP, Central Electricity Authority (CEA) &Central Electricity Regulatory Commision (CERC) web sites. If any other information is required, JICA-ST should inform alongwith purpose of the information and the same would be considered and provided as appropriate.

20) Page 18 , 1)-2, a) Remaining Life Assessment (RLA) for boiler tubes

JICA-ST explained that RLA requires plant overhaul shutdown to inspect the necessary portion of Boiler or Turbine (dismantle of turbine casing), collection of sample materials replica for evaluation.

In response to the NTPC's inquiry, JICA-ST informed performance test is not related to RLA and those are executed separately.

JICA-ST pointed out period of RLA and typical overhaul period as follows;

- Turbine RLA: 15days, Boiler RLA: 6days
- Performance test: 1 day

NTPC informed that typical overhaul durations are as follows

- Turbine Overhaul: 30-35 days, Boiler Overhaul: 10 to 20 days

21) Page 19, d) Assessment of main pumps

NTPC requested to assess performance of turbine of Turbine driven BFP (T-BFP) and pump.

JICA-ST informed Japanese electric power companies have no experience to measure T-BFP performance, therefore JICA-ST proposed to evaluate the parameters . JICA-ST also informed that sub-vendor is able to assess performance of only motor driven pumps.

22) Additional assessment items (Priority List of Issues)

NTPC submitted attached "Priority List of Issues" to JICA-ST for further consideration of this study. JICA-ST reviewed additional assessment items and pointed out as follows;

- Item 1 is difficult to assess by JICA-ST, therefore we will confirm whether some sub-vendor can provide necessary service or not, subject to cost of service being confirmed by JICA. Details to be finalized at kickoff-meeting -2 (Item 1 is applicable to one (1) Unit).
- Item 2 is already included in this study, however some modification is required. Feed water piping assessment is to be studied and informed to NTPC at kickoff-meeting -2. As for efficiency restoration and upgrading, JICA-ST will include study and recommendation only, and not including supplying equipment.
- Item 3, 6, 7, 8 already included in this study
- Item 4 already included in this study (parameter assessment)

- Item 5 is to be applied this study, however details will be discussed at kickoff-meeting -2
- Item 9 is to be applied this study (Item 9 is applicable to two (2) Units)

23) Page 22, Clause 3.3 Training program for Counterpart Members (Training in Japan)

NTPC made some suggestions to make training programs more effective and requested that number of days of plant tour should be increased to have useful exposure to field exercises in the power plants. JICA-ST will consider the request.

24) JICA-ST plans to outsource RLA study. NTPC requested that reputed agencies in Japan may be commissioned so as to provide exposure to Japanese practices.

25) NTPC finds many items of interest from the presentations made in the Workshop. NTPC is compiling a list of items and requests for technical information on those subjects. JICA-ST agreed to consider the request and will help obtain information as far as possible.

Attachments

(1) Attachment-1: Agenda
(2) Attachment-2: List of Attendance
(3) Attachment-3: Briefing of Workshop
(4) Attachment-4: Priority List of Issues
(5) Attachment-5: Inception Report (corrected draft)

The Study
on
Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Attachments to the Minutes of Meeting
of
First Steering Committee: Review of Inception Report

JICA, JICA Study Team ,
Ministry of Power (MOP), NTPC

Attachments

(1) Attachment-1:	Agenda
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Attachment -1

NTPC-JICA Project on Energy Efficiency

Steering Committee Meeting

February 2nd, 2009

Venue: NTPC MCM Room, Scope Complex

Agenda

1.	Welcome address by **Mr. A.K. Mohindru**, GM -NTPC	1000-1005
2	Address by **Mr. Yukihiro Fukuda**, Counsellor, Embassy of Japan, New Delhi	1005-1007
3	Address by **Mr. K.C. Sharma**, Under Secretary, Ministry of Power, GOI	1007-1010
4	Address by **Ms. Adachi Fumio**, Deputy Director, Industrial Development Department, JICA	1010-1012
5	Brief of Kick-off Workshop by **Mr. Pankaj Bhartiya**, NTPC - CenPEEP	1012-1017
6	Observations by **Mr. Noriyuki Shimuzu**, J-Power and JICA Study Team Leader	1017-1022
7	Vote of Thanks	1022-1024

Departure of Counsellor, Embassy of Japan at 1025 Hrs.

Meeting to continue for rest of the day at Scope and further at Noida on February 03,2009 to discuss the Inception Report.

Attachment-2

STEERING COMMITTEE MEETING : FEBRUARY 2-3, 2009

LIST OF ATTENDIES

MOP

(1) Mr.K.C.Sharma (partly)

NTPC

(1) Mr. A.K. Mohindru
(2) Mr. B.M. Singh
(3) Mr. Pankaj Bhartiya
(4) Mr. S. Bandopadhyay
(5) Mr. A.K.Mittal
(6) Mr. M.K.S.Kutty
(7) Mr. A.K.Arora
(8) Mr. Surendra Prasad
(9) Mr. Subodh Kumar
(10) Mr. Partha Nag
(11) Mr. U.S.Verma

JICA

(1) Ms. Fumio Adachi
(2) Mr. Azumi Kakegawa
(3) Mr. Keiji Katai
(4) Ms. Shashi Khanna

JICA Study Team

(1) Mr. Noriyuki Shimizu
(2) Mr. Morikuni Miyagi
(3) Mr. Nobuchika Koizumi
(4) Mr. Takashi Fujimori
(5) Mr. Hiroshi Okame
(6) Mr. Hiroyuki Hayakawa
(7) Mr. Tatsuya Morooka
(8) Mr. Makoto Yotsumoto
(9) Mr. Shinji Kuba

J Power

(1) Mr. Shigeru Kondo

<u>**Attachment 3**</u>

Summary of Kick-off Workshop Presentations

General

1. Total 13 papers have been presented by Teams from 3 utilities.
2. The gross efficiencies of power plants in Japan are:
   - About 41% for sub-critical fleet,
   - Above 42%for super critical fleet and
   - About 43% for Ultra supercritical fleet.
   - Most of the sub-critical fleet is old and majority of new capacities are either supercritical or ultra supercritical.
3. One of the features of Japanese experience has been the <u>sustainability of operating efficiencies close to design</u>.
4. The basis of efficiency management activities is same regardless of steam conditions and unit size. The basis can be applicable to sub-critical units in India also. Accordingly most of the presentations from their team covered experiences on sub-critical units. Some data was also presented collected by them from service providers for LMZ type turbines.
5. Activities for efficiency improvement included:
   - daily / monthly efficiency management,
   - Proper day to day O&M to analyse the gaps and root causes to keep efficiency at design level,
   - Pre- and Post-overhaul evaluation of performance
   - Shut down maintenance.
     - OH intervals defined by law for boiler (2 yrs) and Turbine (4Yrs).
     - For the equipment where 'law' permits discretion in shutdown interval / maintenance, since 2002 the strategy is moving towards 'condition based maintenance' from 'time based maintenance'.
   - Replacements particularly by applying new technologies with high efficiency equipments

Boiler Efficiency Management

6. <u>Combustion management</u> is given high priority:
   - Combustion tuning as an important activity during re-commissioning and change of input coal.

- Low flue gas O2 operation
- Case studies on parametric combustion optimization by varying dampers etc.
- On line measurement of unburnt carbon in fly ash
- Computer Simulation of boiler combustion is able to simulate combustion gas flow, trajectory of particulate, temperature distribution, oxygen concentration, etc.. It is useful for study of combustion optimization (decreasing of unburned carbon and NOx & SOx) and has been initiated in some plants to study problems and optimization.

7. Balancing of coal flow is given high priority:
  - Measurement of coal flow at feeders as accurately as possible
  - Real time measurement of pulverized coal flow through burner pipes using meControl coal system
  - Use of dynamic rotating classifiers in mills to optimize boiler performance

8. Intelligent soot blowing is the normal practice. 'Fuzzy logics' are applied in 'Control Logics', heat absorption is calculated from on-line parameters to operate soot blowers as required. Soot blower maintenance is equally given high priority.

9. High priority to air-heater performance such as:
  - Automatic Sensor Drive Systems (SDS) in air heaters to sustain reduce leakage levels
  - Use of high performance air heater baskets elements for better heat transfer

10. Retrofits of VFDs in important drives.

Turbine Cycle Efficiency Management

11. New types of seals (leaf seals) for turbine inter-stage

12. Application of high performance turbine blade and anti-erosive turbine nozzle

13. Turbine efficiency recovery by:
  - Turbine internals cleaning by honing
  - Scale removal from turbine nozzle

14. Assessment of area wise air quantity ingress into condenser using leak buster

15. Application of Yates meter for Pump performance assessment has been initiated.

Turbine / HP Heaters / Condensers: Some significant overhaul & re-commissioning practices:

16. Turbine oil flushing procedures after O/H

17. Turbine forced cooling procedure is followed for reduction of overhaul time duration.

18. HP Turbine casing bolt loosening before stopping of Turbine.

19. Inspection & repair of turbine coupling bolts.

20. Actual over speed test at 25% load (during hot condition) after turbine overhaul.

21. Procedure for fastener checking & replacement based on DPT.

22. Practice of High pressure cleaning of HP heaters.

23. HP heater tube eddy current test.

24. HP Heater vacuum test.

25. Condenser eddy current test for 100% tubes in ten days

RLA of Boiler & Turbine

26. The tests done and tools used for RLA of boiler & turbine presented.

27. Use of on site electrical discharge sampling device for Small Punch Creep test for tube RLA

28. RLA of transformers also covered. Generator RLA was not discussed though it may be one of the items of study.

Transformers

29. Life assessment of transformer by non-destructive method (insulation paper sampling eliminated):

- Assessment of insulation paper degradation by $CO+CO_2$ and furfural measurements plotted against DP (degree of polymerization) based on the reference data prepared for 99 transformers.
- Cumulative CO + CO2 data accounted after degassing for life estimation purposes.

Control and instrumentation (C&I)

30. Assessment of control systems: system for periodic assessment

31. System of 'Root cause analysis' of failures within 3-4 days.

Attachment 4

Priority List of Issues

1. Diagnosis of Boiler problems including surface reengineering to address issues like shortfall in steam temperatures, temperature imbalance at boiler outlet, high RH sprays, high exit gas temperatures at boiler outlet, Combustion tuning & optimization
2. HP / IP turbine performance & condition assessment (including associated piping and FW piping); Efficiency restoration & Up gradations
3. Assessment of Large Pumps (Boiler Feed Pumps, Condenser cooling water Pumps including assessment by Yates meter)
4. Assessment of Steam Turbine of TDBFPs
5. Predictive Diagnostic Technologies
6. Assessment of Control Systems
7. Assessment of Condenser air-in-leakage
8. Boiler Inspection & RLA (Tubes & Headers)
9. Inspection & study for Air Heater Performance improvement

8.1.2 MoM of Second Steering Committee

The Study
on
Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Minutes of Meeting
of
Second Steering Committee: Review of Inception Report

JICA, JICA Study Team ,
Ministry of Power (MOP), NTPC

Mr. D.K.Agrawal
General Manager - I/C
NTPC Limited
India

Mr. Noriyuki Shimizu 14/12/09
Leader
JICA Study Team
Japan

DATE : **29th October, 2009**
VENUE : **Conference Room No. 108, 1st Floor,**
R &D BUILDING, NTPC CenPEEP, Noida

Mr. D.K. Agrawal, GM I/C welcomed Mr. Fukuda, Counselor, Embassy of Japan, Mr. Chandan Roy, Director (Operations) & Chairman, Steering Committee, Mr. Miyake & Mr. Inada, Embassy of Japan, Mr. Katai, JICA India, Mr. Shimizu, team leader, all members of JICA ST and executives of CenPEEP for 2nd Steering Committee Meeting on 'The Study on Enhancing Efficiency of Operating Thermal Power in NTPC-India'.

He talked in brief about activities done by the Study group comprising members from JICA ST, CenPEEP and NTPC Stations. He mentioned that series of discussion have taken place with JICA-ST and JICA officials on various aspects of Study, finalization of the scope of study and selection of units as per mutually agreed criteria. He appreciated that the request for training was included under the project at Japanese facilities for knowledge and skill up gradation and understanding of Japanese practices. He thanked JICA for this.

He mentioned that feed back of training program on periodic inspection is very good and found to be useful. Some of the practices of Japanese Utilities may be adopted in NTPC such as safety-net at every two meter height, camera for surveillance on unsafe act, Audio visual training on safety for all the workers during overhaul, Robots for Economizer & super heater inspection, use of pneumatic tools for boiler tube cutting etc. CenPEEP will communicate the feedback on the training program shortly so that the future training program is more effective.

He also mentioned about expectation of NTPC for study of surface re-engineering to solve the problem of Vindhyachal unit -7. But study could not be organized by JICA-ST due to non availability of potential service providers during the defined work-window. However he informed that Combustion Simulation study of boiler is being done under this study program for U-7 of Vindhyachal.

He pointed out that change in OH schedule of the units leading to changes in the candidate units and in SOW at each stations and readjustment of activities to meet the tight work - window and time scale for study project of JICA ST. The planning and the preparatory works involved in the organization of field visit at plant, data organization, briefing to the plant people and coordination with JICA-ST was emphasized.

Referring to the progress of 3rd field visit, he mentioned that the performance tests have been completed at all the three plants. Helium leak buster test has been carried out at Singrauli. However, we need more information for replication of the technique in NTPC. In this context, we had already requested for additional information.

