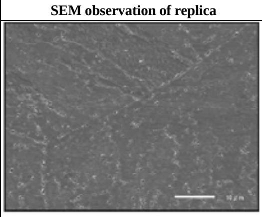
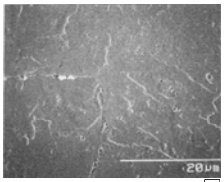
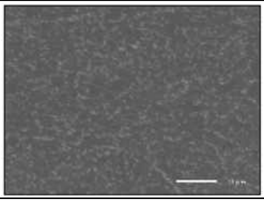
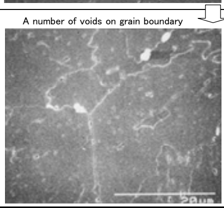
Creep void observation results (Singrauli #6)

Components	Location		Observed region	SEM (Scanning Electron Microscope observation) Creep void damage
RH outlet header	Right	Circumferential weld	Fine grain HAZ	No void
			Coarse grain HAZ	No void
			Weld metal	No void
Main steam pipe	Left	Circumferential weld (near the stop valve) extrados side	Fine grain HAZ	No void
			Coarse grain HAZ	No void
			Weld metal	No void

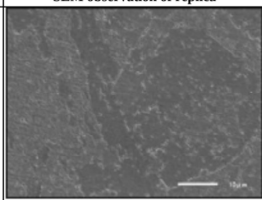
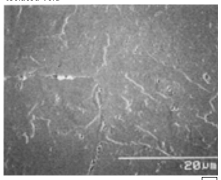
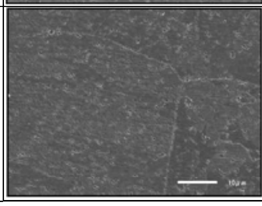
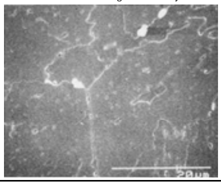
Creep void observation results (Unchahar #2)

Components	Location		Observed region	SEM (Scanning Electron Microscope observation) Ceep void damage
Final SH outlet header	Rightside of header	Circumferential weld	Fine grain HAZ	No void
			Coarse grain HAZ	No void
			Weld metal	No void
Main steam pipe	Right	Circumferential weld (near the stop valve)	Fine grain HAZ	No void
			Coarse grain HAZ	No void
			Weld metal	No void

Creep void observation results (Singrauli #6)

		SEM observation of replica	Reference Picture
RH outlet header left (SA 335 P22)	Coarse grain HAZ		Isolated void 
Main steam pipe left (SA 335 P22)	Coarse grain HAZ		A number of voids on grain boundary 

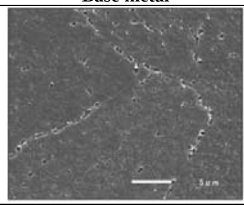
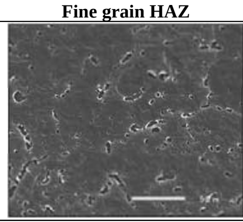
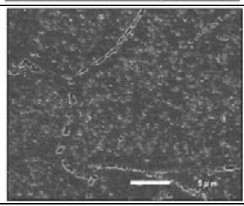
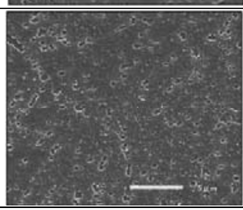
Creep void observation results (Unchahar #2)

		SEM observation of replica	Reference Picture
Final SH outlet header (SA 335 P22)	Base metal		Isolated void 
Main steam pipe right (SA 335 P22)	Base metal		A number of voids on grain boundary 

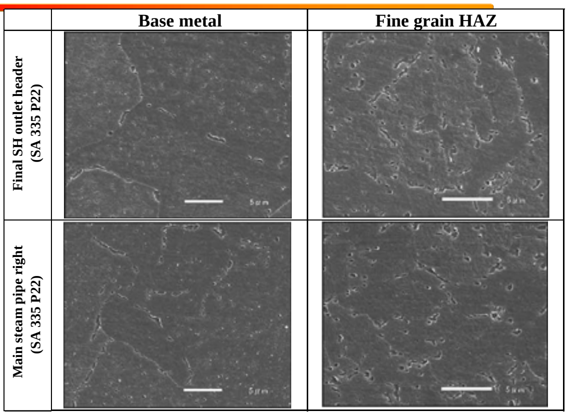
Average diameter and volume fraction of grain boundary precipitates

Observation item		Microstructure	Carbide precipitation	Precipitates free band width along grain boundary	Creep void grade	Average diameter of grain boundary precipitates	Average volume fraction of grain boundary precipitates
Observation method		Optical microscope	TEM (Transmission Electron Microscope)		SEM (Scanning Electron Microscope)		
Observed target		Micro crack and microstructural degradation	Morphology and distribution of precipitates	Quantitative evaluation of precipitates free band width	Micro crack and creep void	Quantitative evaluation of grain boundary precipitates	Quantitative evaluation of grain boundary precipitates
Observed magnification		×500 ×1000	×2000 ×10000	×2000	×500 ×2000	×3000 (Base metal) ×4000 (Fine grain HAZ)	
Observed area	Base metal	○	○	○		○	○
	Intercritical zone	○					
	Fine grain HAZ	○	○			○	○
	Coarse grain HAZ	○	○		○		
	Weld metal	○	○				

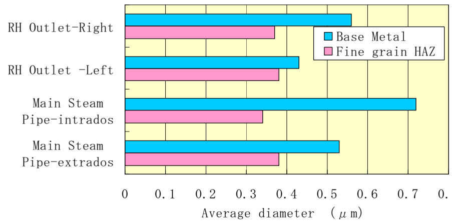
Average diameter and volume fraction of grain boundary precipitates （Singrauli #6)

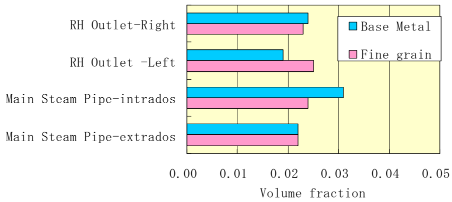
	Base metal	Fine grain HAZ
RH outlet header left (SA 335 P22)		
Main steam pipe left (SA 335 P22)		

Average diameter and volume fraction of grain boundary precipitates (Unchahar #2)

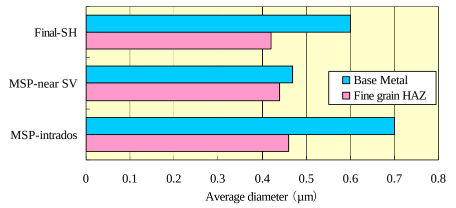


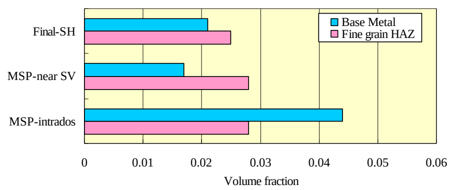
Average diameter and volume fraction of grain boundary precipitates （Singrauli #6)



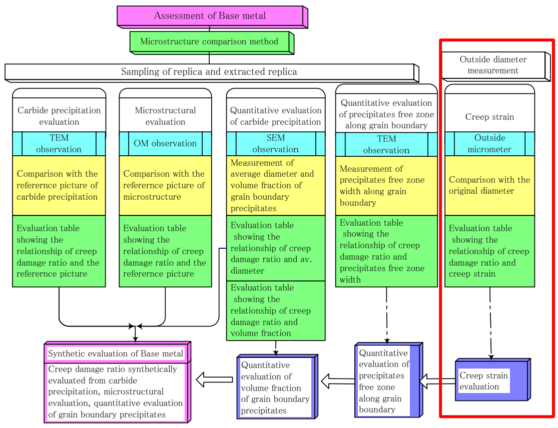


Average diameter and volume fraction of grain boundary precipitates (Unchahara #2)