Pump efficiency test using Yates meter have been carried out at three stations. The report on the demonstration test is to be received. However, for confidence building on the technique and its replication, more information on the procedure and calculation will be needed. He expressed that these two techniques will be very useful as a diagnostic tool. Boiler RLA study is in progress at Singrauli & C&I assessment is in progress at Unchahar. Boiler RLA team will go to Unchahar on 3rd Nov for boiler inspection from Singrauli.

He also mentioned about the constraints on logistics due to large contingent of JICA-ST & CenPEEP member at the time of unit overhauling. Stations some how managed the requirements with cooperation of JICA ST team members. It might have caused some inconvenience to the JICA-ST and thanked them for cooperation in this regard.

He informed that a request for the extension of the project beyond Oct'2010 which has been communicated to JICA through MOP & MOF. This is needed to make sufficient time available for organizing the selected demonstration / execution at plants based on data/information, study which will be available not before January 2010.

He also mentioned about details of the Japanese practices in critical areas. JICA ST has provided some information and promised that remaining information would be provided in due course. We hope that the information would be provided shortly so that gainful discussion and learning can take place. He also requested JICA ST to provide as much information as possible on Japanese practices in critical areas in the spirit of sharing information for learning and mutual benefits.

Mr. Yukihiro, Fukuda counselor Embassy of Japan expressed pleasure in attending the 2nd Steering Committee meeting and mentioned that this project is important for all of Indian people. The Indian economy is continuously growing; power shortage is a big concern and the power requirement will further grow in the future. Environmental matter with regard to greenhouse gas emission is important issue for new Japanese government. He emphasized that data required for JICA ST should be made available and NTPC's response in this regard is appreciated. He hoped that the training programs will be useful for NTPC staff as they will be able to get technical skill and know-how of Japanese utilities practice.

Mr. Keiji Katai, JICA, New Delhi expressed sincere thanks to both JICA ST and NTPC for their cooperation for this project. JICA had many project in India not only for power sector but also for social sector. He mentioned that NTPC collaborations with US and high level of performance of NTPC units are great achievement.

JICA ST team is the joint venture of three companies and wants to have best possible analysis for usefulness of the project. He expressed that although the study is being done at 5 power stations and the recommendations will also be useful for other stations. Climate change is important issue and CDM task will also be conducted in this project.

Mr. K. C. Sharma, MOP, could not attend the meeting due to some pre occupation. His message was conveyed by Sh. Pankaj Bhartiya, GM, CenPEEP, In his message, Mr.Sharma expressed his best wishes and full support for the Study group.

Mr. Chandan Roy, Director (Operation), welcomed Counselor Mr. Fukuda, Mr. Miyake & Mr. Inada, from Embassy of Japan, Mr. Katai, Mr. Shimizu, all members of JICA_ST & NTPC team.

He appreciated Japanese culture of meticulous planning, courtesies, politeness and health consciousness. He expressed satisfaction over response of Japanese company working for NTPC and high respect for Japanese practice in India. NTPC has high expectations from this joint study. NTPC has learned a lot from US window, but expectation from this window is also high. He shared the current performance of the units with the average age of 18 years and various challenges & issues ahead for NTPC.

NTPC present capacity is more than 30000 MW and volume of fleet is expected to grow to 75000 MW by the end of 2017. No of units in operation is 117 and is likely to touch to 175 in the near future. It is difficult to maintain the same quality of the people. A robust system is required to control the activities.

He mentioned about difficulties in developing the vendors and also handling the vendor for overhauls as most of the units are planned during monsoon period. He expressed that there is a lot of opportunity for service provider in this country. We encourage the vendors to come, as the scope is very high. Many supercritical plants are going to be commissioned in near future and large opportunity is available for vendors for maintenance of supercritical plants.

Environment issues are getting stronger and technology is driven more by the environment. Customers are getting more aware and stake holders are more demanding. We have to continuously implement the best practices for plant performance improvement.

We are focusing a lot on efficiency and trying to run the unit close to the design efficiency. For the new unit, target HR deviation is 50 kcal/kWh more than design, where as for the old plants the target is 75 kcal/kWh. The system should be able to track the deficiency much ahead and avoid possible failure of the equipments. He emphasized the need of efficiency control with online system. NTPC is working on this model for long term sustainability. System should not be dependent on the individual. Capturing the expertise of the people and making it available for all units is an important objective of expert system. At the end, he expressed that NTPC will get lot of expert advice from this study.

Mr. Shimizu, Leader JICA Study Team (JI CA-ST), explained outline of the Progress Report to the participants

Brief of the Progress Report

- Study team visited 5 NTPC stations along with CenPEEP and analyzed the data & station problem. Originally 3 units were to be selected however finally 8 units were selected for the study to cover all the required scope of work. JICA ST discussed continuously with CenPEEP; planned various activities and collected necessary information / data for the study. JICA ST also followed the change of overhaul schedules.

All field works will be completed by on going 3rd field visits and proposal will be made for efficiency improvement by February 2010. Present condition and problems of selected units were summarized and reviewed.

- JICA ST informed that some of the work were subcontracted to the service providers
    - Control : M/S Yokogawa
    - CDM: contract process in progress
    - Pump : M/s Torishima
    - Helium Leak Buster: M/s FUJI
    - Boiler RLA: M/s Kyudensangyo
    - Turbine Assessment(RLA, Steam Path Audit and Piping): M/s Alstom Japan
- Boiler RLA includes two new techniques.
    - Scanning Electron Microscope
    - Transmission Electron Microscope
    - TOFD (Time of Flight Diffraction)

Issues & Discussion:

- JICA ST explained the combustion simulation study details of Vindhyachal #7. CenPEEP asked about detailed discussion with the service provider. D (O) suggested that NTPC officers should be deputed to Japan for discussion with service provider and participation in the analysis process so that NTPC have sufficient confidence on the result of the combustion simulation study. CenPEEP also requested JICA to send service provider to India for discussion at Vindhyachal station on combustion simulation.
- CenPEEP suggested that the Workshop/Seminar planned during the 4th field visit should be attended by the service provider for better dissemination on the findings of

the study. JICA ST told that the contract with service provider does not include this task. JICA ST will however discuss the matter with JICA.

- JICA ST informed that the test data received in the area of Generator & Generator transformer analysis will be done at Japan. CenPEEP expressed that there would be good learning from the study for NTPC electrical experts and they would be able to get trends and analyze the test data in a better manner.
- JICA ST informed that performance tests were carried out as per NTPC procedure in consultation with JICA ST. The observations by JICA ST were appreciated and shared. NTPC asked that any suggestions on the test procedure will be appreciated.
- JICA ST witnessed O&M operator patrol during 3rd field visit. JICA ST asked to share various O&M procedures for their review. CenPEEP agreed to provide 5 no. of procedures as asked by JICA ST.
- JICA ST visited central stores and simulators at Korba and highly appreciated both.
- NTPC requested to extend the project beyond October 2010 as the time available is very less for planning and arranging execution of some of the recommendations. Mr. Katai informed that extension of the project seems to be difficult.
- NTPC shared that high level of confidence is required on the recommendations before NTPC selects it for execution and replication. NTPC asked support of JICA ST and service providers during execution of the recommendation within study time frame. NTPC also asked that full information be shared as a part of technology transfer and further replication of the same in the other stations for the areas like yatesmeter, He leak buster, RLA techniques etc. However, JICA ST mentioned that those information which are of intellectual property nature, cannot be shared if service providers do not provide information. Mr. Katai said that they would workout the replication mechanism in this context.
- NTPC also conveyed the interest shown by MOP about the new technology being demonstrated by the JICA ST. NTPC enquired about the details of the demonstration planned during February 2010 – October 2010 time slot. NTPC urged them to provide the details and activities calendar so that NTPC can plan the demonstration activities. JICA ST explained that they will assess all activity after #3 field work and inform NTPC about the activities plan of February 2010 – October 2010 during 4th field work. NTPC shared that some of the recommendation may be carried out as demonstration by NTPC and urged JICA ST to provide the required support.
- JICA told that financial study will be done along with the technical proposal evaluation.
- NTPC requested JICA to explore about the future plan after completion of the current study project and also urged JICA and JICA ST to provide required support in some of the demonstration.
- NTPC suggested that the collaboration should not end with the current study and

should identify the potential areas for future collaboration.

Attachment

(1) Attachment-1: Agenda
(2) Attachment-2: List of Attendance
(3) Attachment-3: Progress Report

NTPC-JICA Project

Centre for Power Efficiency & Environmental Protection
(CenPEEP)

The Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

2nd Steering Committee Meeting

Chaired by Director (Operations), NTPC Ltd

October 29th 2009
Venue: Conference Room No. 108, 1st Floor, R &D BUILDING
NTPC CenPEEP, Noida

Agenda

10:30-10:35	Welcome address by Sh. D.K. Agrawal, GM I/C, CenPEEP, NTPC
10:35-10:40	Address by Mr. Yukihiro Fukuda, Counsellor, Embassy of Japan, New Delhi
10:40-10:45	Address by Mr. K.C. Sharma, Under Secretary, Ministry of Power, GOI
10:45-10:50	Address by Mr. Keiji Katai, JICA, New Delhi
10:50-11:00	Address by Sh. Chandan Roy, Director (Operations), NTPC
11:00-11:10	Brief Presentation by CenPEEP on JICA Study
11:10-11:35	Brief of the Project Progress by Mr. Noriyuki Shimizu JICA Study Team Leader o *Activities carried out* o *Future plan* o *Issues & observations*
11:35-11:50	Discussions and suggestions
11:50-11:55	Vote of Thanks

Meeting is to continue for rest of the day to discuss progress of the Study and plan future activities.

ATTENDED BY :

NTPC

(1) Mr. Chandan Roy	Director (Operation)
(2) Mr. D.K. Agrawal	GM I/C, CenPEEP
(3) Mr. Pankaj Bhartiya	GM
(4) Mr. S. Bandopadhyay	GM
(5) Mr. A.K.Mittal	AGM
(6) Mr. Alok Gupta	DGM
(7) Mr. A.K.Arora	DGM
(8) Mr. R.K.Khurana	DGM
(9) Mr. Surendra Prasad	
(10) Mr. Subodh Kumar	
(12) Mr. D.Banerjee	
(13) Mr. Manoj Jha	
(10) Mr. Anand Kr. Jha	
(11) Mr. Rajan Kumar	
(13) Mr. Y.K.Sharma	

Embassy of Japan

(1) Mr. Yukihiro Fukuda,	Counselor
(2) Mr. Yasujiro Miyake	First Secretary
(3) Mr. Goki Inada,	First Secretary

JICA

(1) Mr. Keiji Katai
(2) Ms. Shashi Khanna

JICA Study Team

(1) Mr. Noriyuki Shimizu
(2) Mr. Morikuni Miyagi
(3) Mr. Nobuchika Koizumi
(4) Mr. Tatsuya Morooka
(5) Mr. Takashi Fujimori

J Power

(1) Mr. Shigeru Kondo
(2) Mr. Shingo Takagi

8.1.3 MoM of Third Steering Committee

The Study
on
Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Minutes of Meeting
of
Third Steering Committee
(02.03.2010)

JICA, JICA Study Team,
Ministry of Power (MOP), NTPC

18/6/10

Mr. D.K.Agrawal
General Manager - I/c, CenPEEP
NTPC Limited
India

18/06/2010

Mr. Noriyuki Shimizu
Leader
JICA Study Team
Japan

DATE : 2^{nd} March, 2010
VENUE : NTPC MCM Room,
SCOPE, New Delhi

Mr. D.K. Agrawal, GM I/C, CenPEEP welcomed Mr. Chandan Roy, Director (Operations) & Chairman, Steering Committee, Mr. Toru Kobayakawa, JICA India, Mr. Shimizu, Team leader, all members of JICA ST and other participants for 3rd Steering Committee Meeting on 'The Study on Enhancing Efficiency of Operating Thermal Power in NTPC-India'.

He talked in brief about activities carried out under the Study. He informed that most of the field activities have been completed including Performance Assessment at candidate stations, Demonstration of Boiler RLA techniques & practices, Condition Assessment of Controls & Instrumentation, Life assessment techniques for Generator & Generator Transformers, Combustion Simulation Study for boiler and Financial analysis of proposals. He shared that new techniques like Pump assessment using 'Yatesmeter' and identification & quantification of condenser air-in-leak using 'Helium Leak Buster' have been demonstrated.

He also mentioned that the observations, findings & recommendations of JICA ST were discussed by NTPC engineers from all stations in a workshop and a seminar at PMI, Noida and appreciated the efforts put in by members of JICA ST.

Mr. Toru Kobayakawa, JICA India, expressed thanks to NTPC for inviting him to the 3rd Steering Committee Meeting. He mentioned that he had also participated in the workshop on 'Findings & Recommendations of the Study on 22nd Feb at PMI Noida and was impressed by the enthusiasm shown by the participants in the workshop. He further informed that the three partner utilities of JICA ST, J Power, Kyushu and Chugoku Electric had put in additional efforts in translating Japanese documents in English for sharing their expertise and experiences. He further said that there's a need for enhanced level of exchange between NTPC and JICA ST for implementation of recommendations as the Study comes to a close in Oct'10.