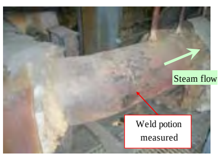




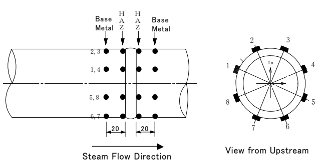
Microstructural comparison method



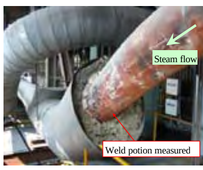
Creep strain evaluation by OD measurement (Singrauli #6)



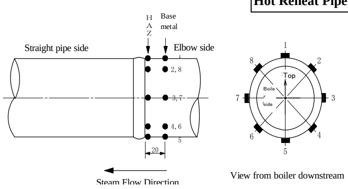
Components	(Averaged measured value-Designed OD) /Designed OD (%)
Platen SH Outlet Header-Left	0.10
De-Superheater-Left	0.94
De-Superheater-Right	0.55
RH Outlet Header-Left	0.37
RH Outlet Header-Right	0.52
Main Steam Pipe-Left	0.08



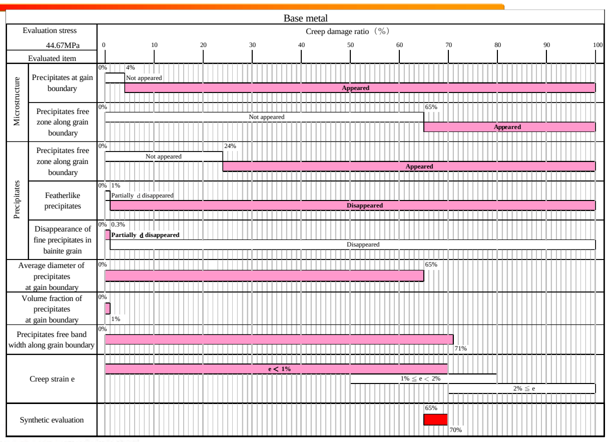
Creep strain evaluation by OD measurement (Unchahar #2)



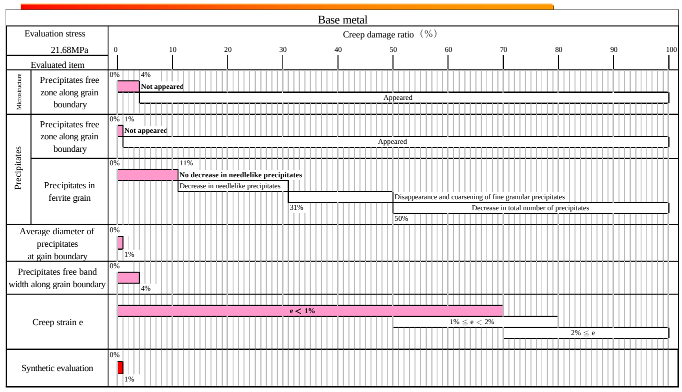
Components	(Averaged measured value-Designed OD) /Designed OD (%)
Final SH Outlet Header	0.74
De-Superheater-Left	0.44
De-Superheater-Right	0.46
RH Outlet Header at left side	0.20
RH Outlet Header at right	0.57
Main Steam Pipe-Right	—
Hot Reheat Pipe-Right	0.01



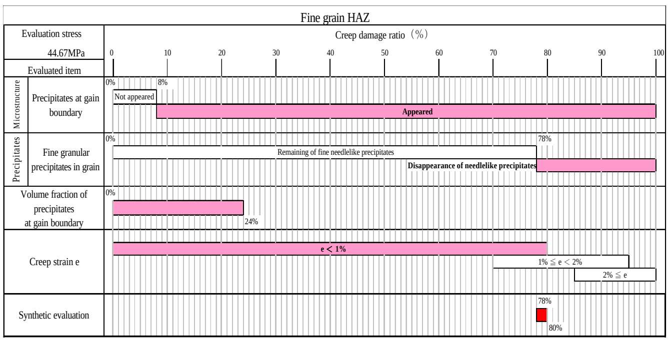
Synthetic evaluation (Base metal of MSP) Singrauli #6



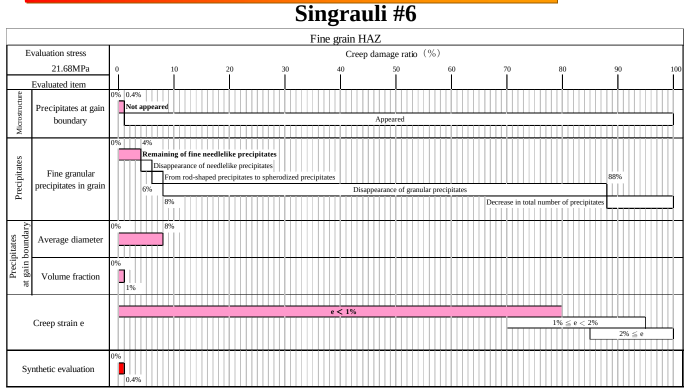
Synthetic evaluation (Base metal of RH header left) Singrauli #6



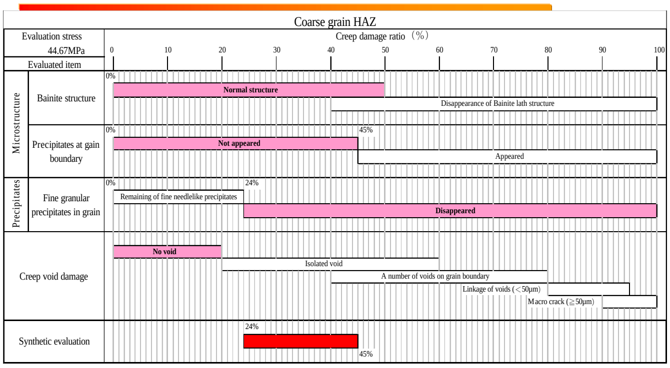
Synthetic evaluation (Fine grain HAZ of MSP) Singrauli #6



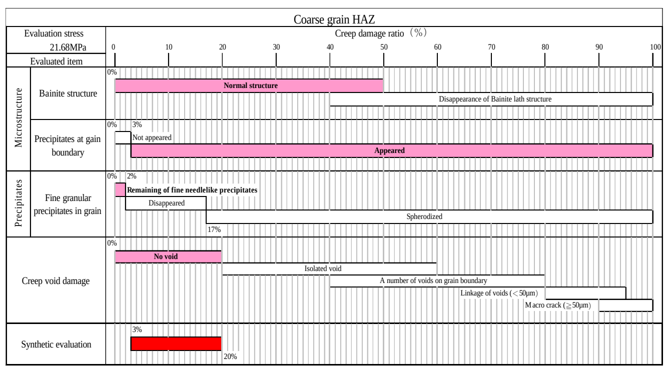
Synthetic evaluation (Fine grain HAZ of RH header left) Singrauli #6



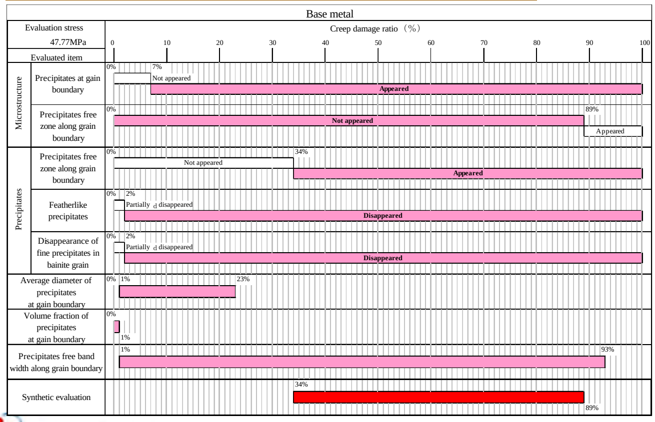
Synthetic evaluation (Coarse grain HAZ of MSP) Singrauli #6