Mr. K. C. Sharma, MOP, welcomed all the participants and expressed pleasure in attending the 3rd Steering Committee meeting. He said that Ministry of Power had provided full support to the collaborative program with JICA and that further support to the Study shall continue. He expressed his best wishes for the program.

Mr. Chandan Roy, Director (Operation), welcomed Mr. Toru Kobayakawa, Mr. Shimizu, all members of JICA ST & NTPC team. He said that present capacity of NTPC is more than 31000 MW and volume of fleet is expected to grow to 75000 MW by the end of 2017. The average age of the NTPC units is about 19 years and robust systems need to be put in place to improve and sustain high performance levels.

He said that CenPEEP provides a window to NTPC to connect to utilities worldwide for continued learning. He mentioned that he had been personally involved in structuring the current program with JICA ST. He appreciated the work carried out by Study Team and the learning opportunities provided by the Study to NTPC engineers.

He said that on the whole it has been a very exciting experience for NTPC and that the learning process should continue beyond seminar or workshops. NTPC would implement the recommendations and put the learning back in the system. He expressed that there should be focus on gap areas for high performance.

At the end, he appreciated the efforts put in by JICA ST members and thanked them for coming to Steering Committee Meeting and all the support during study.

Mr. Subodh Kumar, CenPEEP made a brief presentation outlining various activities carried out at NTPC stations under the Study.

Mr. Shimizu, Leader JICA Study Team summarized the Study focusing on its historical steps, findings and recommendations for each assessment item, road map for Implementation, possible implementation plan and future schedule of the Study. The recommendations for improvement of efficiency of the target units were appreciated by all the participants.

Mr. Shimizu said that further deliberation is necessary in NTPC before decision making for implementation of each recommendation. He stressed that JICA ST is a Joint Venture formed by three Japanese Electric Utilities and they are not Equipment manufacturers and outlined the possible activities which JICA ST can execute.

Regarding the future schedule, he mentioned that the suggested items in FY2010 namely Turbine RLA and Training in Japan for Boiler RLA need JICA consent before finalization. For conducting Turbine RLA, he requested Chairman, Steering Committee, Sh. Chandan Roy for firm schedule of units between June and July 2010 as Turbine RLA could not be carried out in FY 2009 due to changes in shut down schedule of target units and constraints due to specific work window of JICA ST. He said that this action could result in timely acceptance by JICA.

Mr. Miyagi presented the salient findings of Combustion Simulation Study carried out for Vindhyachal boiler.
Mr. Hayakawa presented the salient observations of the demonstration of boiler Residual Life Assessment techniques carried out at Singrauli Unit 6 & Unchahar Unit 2.
Mr. Fujimori presented Japanese practices of Residual life Assessment of Generators & Generator Transformers.

Discussion Points:

- NTPC appreciated the 'Combustion Simulation Study' carried out for Vindhyachal Unit 7 boiler and requested JICA ST for additional simulation cases to find solution to the problem of shortfall and imbalance in steam temperatures. It was specifically requested to simulate three scenarios as follows to achieve rated steam temperatures.
    - Simulated Coal flow imbalance amongst the corners
    - Simulated variations from nominal value in wind box pressure (Same pressure in both left and right wind boxes)
    - Simulated variation in imbalance in left and right wind box pressure

  The intent in each of the above scenarios is to create abnormal fireside conditions to achieve design steam temperatures and minimal imbalance between left and right without boiler modifications.
  NTPC also requested for association of NTPC engineers during the Simulation exercise by the Japanese service provider.

  JICA ST informed that they would discuss with service provider and revert back; Also, that the contract with Service Provider has finished and further approvals from JICA would be required for additional simulation cases and participation in the simulation.

- NTPC requested JICA ST to conduct Turbine RLA as per Scope of Work before completion of the Study in Oct'10. NTPC will write separately to JICA with firm schedule (without any changes at later stage) of unit overhauls (maximum 2 units), wherein Turbine RLA can be carried out within the window of June/July 2010.

- JICA ST has recommended that a team of NTPC engineers (Six persons for eight training days) could be trained in Boiler Inspection & RLA techniques at Kyuden Sangyo, Japan to upgrade their skills and demonstrate new techniques. NTPC will write separately to JICA requesting for organizing the training in Japan.

- Sh. Chandan Roy, Chairman, Steering Committee, suggested that the collaboration should continue after completion of the current study and should identify the potential areas for future collaboration. A mechanism to continually share knowledge and experience should be established through a possible utility exchange program and regular trainings in Japan.

  Mr. Toru Kobayakawa, JICA India informed that the current study has a defined Scope of Work and any further collaboration can be done separately on a project basis. He also mentioned that there are other similar programs such as APP (Asia-Pacific Partnership on Clean Development and Climate) supported by Ministry of Economy, Trade & Industry (METI), Japan and the information exchange program with the Japanese electric utility that may be utilized by NTPC.

The meeting ended with a 'Vote of Thanks' by Sh. Pankaj Bhartiya, GM (CenPEEP)

Attachment

(1) Attachment-1:	Agenda
(2) Attachment-2:	List of Attendees

ATTENDED BY :

NTPC

(1) Mr. Chandan Roy
(2) Mr. D.K. Agrawal
(3) Mr. A.K. Mahendru
(4) Mr. H.K. Sandhir
(5) Mr. A.K. Sinha
(3) Mr. Pankaj Bhartiya
(4) Mr. S. Bandopadhyay
(5) Mr. A.K.Mittal
(6) Mr. Alok Gupta
(7) Mr. A.K.Arora
(8) Mr. R.K.Khurana
(9) Mr. Surendra Prasad
(10) Mr. Subodh Kumar
(12) Mr. D.Banerjee

JICA

(1) Mr. Toru Kobayakawa
(2) Ms. Shashi Khanna

JICA Study Team

(1) Mr. Noriyuki Shimizu
(2) Mr. Morikuni Miyagi
(3) Mr. Nobuchika Koizumi
(4) Mr. Hiroyuki Hayakawa
(5) Mr. Takashi Fujimori
(6) Mr. Kyoichi Nakanishi
(7) Mr. Katsumi Yoshida

J Power

(1) Mr. Shingo Takagi

8.1.4 MoM of Fourth Steering Committee

The Study
on
Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Minutes of Meeting
of
Fourth Steering Committee
(14.09.2010)

JICA, JICA Study Team,
Ministry of Power (MOP), NTPC
Venue: NTPC Noida

Pankaj Bhartiya

Mr. Pankaj Bhartiya
General Manager
NTPC Limited
India

Mr. Noriyuki Shimizu
Leader
JICA Study Team
Japan

Mr. Pankaj Bhartiya, GM, CenPEEP welcomed Mr. S.C. Pandey, Executive Director (Engg) NTPC, & Chairman, Steering Committee, Mr. Yukihiro Fukuda, Counsellor, Embassy of Japan, New Delhi, Mr. Goki Inada, First Secretary, Embassy of Japan, Mr. K.C. Sharma, Under Secretary, Ministry of Power, Govt. of India, Mr. Hiroshi Suzuki, Senior Representative, JICA India, Mr. Sharad Anand, Executive Director (NETRA), NTPC and N. Shimizu, Team leader JICA-ST, Mr. H.K. Sandhir, GM(OS), Mr. Thangapandian, GM-Vindhyachal, Mr. D. Bhattacharya, GM-NETRA and all members of JICA ST and other participants for attending 4th Steering Committee Meeting on 'The Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India'.

He talked in brief about the journey of the project and study activities carried out under the Study. He informed that activities of the study project have been completed and JICA ST has submitted the draft final report. He also mentioned that the observations, findings & recommendations of JICA ST were discussed by NTPC engineers from all stations in a workshop and seminar at PMI, Noida and appreciated the efforts put in by members of JICA ST. Engineers from four state utilities and World bank also participated in seminar. He also mentioned that the dissemination process will continue through various workshops and seminars being organized by CenPEEP.

Mr. Yukihiro Fukuda, Counsellor, Embassy of Japan, New Delhi, in his opening remarks expressed happiness and honor for his participation in 4th and final Steering Committee Meeting. He shared that the dissemination of the study findings in the workshop and seminar organized at PMI has been quite successful. He thanked NTPC team and MOP officials who worked hard to make the study successful. He mentioned that the Guideline and Manual prepared during the Study and the recommendations of the Study would be very useful and contribute to the efficiency improvement of NTPC plants and Indian power sector.

Mr. Hiroshi Suzuki, Sr. Representative, JICA India, thanked JICA ST and NTPC for executing the study project successfully. He appreciated strong involvement of NTPC team in the study execution and shared that the recommendations are to be realized by NTPC independently. He shared that this is a successful study and would help in development of Indian Power Sector.

Mr. S.C. Pandey, Executive Director (Engg) NTPC, & Chairman, Steering Committee welcomed Mr. Yukihiro Fukuda, Counsellor, Embassy of Japan, Dr. Goki Inada, Embassy of Japan, Mr. Hiroshi Suzuki, Sr. Representative, JICA India, JICA ST and all the participants and appreciated the successful execution of the study through continuous interaction with Japanese Utilities and service providers. He stressed that the findings of the study should be disseminated in Indian Power sector. He assured that NTPC would try to translate the learnings into practice and replicate the same. He further shared that NTPC needs to bridge the gap between design and operating efficiencies and sought Japanese support for the same.

Mr. Pandey emphasized the need for

- A mechanism for further interaction of NTPC with Japanese experts
- Training of 3-4 NTPC teams in Japan every year
- Visits of NTPC senior officials to Japanese utilities.

He thanked Counsellor, Japanese embassy, JICA India and MOP for their support to the Study.

Mr. K. C. Sharma, MOP, welcomed all the participants and expressed pleasure in attending the 4th Steering Committee meeting. He said that CenPEEP had continuously briefed Ministry of Power about the progress of the Study. He expressed that NTPC has benefited from the interactions during the six training programs conducted in Japan. He said that the Study findings will benefit Indian Power Sector.

Mr. Sharad Anand, ED, NETRA welcomed the Japanese team and said that the current study on efficiency enhancement is very timely. He shared that a large no of NTPC units have crossed 100000 operating hours and demonstration & training on boiler and turbine RLA were very useful.

Mr. A.K.Arora, CenPEEP made a brief presentation outlining the Scope and methodology of various activities carried out at NTPC stations and the salient learnings from the Study and the visit of NTPC counterpart team to Japan.

Mr. Shimizu, Leader, JICA Study Team in his presentation summarized the study findings, recommendations for each assessment item, road map for Implementation and current status of various proposals. He further discussed the achievement of study vis-a-vis study objectives and shared his observations. He sought information on the current status of action plan for Vindhyachal U-7. The same was provided by Mr. Thangapandian.

Mr. Miyagi presented the salient findings of Combustion Simulation Study carried out for Vindhyachal U-7 boiler. He said that the additional simulations for variation in corner to corner coal flow and air flow, as requested by NTPC, have been completed. He shared that there is no impact of introducing corner to corner air and coal flow imbalance on temp imbalance and MS temperature. He also informed that training and discussion on combustion simulation in Japan, as requested by NTPC, has been completed.

Discussions:

- Mr. S. Bandyopadhyay, GM, CenPEEP, informed that Misumi plant in Japan uses multi point Oxygen probes for representative measurements - 4 measurement points in each probe and three probes in each gas duct. NTPC can also consider use of similar systems.
- Mr. Bandyopadhyay also pointed out that the techno economic analysis for air heater seals and turbine seals is based on the experience of improvement achieved in Japanese utilities and the proposals need to be customized for high ash Indian coals and operating conditions with the technical justification for improvement proposed.

  Mr. Shimizu responded that Japanese OEM can explore options to address high ash impacts.
- Mr. Thangapandian, informed that the simulation study recommendations are very useful. In line with the recommendation of the study and discussions with OEM, Cross connection after divisional panel, increase in LTSH area and upgradation of Reheater tube material are being planned. Its execution may take 2 to 3 years time. He also said that the use of ALCS in air heaters of older units would lead to improved ID fan margins and performance improvement.
- Mr. P. Bhartiya, GM, CenPEEP also informed the participants that all stakeholders like Project Engg, R&M Engg, NETRA, OS, CDM group etc (of NTPC) were associated during the course of study so that the recommendations can be critically analysed. He further reiterated the need of suitable mechanism for continued interaction between NTPC and Japanese Utilities and training of NTPC teams in Japan.
- Mr. Sharad Anand appreciated the collaborative study in the light of Indo-Japan friendship and reiterated the importance of efficiency improvement for reducing GHG emissions. He emphasized the need for making a detailed action plan for

efficiency improvement.

- Mr. S.C. Pandey, ED Engg, suggested to continue the information exchange and learnings of best practices through exchange visits of senior officials and explore areas of further cooperation.