Synthetic evaluation (Coarse grain HAZ of RH header left) Singrauli #6



Synthetic evaluation (Base metal of MSP) Unchahar #2



Residual life assessment results of pipes (Singrauli #6)

Components	Location	Material	Region	Evaluation results: Creep life consumption ratio (%)	Residual life (hr)	Evaluated residual life (h)
Platen-SH OutletHeader-Left	Base Metal at left side	SA 335 P12	Base Metal	9 ～ 16	903,000 ～ 1,739,000	140,000
	circumferential weld at left side		Base Metal	9 ～ 16	903,000 ～ 1,739,000	
			Fine grain HAZ	34 ～ 38	281,000 ～ 334,000	
			Coarse grain HAZ	0 ～ 18	784,000 <	
De-Suerheater-Left	Circumferential weld	SA 335 P12	Base Metal	8 ～ 16	903,000 ～ 1,978,000	100,000
			Fine grain HAZ	0 ～ 19	733,000 <	
			Coarse grain HAZ	19 ～ 45	210,000 ～ 733,000	
De-Suerheater-Right	Circumferential weld	SA 335 P12	Base Metal	0 ～ 1	17,028,000 <	100,000
			Fine grain HAZ	0 ～ 19	733,000 <	
			Coarse grain HAZ	19 ～ 45	210,000 ～ 733,000	
RH Outlet Header-Left	Circumferential weld at left side	SA 335 P22	Base Metal	0 ～ 1	17,028,000 <	340,000
			Fine grain HAZ	0 ～ 0.4	42,828,000 <	
			Coarse grain HAZ	3 ～ 20	688,000 ～ 5,561,000	
RH Outlet Header-Right	Circumferential weld at right side	SA 335 P22	Base Metal	4 ～ 6	2,695,000 ～ 4,128,000	1,300,000
			Fine grain HAZ	0 ～ 0.4	42,828,000 <	
			Coarse grain HAZ	2 ～ 3	5,561,000 ～ 8,428,000	
Main Steam Pipe-Left	Circumferential weld,extrados	SA 335 P22	Base Metal	65 ～ 70	74,000 ～ 93,000	37,000
			Fine grain HAZ	8 ～ 21	647,000 ～ 1,978,000	
			Coarse grain HAZ	0 ～ 20	688,000 <	
Main Steam Pipe-Left	Circumferential weld,intrados	SA 335 P22	Base Metal	65 ～ 70	74,000 ～ 93,000	21,000
			Fine grain HAZ	78 ～ 80	43,000 ～ 49,000	
			Coarse grain HAZ	24 ～ 45	210,000 ～ 545,000	

(Operation hours／Creep life consumption ratio) × 100− operation hours

Residual life assessment results of pipes (Unchahar #2)

Components	Location	Material	Region	Evaluation results: Creep life consumption ratio (%)	Residual life (hr)	Evaluated residual life (h)
Final SH Outlet Header	Circumferential weld at right side	SA 335 P22	Base Metal	4	3,338,000	270,000
			Fine grain HAZ	1 ～ 4	3,338,000 ～ 13,771,000	
			Coarse grain HAZ	9 ～ 20	556,000 ～ 1,406,000	
De-Suerheater-Left	Circumferential weld	SA 335 P12	Base Metal	16 ～ 31	310,000 ～ 730,000	96,000
			Coarse grain HAZ	0 ～ 42	192,000 <	
De-Suerheater-Right	Circumferential weld	SA 335 P12	Base Metal	16 ～ 31	310,000 ～ 730,000	96,000
			Coarse grain HAZ	0 ～ 42	192,000 <	
RH Outlet Header	Circumferential weld at left side	SA 335 P22	Base Metal	2 ～ 6	2,179,000 ～ 6,816,000	700,000
			Fine grain HAZ	7 ～ 9	1,406,000 ～ 1,848,000	
			Coarse grain HAZ	3 ～ 6	2,179,000 ～ 4,498,000	
	Circumferential weld at right side,top	SA 335 P22	Base Metal	2 ～ 6	2,179,000 ～ 6,816,000	270,000
			Fine grain HAZ	9 ～ 14	854,000 ～ 1,406,000	
			Coarse grain HAZ	6 ～ 20	556,000 ～ 2,179,000	
	Circumferential weld at right side,front	SA 335 P22	Base Metal	2	6,816,000	270,000
			Fine grain HAZ	9 ～ 14	854,000 ～ 1,406,000	
			Coarse grain HAZ	6 ～ 20	556,000 < 2,179,000	
Main Steam Pipe-Right	Circumferential weld,intrados	SA 335 P22	(Base Metal)※	(34) ～ (74)	(49,000) ～ (270,000)	69,000
			(Fine grain HAZ)※	(13) ～ (42)	(192,000) ～ (931,000)	
			Coarse grain HAZ	32 ～ 50	139,000 ～ 296,000	
	Circumferential weld,near the stop valve	SA 335 P22	(Base Metal)※	(34) ～ (89)	(17,000) ～ (270,000)	270,000
			(Fine grain HAZ)※	(13) ～ (42)	(192,000) ～ (931,000)	
			Coarse grain HAZ	0 ～ 20	556,000 <	
Hot Reheat Pipe-Right	Circumferential weld	SA 335 P22	Base Metal	6 ～ 16	730,000 ～ 2,179,000	240,000
			Fine grain HAZ	19 ～ 22	493,000 ～ 593,000	
			Coarse grain HAZ	14 ～ 20	556,000 ～ 854,000	

※: : Regarded as reference for OD measurement was not carried out.

Summary of inspection results

Inspection item	Inspection results
VT	･Water wall, SH, RH panel was visually inspected from the view point of erosion, attrition and distortion of panel arrangement.
THICKNESS MEASUREMENT	･Thickness of tubes was measured mainly at erosion area for water wall, SH, RH. ･Measured thickness was discussed in terms of thickness management criteria.
SUS SCALE DEPOSITION INSPECTION	･SUS scale deposition was inspected at bottom bend portion ub SH and RH panel. ･On the whole SUS scale deposition was not significant with 15% fullness at most.
SAMPLE TUBE INSPECTION	･SH, RH sample tubes were inspected for the oxide scale adhesion condition microstructure hardness and so on.
CREEP RUPTURE TEST	･As a result of creep rupture test for the base metal and the weld joint of SH and RH, min. evaluated residual life was 35,000 hours for the weld joint for Final SH tube in Unchahar #2.

RECOMMENDATION (Boiler RLA)

1. **Singrauli #6** : Implement RLA of main steam pipes including outer diameter measurement and replica sampling before the estimated residual life of 21,000 hrs. Coarse grain HAZ region is the most critical region indicated no creep damage with no creep void. However, in base metal region the estimated residual life for left MS pipe is 21,000 hrs with a little microstructural degradation.
2. **Unchahar #2**:
   For main steam Pipe, the estimated residual life of coarse grain HAZ region is 69,000 hrs. 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. For accurate estimation of residual life, creep strain (OD) measurement along with microstructure is recommended to be carried out preferably within 8,000 hrs or practically at the earliest opportunity.

RECOMMENDATION (Boiler RLA)

3. **Criteria for tube replacement**: In Japan alternative thickness criteria for more precise judgment of safety margin, such as tsr (thickness shell required) method is used. NTPC can also consider the use of such criteria in consultation with OEM rather than the method of thickness decrease ratio from design thickness.
4. **Scope of RLA**: Conduct RLA focusing or emphasizing on critical parts considering creep life after identification of critical parts, instead of all high temperature pressure parts, which NTPC focuses on currently.