The meeting ended with a 'Vote of Thanks' by Sh. S. Bandyopadhyay, GM (CenPEEP)

Attachment
(1) Attachment-1: Agenda
(2) Attachment-2: List of Attendees

ATTENDED BY :

NTPC

1. **Mr. S.C. Pandey**
2. **Mr. Sharad Anand**
3. **Mr. H.K. Sandhir**
4. **Mr. Pankaj Bhartiya**
5. **Mr. S. Bandyopadhyay**
6. **Mr. V. Thangapandian**
7. **Mr. D. Bhattacharjee**
8. **Mr. A.K.Mittal**
9. **Mr. J. Rajendran**
10. **Mr. Brajesh Singh**
11. **Mr. S. Sarkar**
12. **Mr. S.Hembram**
13. **Mr. R. Daga**
14. **Mr. A.K. Arora**
15. **Mr. R.K.Khurana**
16. **Mr. Surendra Prasad**
17. **Mr. Subodh Kumar**
18. **Mr. Partho Nag**
19. **Mr. S.P. Karna**
20. **Mr. A.K. Das**
21. **Dr. D. Banerjee**
22. **Mr. U.S. Verma**
23. **Mr. Anand K. Jha**

24. Mr. Manoj Kumar
25. Mr. Yogesh Kumar

Japan Embassy

1. Mr. Yukihiro Fukuda
2. Dr. Goki Inada

JICA

1. Mr. Hiroshi Suzuki

JICA Study Team

1. Mr. Noriyuki Shimizu
2. Mr. Morikuni Miyagi
3. Mr. Nobuchika Koizumi
4. Mr. Tatsuya Morooka
5. Dr. Hiroyuki Hayakawa
6. Mr. Takashi Fujimori
7. Mr. Kyoichi Nakanishi
8. Mr. Katsumi Yoshida
9. Mr. Makoto Yotsumoto

8.2 Presentation Slides

8.2.1 #1 Work Shop

JICA Study Team for Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Introduction for Workshop on Efficiency Management Activities in Japan

Noriyuki SHIMIZU

J-POWER

Japan International Cooperation Agency

Objectives of The Study

1. To improve the efficiency of coal-fired thermal power stations in India
2. To transfer to our counterpart the technology that is necessary to achieve the above objective

by applying the manners and technologies typically implemented by Electric Utilities in Japan

---

Study Team Formation

Joint Venture of:

Installed Capacity (MW)

- Electric Power Development Co., 16.4GW
- Kyusyu Electric Power Co. 19.7GW

and

- Chugoku Electric Power Co. 11.8GW

Study Team Formation

Joint Venture of:

- Electric Power Development Co.,
- Kyusyu Electric Power Co.

and

- Chugoku Electric Power Co.

Experiences+Strength:

⇒Many International Consulting Projects, 16 in India

⇒Cooperation Agreement with NTPC

⇒Training System and Experiences for oversees Trainees

Team Member

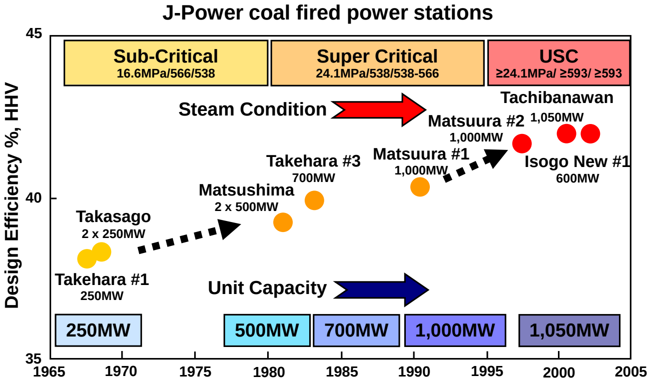
Shimizu	J-Power	Leader
Miyagi	J-Power	Sub -leader, Boiler
Koizumi	J-Power	Turbine, RLA-turbin
Fujimori	Chugoku EPCo	Electrical
Okame	Chugoku EPCo	C&I
Hayakawa	Kyushu EPCo	RLA-boiler
Morooka	J-Power	Efficiency Assesment
Yotsumoto	J-Power	CDM
Yamaguchi	Kyushu EPCo	Economic&Financial
Kuba	Kyushu EPCo	Coordinator
Tamura	Chugoku EPCo	Training Program

Trend of Efficiency Improvement

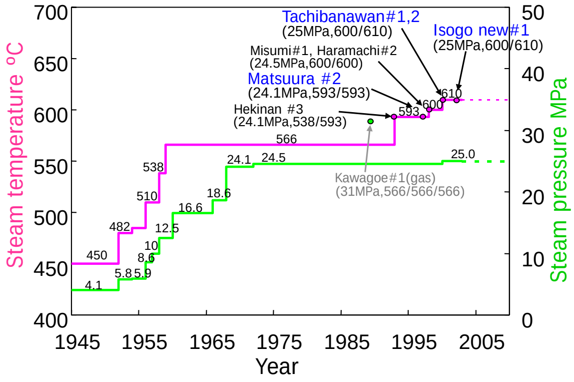
Coal fired thermal power stations in Japan

1. Upgrade of steam condition
   - sub critical < 22.1MPa
   - super critical ≥22.1MPa, ≤ 566ºC
   - ultra super critical ≥22.1MPa, >566ºC
2. Size up of Unit Capacity
   - ~200MW to 1,000MW+
3. R&D of new technologies
   - IGCC
   - IGFC

Efficiency Improvement



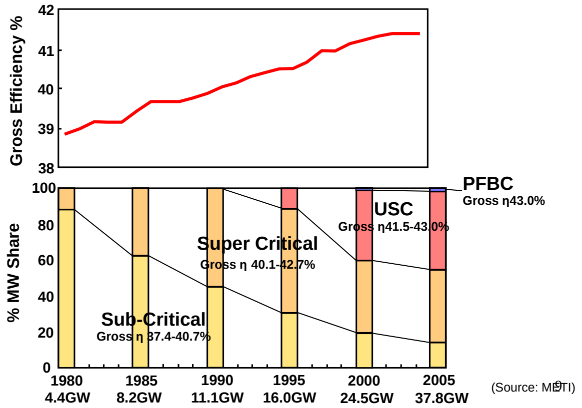
Upgrade of Steam Condition



USC Coal-fired Power Stations in Japan

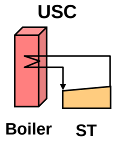
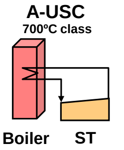
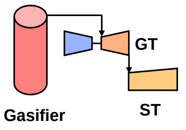
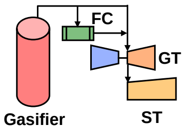
Electric Power Co.	Power Station	MW	MPa/MST/RST	COD
Chubu	Hekinan #3	700	24.1/538/593	1993
Tohoku	Noshiro #2	600	24.1/566/593	1994
Hokuriku	Nanao Ota #1	500	24.1/566/593	1995
Tohoku	Haramachi #1	1,000	24.5/566/593	1997
J-Power	**Matsuura #2**	**1,000**	**24.1/593/593**	**1997**
Chugoku	**Misumi #1**	**1,000**	**24.5/600/600**	**1998**
Hokuriku	Nanao Ota #2	700	24.1/593/593	1998
Tohoku	Haramachi #2	1,000	24.5/600/600	1998
Shikoku	Tachibanawan	700	24.1/566/593	2000
J-Power	**Tachibanawan #1**	**1,050**	**25.0/600/600**	**2000**
Hokuriku	Turuga #2	700	24.1/593/593	2000
J-Power	**Tachibanawan #2**	**1,050**	**25.0/600/600**	**2000**
Chubu	Hekinan #4	1,000	24.1/566/593	2001
J-Power	**Isogo New #1**	**600**	**25.0/600/610**	**2002**
Hokkaido	Tomatoh Atsuma #4	700	25.0/600/600	2002
Chubu	Hekinan #5	1,000	24.1/566/593	2002
Kyushu	**Reihoku #2**	**700**	**24.1/593/593**	**2003**
Tokyo	Hitachinaka #1	1,000	24.5/600/600	2003
Tokyo	Hirono #5	600	24.5/600/600	2004
Kansai	Maizuru #1	900	24.5/595/595	2004

Historical Efficiency Improvement



(Source: METI)

R&D of New Technology

PCF		IGCC 1500ºC class	IGFC
USC 	A-USC 700ºC class 		
Gross η: 43% Net η: 41% (HHV)	Gross η: 50% Net η: 48%	Gross η: 51-53% Net η: 46-48%	Gross η: ≥60% Net η: ≥55%

(Source: JCOAL)

R&D of New Technology (cont'd)

IGCC Demo Plant	IGFC Pilot Plant EAGLE
▪ Output: 250MWe ▪ Test Period: 2007-2009 ▪ Developer: CCP R&D Co. (10 EPCos & CRIEPI) ▪ Air-blown gasifier  Nakoso, Clean Coal Power R&D Co., Ltd.	▪ Coal feed rate: 150t/d ▪ Test Period: 2001-2009 ▪ Developer: J-Power ▪ Oxygen-blown gasifier  Wakamatsu Research Institute, J-Power

(Source: JCOAL)

Efficiency Management

1. Efficiency of coal fired power stations in Japan has been improved by upgrading of steam condition and size-up of unit capacity.
2. However, basis of efficiency management activities is same regardless of steam condition and unit size.
3. Such a basis can be applied to coal fired power stations in India, where sub-critical and 200-500MW class units are dominant.

Typical Efficiency Management

1. Proper operation and maintenance to keep the efficiency at the level of the design efficiency
2. Active performance improvement by applying new technologies and/or replacing with high efficient equipment

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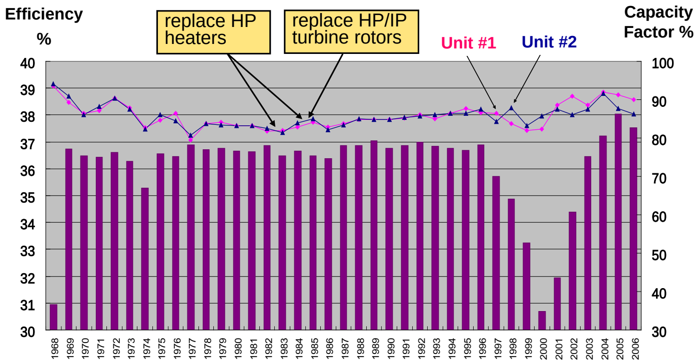
Typical Efficiency Management Record

J-Power Takasago coal fired power station, 2x250MW



Proper O&M

1. Monitor efficiency trend periodically
2. Analyze the deviation between current efficiency and the design efficiency to get the root cause
3. Devise countermeasures both during operation and /or periodical inspection shut-down

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Activities in Takasago during 40years

1. Shut-down Maintenance

   Boiler: Biennially, Turbine: once every 4 years
2. Major Replacements of Facility
   - Boiler Tubes & SH/RH: 1985, 86, 89, 90, 91, 93, 94, 95, 96, 97 & 98
   - ESP Electrodes: 1987 & 88
   - Turbine Rotors: 1984 & 1985
   - FGD Absorbers: 1985 & 1986
   - Control System: 1985 & 1996
3. Daily Efficiency Management
4. CMMS (Computerized Maintenance Management System): 2002-
5. PdM (Predictive Maintenance by thermograph, vibration, oil analysis): 2002-

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Typical O&M Activities

1. Operation
   - proper combustion management to reduce unburned carbon loss
   - proper soot blowing to prevent increase of flue gas temperature
   - proper management of feed water quality to prevent boiler tube corrosion and heat loss through boiler drum water blow
   - monitoring of air ingress into condenser

Typical O&M Activities (cont'd)

2. Maintenance
   - gap adjustment and replacement of turbine labyrinth seal
   - gap adjustment and replacement of AH seal
   - water washing and replacement of AH element
   - scale removal from turbine nozzle
   - boiler chemical washing
   - replacement of plugged condenser tubes

Active Performance Improvement

1. Gross heat rate improvement
   - application of AH SDS (Sensor Drive System) to reduce air leakage
   - application of high performance AH element for better heat exchange and corrosion proof
   - optimization of soot blowing
   - low flue gas O2 operation
   - application of high performance turbine blade and anti-erosive turbine nozzle

---

Active Performance Improvement

2. Net heat rate improvement (reduce in-house power consumption)
   - application of variable speed/pitch fans
   - partial in-service of aux. equipment

Workshop Agenda

1. Introduction
2. Efficiency management in Japan
3. Boiler performance improvement, RLA
4. Turbine/Aux. performance improvement, RLA
5. Electrical
6. C&I

We are happy to work with you to improve efficiency of coal fired power plants in NTPC/India as well as to proceed with technology transfer to our counterpart.

Thank You !

JICA Study Team for Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Efficiency management in Japan

Tatsuya MOROOKA

J-POWER

Table of Contents

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1) Efficiency management concept in Japan

○Existing thermal power plants
Maintenance of design thermal efficiency
(proper Operation &Maintenance)

○New thermal power plants
Introduction of Best Available Technology
(GT combined cycle,USC)

---

2) Thermal Power Plants operation in Japan

○Thermal Power Plants
・Introduction of the latest performance technology
(for construction time)

○Independent Transmission System in island of Japan
・Operation from base load to peak load
(based on supply and demand)

---

2) Thermal Power Plants operation in Japan

To improve
the thermal efficiency of thermal power plants ・・・

【Ideal】
・Construct large capacity &
high efficiency thermal power plants
・Maintain design thermal efficiency
・Operate at maximum load ! but ・・・

---

2) Thermal Power Plants operation in Japan

【Reality】
・Life cycle of thermal power plant is about 40～50 years.
・We can’t construct large capacity thermal power plants because of stagnant electric demand in Japan.
・To accomplish electric power supply stability (social mission), we must operate from minimum to maximum loads.
・Utilization factor is decreasing due to increase of non fossil fuel’s electric power. (nuclear , solar etc.)

2) Thermal Power Plants operation in Japan

Number of units and total MW by COD decade
- coal fired power plants in Japan as of Y2005-

~1960' s	8 units	1,448MW
1970' s	3 units	550MW
1980' s	21 units	7,699MW
1990' s	23 units	14,067MW
2000' s	25 units	13,341MW

※There are some old units alive.