RECOMMENDATION (Boiler RLA)

5. **New techniques**: Apply new techniques and equipments such as
   - SUS scale detection
   - TOFD
   - Advanced metallurgical observation technique using SEM,TEM
   - Precise surface polishing treatment for replica.
6. **Advanced training**: Conduct advanced training of new techniques for NTPC inspection engineers in Japan.

Manual & Guideline

Boiler RLA

Manual & Guideline related to Boiler RLA

✓ **2-1-3) Boiler RLA Manual**

Boiler RLA Manual	**Thickness measurement**
	SUS scale deposition inspection
	PT(DPT)
	UT
	TOFD (Time of Flight Diffraction)
	Sample tube inspection
	Sampling of replica and extracted replica
	Boiler remaining life assessment
	Creep rupture test

✓ **2-1-4) Data collection of new boiler for future RLA Guideline**

✓ **2-1-2) Techniques for boiler tube cleaning after cutting (before welding) Manual**

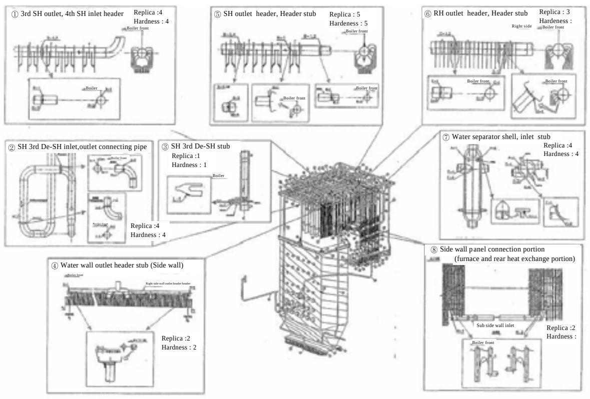
2-1-4) Data collection of new boiler for future RLA Guideline

Example of initial data sampling in new power plants

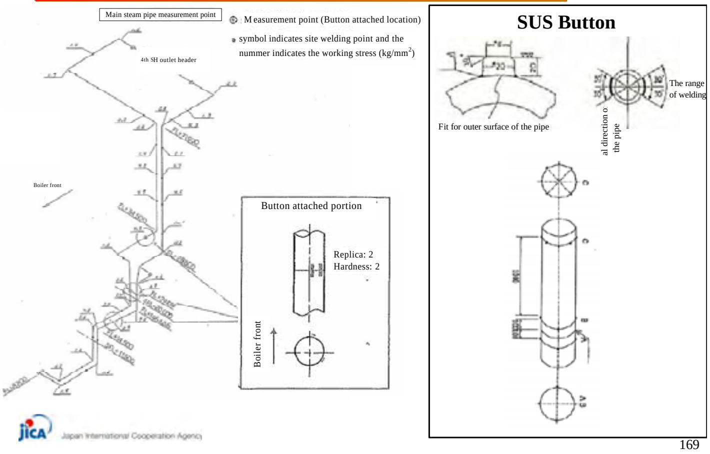
	Componetns	Replica sampling	Haredness measurement	Outside diameter measurement
Shell and header	Water separator	2	2	–
	SH outlet header	4	4	2
	RH outlet header	2	2	1
	3rd SH outlet header	2	2	1
	4th SH inlet header	2	2	1
	Water separator inlet stub	2	2	–
	Water wall outlet header stub (side wall)	2	2	2
	SH outlet header stub	1	1	1
	RH outlet header stub	1	1	1
Main pipe	Main steam pipe	8	8	4
	Hot reheat pipe	8	8	4
	Hot reheat pipe spherical Y piece	4	4	–
	High pressure turbine bypass pipe	1	1	1
Others	3rd SH De-SH outlet connecting pipe	2	2	1
	3rd SH De-SH inlet connecting pipe	2	2	1
	3rd SH De-SH stub	1	1	–
	Side wall panel connection portion (furnace and rear heat exchange portion)	2	2	2

Boiler tube : thickness measurement at constant points, reserved boiler tube for initial creep rupture data and so on.