---

2) Thermal Power Plants operation in Japan

○Approach for performance improvement

- ･Replace
- ･Renovation
- ･Routine O&M

---

2) Thermal Power Plants operation in Japan

○Replace

introduction of
Best Available Technology(BAT)

- ･LNG combined cycle
- ･USC etc.

---

2) Thermal Power Plants operation in Japan

○Renovation

remodeling according to aging deterioration

⇒Renovation by BAT

･steam turbine blade (3D shaped) etc.

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2) Thermal Power Plants operation in Japan

○Routine O&M

overhaul & daily mending

⇒just good timing
to maintain design thermal efficiency

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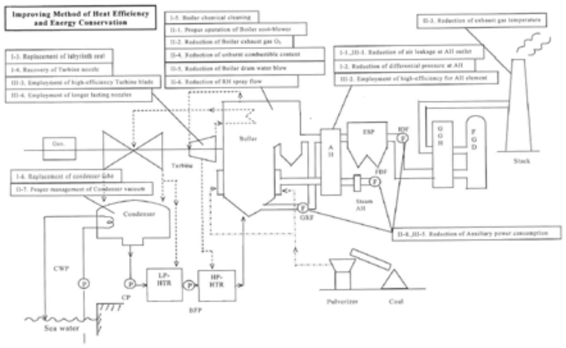
2) Thermal Power Plants operation in Japan



2) Thermal Power Plants operation in Japan

○Efficiency management in Japan

Replace
Renovation
◎Routine O&M

※Large investment to construct new power plants
⇒We value Routine O&M to maintain design thermal efficiency.

2) Thermal Power Plants operation in Japan

Japan : maintain design thermal efficiency
India : ??? (coal fired power plants)

○POINT on this study

We pay attention to the difference between the design and the actual thermal efficiency .

⇒If there is a difference even a little, we might be able to improve the present efficiency without large investment.
To keep the design thermal efficiency is an simple & quiet activity. But it’s a very important activity.

3) Management of thermal efficiency

○Management of thermal efficiency
- use of design coal
- management of daily actual efficiency
- management of monthly actual efficiency
- performance test（before & after periodical inspection）
- coal scale management (conveyer , coal feeder)
- maintenance management ⇒4) Maintenance scheme and program in Japan

We want to evaluate the difference of above-mentioned items between Japan and India.

3) Management of thermal efficiency

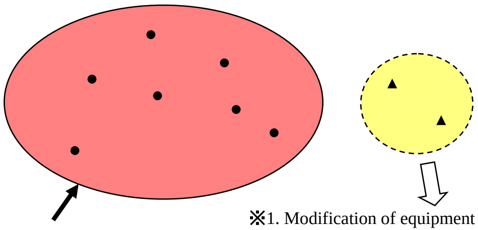
○Use of design coal

It’s a very important factor to use design coal to maintain design thermal efficiency.

⇒If we don’t use design coal, it causes the thermal efficiency decrease.
We need to select or blend the coal to keep design thermal efficiency.

3) Management of thermal efficiency

[design coal] [other than design coal]



selection or blending

※1. Modification of equipment to maintain emission regulation is indispensable.
2. As for the other influence, we study cost effectiveness of modification.

3) Management of thermal efficiency

○management of daily actual efficiency
- decision of items and values to be managed for thermal efficiency and in-house power requirement
- proper operation within allowable range decided above

※example of items to be managed for thermal efficiency
boiler : EcoO2, unburned carbon in ash
air heater : in and out gas temperature, differential pressure
steam turbine : main steam flow, 1st stage outlet pressure
condenser : vacuum
feed water heaters : inlet feed water pressure of high pressure heaters

3) Management of thermal efficiency

○management of <u>monthly</u> actual efficiency

[In Japan]

- Each power station has responsibility to manage the actual efficiency. (not head office)
- The power plant can promptly discover the change in efficiency.
- The monitor and the analysis can be done at the same time in the power plant.
- The power plant can study improvement of efficiency most appropriately.

---

3) Management of thermal efficiency

○management of <u>monthly</u> actual efficiency

[specific way of management]

- We record many data at rated output once every month.
- The purpose of record is to evaluate the difference between design values and actual values.
- example of evaluation items
  - boiler efficiency
  - steam turbine efficiency
  - gross thermal efficiency

---

3) Management of thermal efficiency

○performance test

boiler：heat loss method

turbine：heat input and output method

thermal efficiency：heat input and output method

---

3) Management of thermal efficiency

○coal scale management (conveyer , coal feeder)

- scale of conveyors for loading to and discharging from coal stock yard
  - zero point adjustment: every day
  - calibration : once every month
- coal feeder scale
  - calibration : periodical inspection
- coal property analysis
  - coal loading conveyer :each ship
  - discharging conveyer :moisture content (every day)
    calorific value (10 days average)
    ash composition (10 days average)

---

4) Maintenance scheme and program in Japan

○Regulation system in Japan (Electric Utilities Industry Law)

Direct participation of the government
⇒Review of safety control about autonomous periodic safety inspection（Art.55）
Utility's voluntary preservation of security
⇒ Autonomous periodic safety inspection（Art.55）

- Overhaul interval
  boiler : Biennially
  (steamdrum, header, tube, BFP, FDF,IDF etc.)
  turbine : once every 4 years
  (steamturbine,condenser,MSV,GOV,RSV etc.)

---

4) Maintenance scheme and program in Japan

※Based on the Electric Utilities Industry Law･･･

a . Equipment for which overhaul is required

b . Equipment for which overhaul is not required
(we can decide the interval of overhaul)

⇒We schedule overhaul based on ･･･
- the Law (a)
- previous overhaul results (b)
- equipment conditions (b)

4) Maintenance scheme and program in Japan

Plant Maintenance Cycle

Plant Overhaul Maintenance Cycle

Year	1	2	3	4	5	6	7	8
Boiler Plant	M	BA	M	BA	M	BA	M	BA
Turbine Plant		TS		TA		TS		TA

Typical Maintenance Outage Days

Class	BATA	BATS	M
300MW	45 days	43 days	15 days
500MW	63 days	55 days	15 days

Note: **BA(Boiler Major) TA(Turbine Major) TS (Turbine Minor)**
M (Intermediate Inspection)

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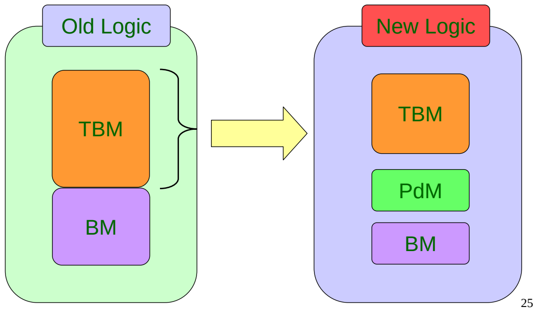
4) Maintenance scheme and program in Japan

･Introduction of PdM technologies



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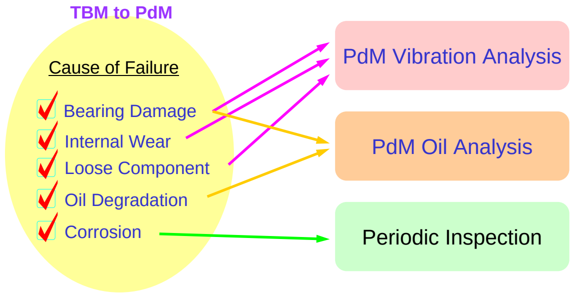
4) Maintenance scheme and program in Japan



Summary

1) Efficiency management concept in Japan

･Existing thermal power plants

⇒maintain design thermal efficiency

･New thermal power plants

⇒Best Available Technology

2) Thermal Power Plant operation in Japan

･Replace , Renovation , ◎Routine O&M

･POINT on this study

The thermal efficiency difference

between the design and the actual.

Summary

3) Management of thermal efficiency

･We want to evaluate the difference between Japan and India.

use of design coal

management of daily actual efficiency ･･･ etc.

4) Maintenance scheme and program in Japan

･Regulation system in Japan

･Plant maintenance cycle

･PdM technology (TBM⇒PdM)

Thank You !

Japan International Cooperation Agency

JICA Study Team for Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India

Boiler Portion

Contents

1. Boiler Performance improvement introduction of cases in Japan
2. Real time Measurement of Coal in Coal fuel pipes
3. Online Measurement of the Unburned carbon in the Fly Ash
4. Air Heater
5. Boiler Combustion Turning
6. Boiler Annual Inspection Period improvement by Scaffolding

---

Boiler Performance improvement Introduction of cases in Japan

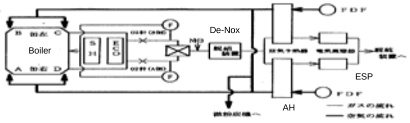
Eco Outlet gas O2 unbalance improvement

(Source: Energy conservation best practice national competition in 1994 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

1. Improvement Target:

To reduce unburned carbon by the modification of OFA damper control.

(Plant Rated Output: 406 MW , Fuel : Coal & Oil)



2. Phenomenon & Countermeasure

Boiler combustion air is controlled by FDF vane under the Boiler automatic control system which calculated total input fuel signal and Economizer (ECO) outlet O2 measurement value. However A and B side gas duct ECO O2 dose not controlled. (ECO outlet gas O2 A side: 4.2%, B side: 3.7%) They expected inhomogeneous combustion in the furnace.

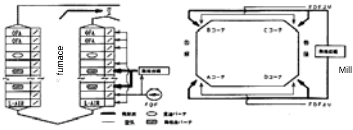
Boiler Performance improvement Introduction of cases in Japan

Eco Outlet gas O2 unbalance improvement

(Source: Energy conservation best practice national competition in 1994 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

They focused on the OFA

and L-AIR damper control.



3. Improvement process

Study for OFA, L-AIR damper control system

Temporary Modification of OFA, L-AIR damper control system

Balance Test of ECO O2

Decision of Measurement from the test result

4. Result

Original=> ECO O2 A side: 4.2%, B side: 3.7%

Modification=> A side: 3.8%, B side: 3.8%

Boiler Performance improvement Introduction of cases in Japan

Boiler Gas Recirculation Fan (GRF) power consumption improvement by the speed control devices

(Source: Energy conservation best practice national competition in 1994 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

1. Improvement Target:

To reduce GRF power consumption without affecting fuel combustion in the Boiler.

(Plant Rated Output: 600 MW , Fuel : Oil)

2. Current Situation & Analysis (Plant Rated Output: 600 MW , Fuel : Oil)

a) 70% of Station power is consumed by GRF, FDF and CWP

b) Comparison study (actual and theoretical value) of the above three (3) major equipment power consumption

GRF (damper control): Theoretical value (Power assumed by the calculation) < Actual ➔ detail study is required

FDF (variable pitch control): Theoretical value> Actual ➔ no room for reduce power consumption

CWP (variable pitch control): Theoretical value = Actual ➔ no room for reduce power consumption

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Boiler Performance improvement Introduction of cases in Japan

Boiler Gas Recirculation Fan (GRF) power consumption improvement by the speed control devices

(Source: Energy conservation best practice national competition in 1994 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

3. Improvement process

a) Study for large scale fan control system, cost and construction period.

b) Evaluation of those systems

c) Preparation of execution schedule (construction schedule)

4. Result

a) Unit 1 GRF applied VVVF system. Reduced Power consumption: 1190 kW (3560-2370)

Item	(a) Energy conservation	(b) Cost	(c) Reliability	(d) Operation	(e) Modification period	(f) Total points	(g) Result
variable wing	3	1	3	3	1	27	NA
Hydraulic coupling	3	2	3	3	3	162	A
VVVF	3	2	3	3	3	162	A
Pole change	2	3	3	1	1	53	NA
Evaluation Points 3	High (H)	H	H	H	Short	(axbxcxdxe)	
2	Medium (M)	M	M	M	-		
1	Low (L)	L	L	L	Long		

Boiler Performance improvement Introduction of cases in Japan

Improvement of Boiler efficiency by the Mill rotating classifier control program change

(Source: Energy conservation best practice national competition in 2002 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

1. Improvement Target:

To improve Boiler efficiency by the high fineness of pulverized coal.

(Plant Rated Output: 600 MW , Fuel : Coal & Oil)

2. Current Situation & Analysis

a) Boiler efficiency changed by the type of Coal.

Difference between Australia Coal A and D is 1 %.

b) Coal characteristic effected to dry gas heat loss, water heat of evaporation loss and unburned fuel loss.

It is necessary to take long period of operation test result in order to make effective operation procedure for reduction of dry gas heat loss and water heat of evaporation loss. Therefore ,they focused on the unburned fuel loss reduction.

Improvement of Boiler efficiency by the Mill rotating classifier control program change

(Source: Energy conservation best practice national competition in 2002 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

3. Improvement process:

a) Study of Mill rotating classifier control program ➔ Rotating speed change

b) Study of Mill outlet flow rate of coal and fineness of coal

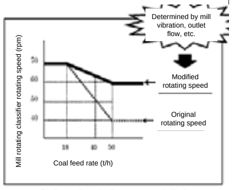
c) Study of Mill vibration and power consumption

4. Result

a) Boiler efficiency and Mill power consumption increased.

However total cost reduced.

	Australia Coal A		Australia Coal B	
	Before modification	After modification	Before modification	After modification
Unburned fuel loss	0.4 %	0.3%	0.25%	0.15%
Boiler efficiency	90.04%	90.13%	90.11%	90.21%
Mill Power Consumption	1,707 kW	1,971 kW	1,847kW	2,151 kW



図－９　ミル回転分級機回転数プログラム（変更後）

Improvement of Power Consumption by the Low O2 Operation

(Source: Energy conservation best practice national competition in 2001 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

1. Improvement Target:

To reduce power consumption of draft fans by the low O2 operation under the adequate Boiler combustion air.

(Plant Rated Output: 175 MW , Fuel : Oil)

2. Current Situation & Analysis

a) Boiler outlet gas O2: 3.0% at 175MW , 3.5% at 145MW.

b) Boiler combustion air is controlled by main steam flow and gas O2 signal.

c) Unburned fuel is able to measure at ESP hopper.

d) Boiler outlet O2 is fluctuating plus minus 0.2%

e) It is necessary to utilize OAP (OFA) and secondary air resister for air supply

f) Boiler outlet gas analysis is required for review of combustion state.

Improvement of Power and/or Fuel consumption by the Low O2 Operation

(Source: Energy conservation best practice national competition in 2001 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

3. Confirmation test

a) Conditions

Boiler outlet O2 value change, 4 hours constant output (MW) and 4 hours and OAP (OFA) and secondary air resister adjustment

175 MW: 3.0% O2, 2.5% O2, 2.3% O2, 140MW: 3.5% O2, 3.0% O2, 2.8% O2

4. Result

a) Draft Fan power Consumption & Boiler Efficiency

MW	O2 set value(%)	Power Consumption (kW)	Reduction (kW)	Boiler Efficiency (%)	Deference (%)
175	3.0	2,033.19	74.67	86.36	0.25
	2.5	1,958.52		86.61	
140	3.5	1,712.85	61.74	87.15	0.07
	3.0	1,651.11		87.22	

Shortening of the duration for Annual Inspection work by the new method

(Source: Energy conservation best practice national competition in 2001 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

1. Improvement Target

To reduce 104 days duration of annual inspection on 600MW coal fired thermal power plant. (Plant Rated Output: 600 MW , Fuel : Coal & Oil)

2. Current situation & analysis

a) Unit 1 annual inspection duration on fiscal year 1998 required 104 days for all of the power plant equipment.

b) Lot of Dead time and waiting time for the works

c) Boiler furnace scaffolding assembling/disassembling and/or ash scrape out required time and manpower.

d) Limitation of crane utilization time due to the same schedule of dismantles for Generator and Steam Turbine.

e) It was take time repair the machine at the factory

f) Boiler combustion tuning was executed about 26 days

g) the manager could not instruct to staff timely due to the coordination meetings

---

Shortening of the duration for Annual Inspection work by the new method

(Source: Energy conservation best practice national competition in 2001 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

3. Result

(): shortening days

a) critical works applied two (2) shift working: (5days)

b) reviewing number of meeting and changing start of the works: (2days)

c) rationalizing boiler combustion tuning: (1day)

d) changing of Generator H2 leak test: (2days)

e) reviewing of control characteristic confirmation test items: (3days shortening)

f) holding of spare parts for the machine which repair at the factory : (5 - 11days)

h) modification of Boiler furnace scaffolding : (6days)

i) developing/operating acoustic wave ash scrap out system from the Boiler: (1day)

j) developing/operating ash removal equipment by water-jet: (1day)

k) re-scheduling Turbine inspection: (5days)

l) reviewing Boiler inspection items and applying two (2) shift working: (10days)

Shortening of the duration for Annual Inspection work by the new method

(Source: Energy conservation best practice national competition in 2001 fiscal year in Japan, which was organized by Ministry of Economy, Trade and Industry)

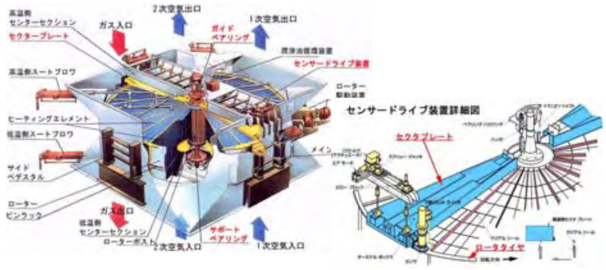
3. Result

	1997	1998	1999
(a) Annual Inspection Unit	Unit 1	Unit 2	Unit 1
(b) Type of Annual Inspection	Boiler: Full Turbine: Partial	Boiler: Partial Turbine: Simplified	Boiler: Partial Turbine: Simplified
(c) Duration	104 days	78 days	58 days
(d) Boiler preventive maintenance period	20 days	14 days	10 days

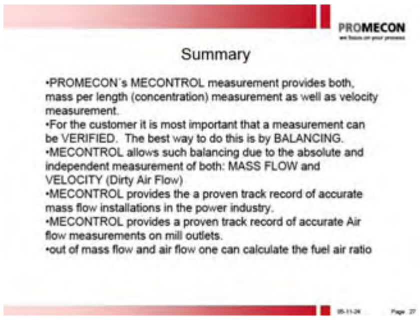
Boiler Performance improvement
Air Heater

Automatic Leakage Control

Tri-sector Air Heater



Boiler Performance improvement
Real time measurement of Coal in Coal fuel pipes



Summary

- PROMECON´s MECONTROL measurement provides both, mass per length (concentration) measurement as well as velocity measurement.
- For the customer it is most important that a measurement can be VERIFIED. The best way to do this is by BALANCING.
- MECONTROL allows such balancing due to the absolute and independent measurement of both: MASS FLOW and VELOCITY (Dirty Air Flow)
- MECONTROL provides the a proven track record of accurate mass flow installations in the power industry.
- MECONTROL provides a proven track record of accurate Air flow measurements on mill outlets.
- out of mass flow and air flow one can calculate the fuel air ratio

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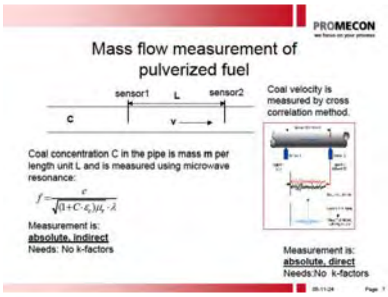
Boiler Performance improvement
Real time measurement of Coal in Coal fuel pipes



Mass flow measurement of pulverized fuel

Coal velocity is measured by cross correlation method.

Coal concentration C in the pipe is mass m per length unit L and is measured using microwave resonance:

$$f = \frac{c}{\sqrt{(1+C\cdot\varepsilon_r)\mu_r}\cdot\lambda}$$

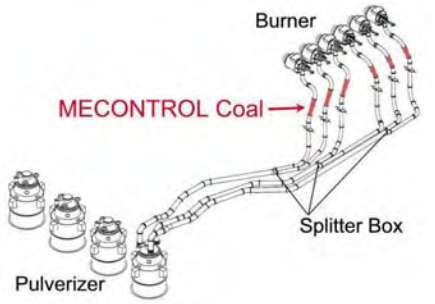
Measurement is:
absolute, indirect
Needs: No k-factors

Measurement is:
absolute, direct
Needs:No k-factors

Boiler Performance improvement
Real time measurement of Coal in Coal fuel pipes

MECONTROL Coal Measurement Cabinet

Boiler Performance improvement
Real time measurement of Coal in Coal fuel pipes



Boiler Performance improvement
Online Measurement of the Unburned carbon in the Fly Ash

Combustion optimization

MECONTROL UBC

Online measurement of the unburned carbon in the fly ash

Boiler Performance improvement
Online Measurement of the Unburned carbon in the Fly Ash

PROMECON

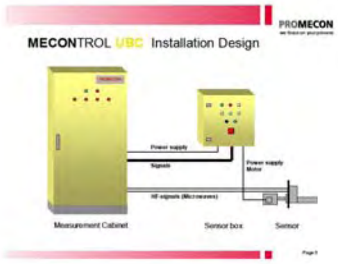
MECONTROL UBC Measurement Principle

Dielectric constant of fly ash is a function of the carbon content. Measuring the shift of frequency in a resonator (Δf) the carbon content can be calculated.

$UBC = A + B \cdot \Delta f$

A and B are the calibration coefficients

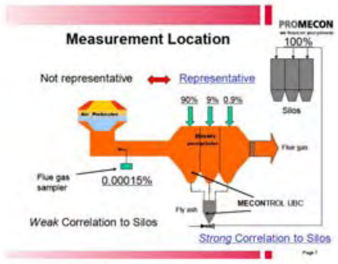
Boiler Performance improvement
Online Measurement of the Unburned carbon in the Fly Ash



PROMECON

MECONTROL UBC Installation Design

Boiler Performance improvement
Online Measurement of the Unburned carbon in the Fly Ash



PROMECON

Measurement Location

Boiler Combustion Turning

Outline of Boiler Combustion Tuning Procedure

1. Condition
    - a) Boiler continuous operation at rated output
    - b) correction of measurement hardware
    - c) providing same type of coal
    - d) soot blower is not applied during the test
    - e) combustion Air box damper setting
2. Measurement items
    - (1) combustion characteristic
        - a) Visual inspection internal of the furnace (brightness, confirmation of combustion status at burner portion)
    - (2) ECO outlet O2
    - (3) Mill
        - a) pulverized coal particle size measurement
        - b) Mill outlet temperature and Amount of Mill pyrite
        - d) Vibration of Mill and Mill operation records (mill motor current, etc..)

Boiler Combustion Turning

Outline of Boiler Combustion Tuning Procedure

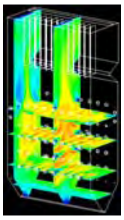
2. Measurement items
    - (4) NOx value
    - (5) Unburned fuel in ash (Sampling of fly ash at EP hopper and measurement of unburned fuel)
    - (6) Slugging and fouling characteristic
        - Confirmation of Bottom ash situation, number of times for soot blower, records of Boiler metal temperature
    - (7) Plant Control characteristic
        - a) Boiler static character
        - b) Boiler dynamic character

Boiler Combustion Turning

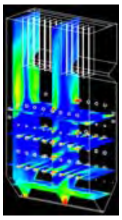
Outline of Computer Simulation

Computer Simulation of boiler combustion is able to simulate combustion gas flow, trajectory of particular, temperature distribution, oxygen concentration, etc..

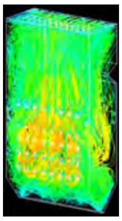
It is useful for study of combustion optimization (decreasing of unburned carbon and NOx & SOx).



temperature distribution



oxygen concentration

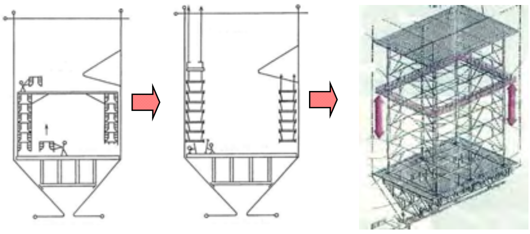


trajectory of coal particular

Boiler Annual Inspection Period improvement by Scaffolding

Scaffolding in the Boiler Furnace

Safety Stage System (Hoisting Scaffolding system)



250MW class boiler scaffolding assembling and disassembling period

(26 days) (16 days) (16 days or less ?)

Thank You !

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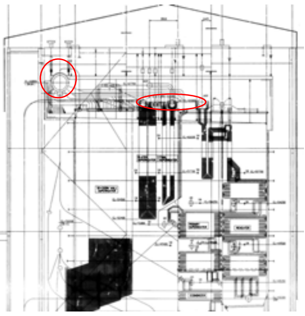
Boiler Portion

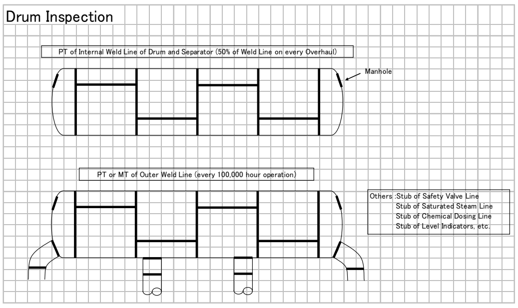
Area of Inspection

Area of Inspection

- **Disassembly and removal of Internal Components for VI**
  - Half Section at Each Inspection
- **Internal Sketch for Recording**
  - Location and Size of Defects
  (Crack, Corrosion, and Erosion)
- **P.T on Welding on Studs, Manhole and Waterline inside Shell**
- **Chemical Analysis on Sedimentation Materials**
- **External Welding Inspection on 100,000 hours**



Steam Drum - Welding Inspection

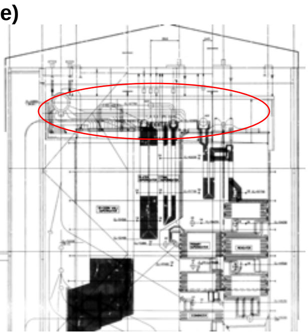


Area of Inspection - 2

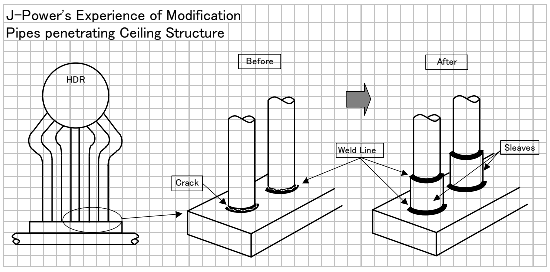
(Upper Level Boiler Structure)

Penthouse Area

- Position of Air vent pipes, hangers and drain lines
  - Boiler Movement due to heat expansion
- PT on Welding Joint of Sampling lines
- P.T on Welding of stub pipes of header
- P.T on Weld line of the roof penetrating pipes for representative pipe



Roof Penetration Area

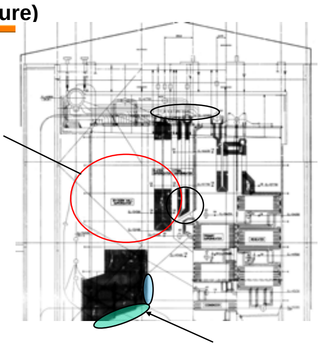


Area of Inspection - 3

(Upper Level Boiler Structure)

Div Wall, Platen, Final SH

- Shot Blasting on Transition Welding and Attachment Welding (+/- 1m from Joints) for Visual Inspection
- P.T on Welding
- Check on Elephant Skin (Fire Crack)

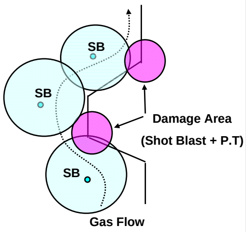


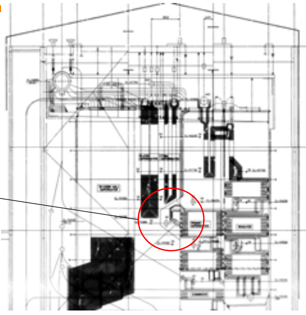
Shot Blast + VI + PT

Area of Inspection - 4 (Upper Level Boiler Structure)

Nose Area

- **Erosion due to Sootblowing**
- **Erosion due to Gas Turbulence**





Area of Inspection -5 Middle Level of Boiler Structure

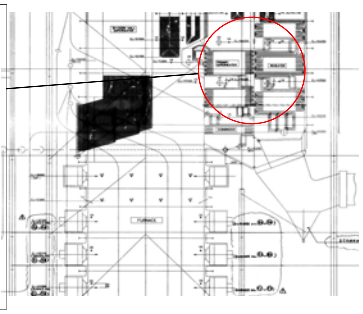
Heat Recovery Area

Major Problem

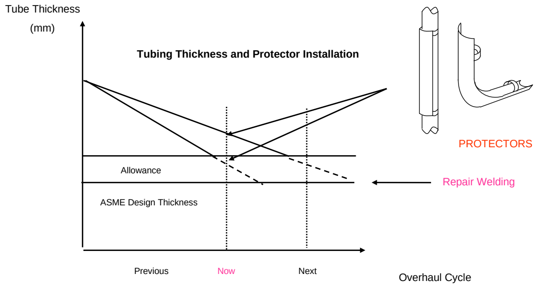
- Ash Erosion by Flue Gas
- Ash/drain cut by Sootblower

Inspection

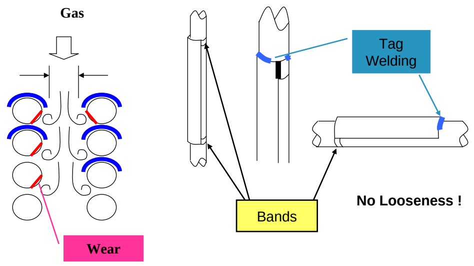
- Air Blow Cleaning
- Visual and Touch Inspection (Especially Corner Area)
- Thickness Measurements



Thickness Measurement and Tube Protector



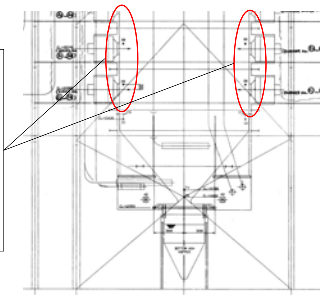
Tube Protectors



Area of Inspection 6 -Lower Level of Boiler Structure

Burner Area

- Damage of castable and bending of its studs
- Fire cracks (Elephant Skin)
- Tube sampling and scale analysis
- Careful inspection required especially after Condenser Sea Water Leak



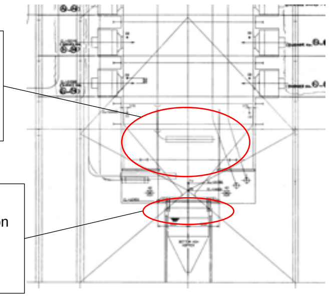
Area of Inspection 6 -Lower Level of Boiler Structure

Boiler Bottom Area

- Piping dent due to Clinker and repair welding
- Check Damages after removal of Scaffolding

Bottom Ash Hopper

- Damage of castable and corrosion of Seal Plates
- Scaling of Overflow Piping → Jet Cleaning



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Life Assessment of Thermal Power Plant Boiler Components

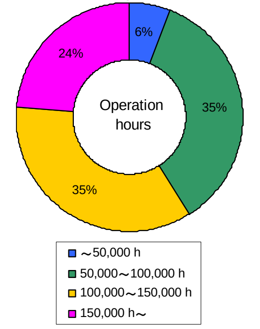
Japan International Cooperation Agency

Failure Classification and Deterioration Factors of Boiler Equipments

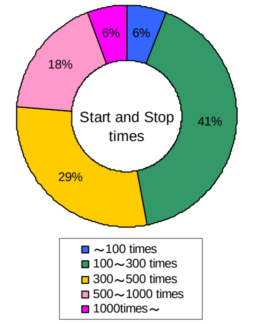
Classification	Deterioration factors
Creep	Long-term creep
	Short-term creep
Fatigue	Thermal fatigue (Low cycle fatigue)
	High cycle fatigue
	Corrosion fatigue
Corrosion	High temperature corrosion
	Low temperature corrosion
	Pitting
	FAC (flow accelerated corrosion)
	Stress corrosion cracking
Errosion	Ash cut
	Steam cut

Operation Condition of Thermal Power Plants

Cumulative operation hours

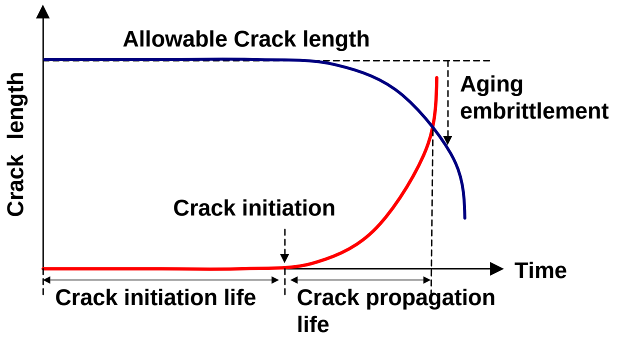


Cumulative start and stop times

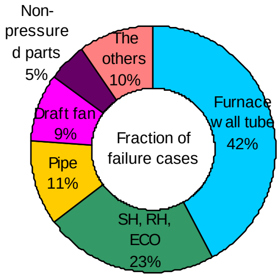


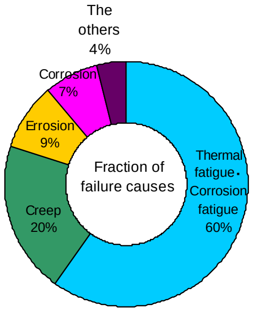
17 units in Kyusyu Electric Power Company

Crack Initiation Life and Crack Propagation Life(1)



Statistics on Failure Cases and Causes of Boiler Equipment

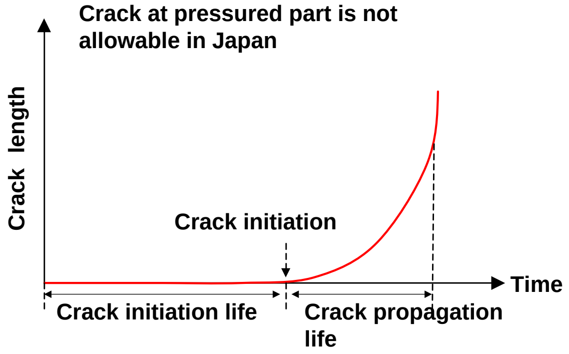




In pressured equipments

Crack Initiation Life and Crack Propagation Life(2)

Crack at pressured part is not allowable in Japan



Non-Destructive Inspection Method for Main Deterioration

Classification	Phenomenon	Non-destructive Inspection method
Creep	Swelling at late life	Replica, etc.
Fatigue	Surface cracking	PT,MT
Corrosion	Decrease of thickness	Thickness measurement
Errosion		
Stress corrosion cracking	Surface cracking	PT,MT
Corrosion fatigue	Inner surface cracking	UT

Boiler Tube Overhaul Inspection

Water wall, SH, RH, Eco tubes

Inspection measure	Deterioration factors	Inspection inerval
VT	Errosion	Periodic inspection (every 2years)
	Corrosion	
	Thermal deformation	
	Cracking	
	Burnout	
PT	Dissimilar metal weld failures	
Thickness measurement	Errosion	
	Corrosion	
Examination of sampling tube	Scale and deposition	Nesessary interval
PT for welding fin	Low cycle fatigue	In case of elongation of periodic inspection interval (max. 2years)
Measures for errosion	Errosion	
Measures for SUS scaling	SUS scaling	
PT for attached metal weld part of tube	Low cycle fatigue	After 80,000 hours operation
Remaining life assessment	Creep	Judge from operation and design condition

---

Steam Drum and Water Drum Overhaul Inspection

Steam drum, Water drum

Inspection measure	Inspection portion	Deterioration factors	Inspection inerval
VT	・Drum inside	Deposit	Periodic inspection (every 2years)
		Corrosion	
		Errosion	
Chemical analysis		Deposit	
PT	・Inner weld line ・Inner corner of stub ・Support and hanging lug	Low cycle fatigue	
MT	・External seam and girth weld line ・Inner weld line of stub	Low cycle fatigue	After 80,000 hours operation

---

Boiler Header Overhaul Inspection

Header

Inspection measure	Inspection portion	Deterioration factors	Inspection inerval
VT	General appearence	Errosion	Periodic inspection (every 2years)
		Corrosion	
		Cracking	
		Leak from weld part	
PT (MT)	Stub weld with no flexible structure and no rounding of weld end toe	Low cycle fatigue	
VT Chemical analysis of deposit	Headder inside	Low cycle fatigue Errosion Deposition	Periodic inspection (every 4years)
PT (MT)	Header stub weld Support metal weld	Low cycle fatigue	After 80,000 hours operation
MT	Header girth weld and seam weld	Creep	
Remaining life assessment	Most damaged header and pipe beyond 450℃	Creep	To extend priodical inspection interval 2 year to 4year after 100,000 hours
	High temperature Header and pipe	Creep	Consideration in inspection plan

---

Aging Deterioration Problem

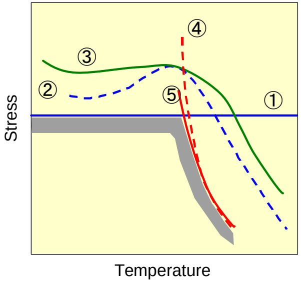
Thickness required is not always enough to creep rupture for aging boilers exceeded 100,000h operation.

$$t = PD/(2S+P)+0.005D$$

P: Internal pressure
D: Outer diameter
S: Allowable stress

What rules allowable stress S ?

$$t = PD/(2S+P)+0.005D$$



① 25% of Standardized tensile strength

② 25% of tensile strength at each temperature

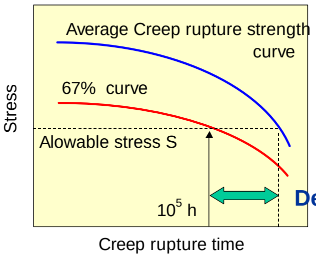
③ 67% of 0.2%proof stress at each temperature

④ 0.01% creep strain/ 10^3 h（Ave.)

⑤ 67% of 10^5 h creep strength（Ave.)
or
80% of 10^5 h creep strength（Min.)

Necessity of Remaining Life Assessment

t =PD/(2S+P)+0.005D

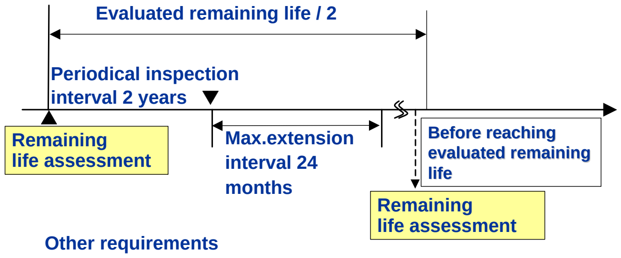


⑤ 67% of 10^5 h creep strength（Ave.）
or
80% of 10^5 h creep strength（Min.）

Designed margin

Actual remaining life ?

Extension of Boiler Inspection Interval by Remaining Life Assessment



Evaluated remaining life / 2

Periodical inspection interval 2 years

Remaining life assessment

Max.extension interval 24 months

Before reaching evaluated remaining life

Remaining life assessment

Other requirements

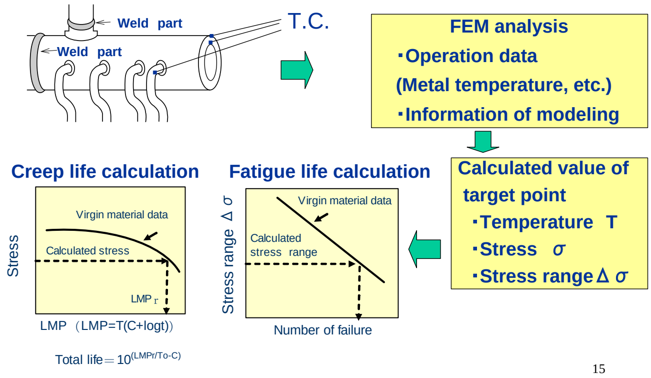
- Countermeasures for failures of own unit and other units
- Adequate operation and maintenance management
- Measures for low cycle fatigue dissimilar metal weld failures and SUS scale accumulation
  etc..

Remaining Life Assessment for High Temperature Components of Boiler

	Positive point	Negative point
Analytical examination	・Applicable to evaluate every necessary point ・Effective for selection of critical point ・Possible to evaluate with future operation mode ・Possible to do on-line monitoring	・Necessary for appropriate material strength data. ・Time and cost consuming with FEM analysis ・Calculation on paper without current damage condition
Destructive examination	・Precise evaluation	・Necessary for extraction of test samples and repairing ・Necessary for a few months to creep rupture ・Unable to monitor at identical point
Non-destructive examination	・Cost effective ・Possible to monitor at identical point	・Limitation of inspection from surface

---

Analytical Examination



FEM analysis
- **Operation data (Metal temperature, etc.)**
- **Information of modeling**

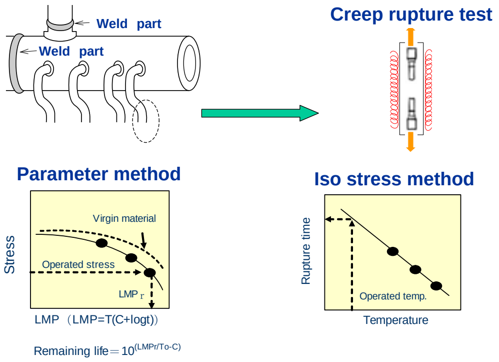
Calculated value of target point
- **Temperature T**
- **Stress σ**
- **Stress range Δσ**

Creep life calculation

Fatigue life calculation

Total life＝$10^{(LMPr/To-C)}$

Destructive Examination



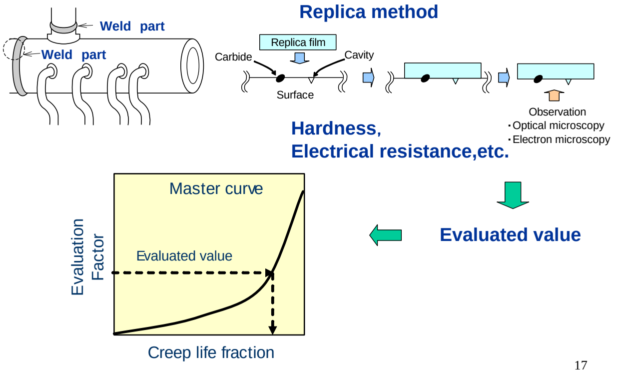
Creep rupture test

Parameter method

Iso stress method

Remaining life＝$10^{(LMPr/To-C)}$

Non-Destructive Examination



Replica method

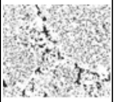
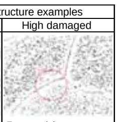
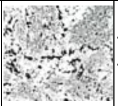
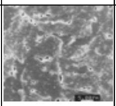
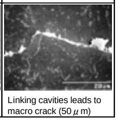
Hardness, Electrical resistance,etc.

Evaluated value

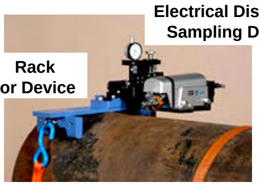
Non-Destructive Examination Technique of Remaining Life Assessment for Boiler

Method	Target to evaluate	Damate to evaluate	Parameter to evaluate
Hardness measuring	Base metal HAZ	Creep Low cycle fatigue	ΔHv, Hv/Hvo
Electrical resisitance	HAZ	Creep	ρ/?o
Chemical composition of carbide	Base metal HAZ	Creep	Mo/Cr
Creep cavity evaluation	HAZ	Creep	(A-parameter ,area fraction, number density,ets.)
Microstructural Comparison	Base metal HAZ	Creep	Creep cavity, Microstructure, Precipitates
Urtra sonic scattering noise	Base metal HAZ	Creep Low cycle fatigue	Ne/Neo
Interparticle spacing	Base metal	Creep	Interparticle spacing
Crystal grain deformation	Base metal	Creep	Grain aspect ratio
Micro-cracking length measurement	Base metal HAZ	Low cycle fatigue	Maximum micro-cracking length

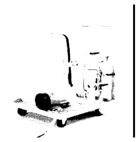
Example of Microstructural Comparison Method

		Observation Result		Standard Microstructure examples	
		Microstructure	Comment	Low damaged	High damaged
Base metal	Precipitates condition		・Not observed free-precipitates zone along grainboundary ・No remarkable degradation ・ϕ_c=1～12%	 No free-precipitates zone along grainboundary	 Free-precipitates zone along grainboundary
HAZ	Precipitates condition		・Fine precipitates remain ・No remarkable degradation	 Fine precipitates remain	 Fine precipitates disappear
	Creep cavity		・Not observed creep cavity ・No remarkable creep damage ・ϕ_c=0～20%	 A few creep cavities	 Linking cavities leads to macro crack (50μm)

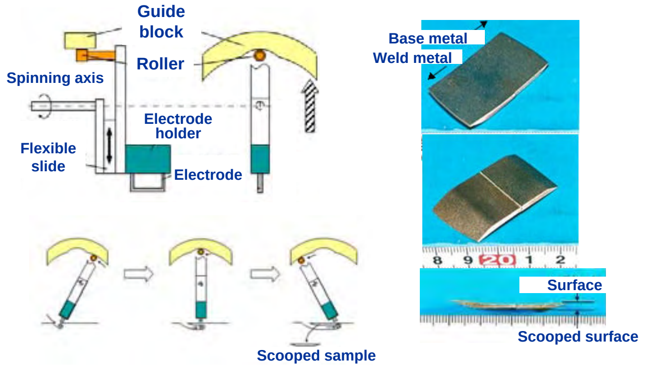
On-Site Electrical Discharge Sampling Device for Small Punch Creep Tests (1)



- ・Thinner and larger sampling with minimum mechanical and thermal damage (about 22mm×30mm×2mm)
- ・Flexible sampling with various shape of components
- ・3～4 hours / 1sampling



On-Site Electrical Discharge Sampling Device for Small Punch Creep Tests (2)



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TURBINE EFFICIENCY

IMPROVEMENT

Nobuchika KOIZUMI

J-POWER

Factors for Turbine Efficiency

Turbine efficiency improvement measures are described using examples.
Factors relating to "heat cycle condition" and "performance of main turbine" are shown below.

Heat Cycle Condition

Factors affecting the heat cycle

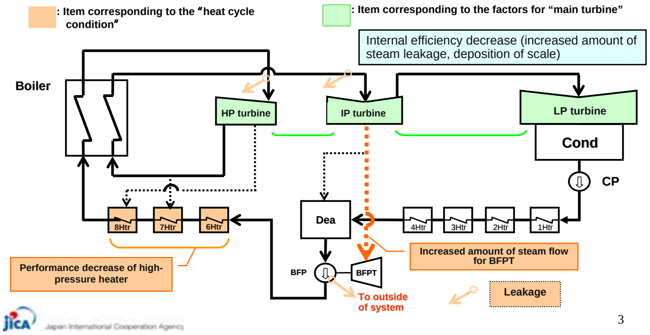
- ◎ Steam condition
- ◎ Condenser Vacuum
- ◎ Temperature of feed water and number of feedwater heaters
- ◎ Driving method for feedwater pump
- ◎ Other factors
  - Supplementary steam for boiler
  - Pressure loss in reheater
  - Boiler spraying
  - Leakage from piping & valve

Performance of main turbine

Factors affecting the turbine

- ◎ Loss in passage between turbine blades
- ◎ Exhaust loss
- ◎ Leakage
- ◎ Mechanical loss

Survey Result of Turbine Efficiency Decrease Factors (before implementing measures)


🟧 : Item corresponding to the "heat cycle condition"

🟩 : Item corresponding to the factors for "main turbine"

Internal efficiency decrease (increased amount of steam leakage, deposition of scale)

Performance decrease of high-pressure heater

Increased amount of steam flow for BFPT

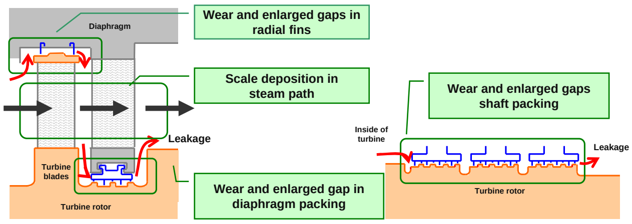
Leakage

Internal Efficiency Decrease Factors in Main Turbine

The figure below is to explain schematically efficiency decrease factors identified for the unit. A major factor among these was identified as wear over years in materials used to seal off steam flow inside the turbine.

◎ **Loss in steam path between turbine blades**

◎ **Leakage**



Wear and enlarged gaps in radial fins

Scale deposition in steam path

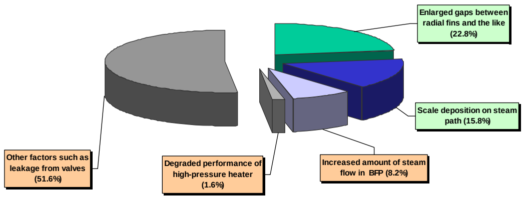
Wear and enlarged gap in diaphragm packing

Wear and enlarged gaps shaft packing

Analysis of Turbine Efficiency Decrease Factors

The graph below shows distribution of efficiency decrease based on comparisons between the result of the survey and the efficiency as indicated in the initial data collected at the unit's start of operation.
To summarize the result, roughly 60% of total decrease could be attributed to the factors corresponding to the "heat cycle condition," and roughly the remaining 40%, to the "main part of the turbine."

Decrease attributable to the main part of turbine: 38.6% (roughly 40% of total)

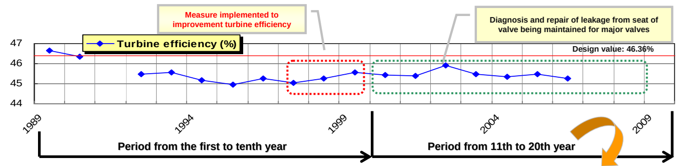


Decrease attributable to heat cycle condition: 61.4% (roughly 60% of total)

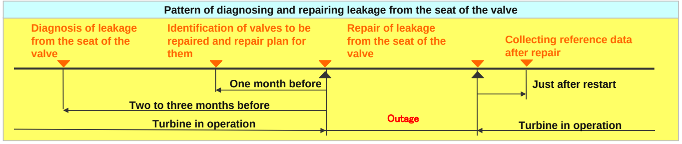
Result of Measures

Efficiency decrease factor			Description of measure	Evaluation of measure		Influencing degree	
Changed performance of main turbine	High-pressure	1. Enlargement of gaps between radial fins	Adjustment for proper gap(s) through parts replacement	+0.05%	0.42%	21.0%	100%
		2. Enlargement of gap in diaphragm		+0.10%			
		3. Enlargement of gap in shaft packing		+0.23%			
		4. Scale deposition on steam path	Removing scales	+0.04%			
	Medium-pressure	1. Enlargement of gaps between radial fins	Adjustment for proper gap(s) through parts replacement	+0.10%	0.21%	10.5%	
		2. Enlargement of gap in diaphragm		+0.06%			
		3. Enlargement of gap in shaft packing		+0.02%			
		4. Scale deposition on steam path	Removing scales	+0.03%			
	Low-pressure	1. Scale deposition on steam path	Removing scales	+0.03%	+0.03%	1.5%	
Changed performance of high-pressure heater		1. Increeased terminal temperature difference (TD)	Water jet washing of interior of tubes	+0.04%	0.04%	2.0%	
Increased amount of steam for driving BFP turbine		1. Raised feed water pressure	Chemical cleaning of boiler	-0.01%	0.13%	7.5%	
		2. Decreased feed water volume	Improvement of water chemistry	+0.14%			
Others		1. Internal leak in water-steam system	Investigation and repair of leaking valves	+1.15%	+1.15%	57.5%	

Measures for Turbine Efficiency



This pattern is maintained and carried out with periodic inspections (in two-year cycles) to maintain efficiency.


Pattern of diagnosing and repairing leakage from the seat of the valve

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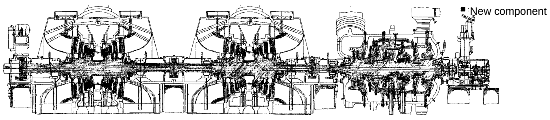
Effect of renovation of turbine main component (Example)



Major new component

1) HP·IP rotor
2) HP·IP inner casing
3) LP rotor

Turbine	Item	Efficiency improvement (relative value)
HP·IP	Control stage	0.2 %
	New design blade	0.7 %
	New seal	0.2 %
	Recovery	0.7 %
LP	New design blade	1.2 %
	Recovery	0.5 %
Total		3.5 %

Thank You !