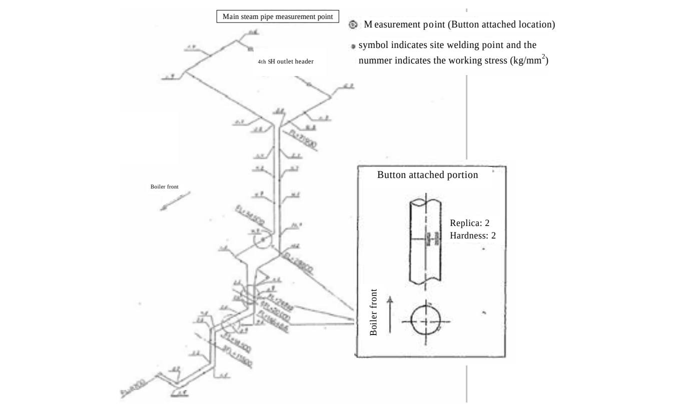
Example of measurement points for initial data



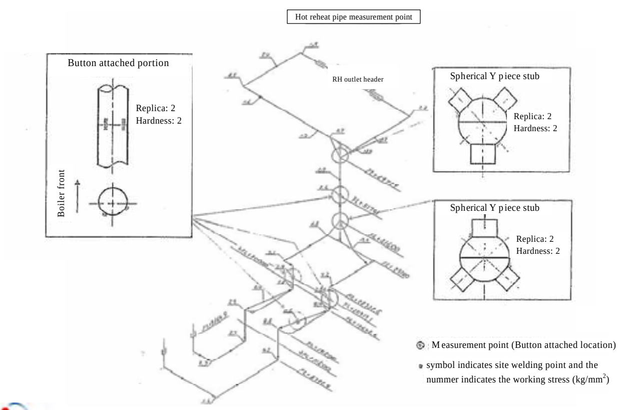
Example of measurement points for Main steam pipe



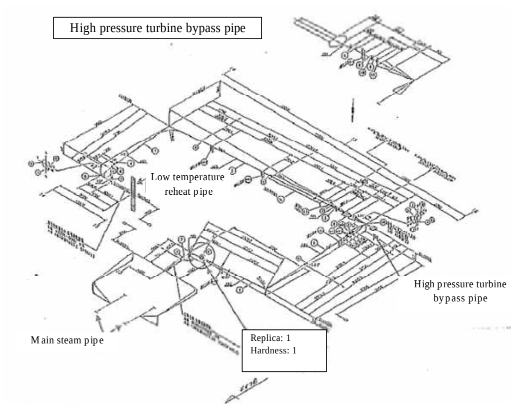
Measurement points for Main steam pipe



Measurement points for Hot reheat pipe

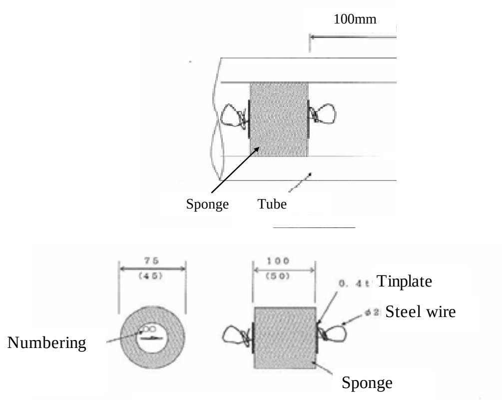


Measurement points for High pressure turbine bypass pipe



2-1-2) Techniques for boiler tube cleaning after cutting (before welding) Manual

Sponge image for prevention against foreign material mixing



5. 3) Kiken Yochi (KY) Meeting Manual

KYM (Kiken Yochi Meeting :danger prediction meeting)

【Scope】

This is applied to the meeting prior to working for workers to have the precaution against danger.

【General】

KYM is one of activities for safety work, predicting danger and setting the preventive measures. In general KYM consists of 4 steps that are grasping the current status, focusing on a few potential hazards by brainstorming, collecting the countermeasures by brainstorming, setting the objective to act focusing one or two countermeasures using KY board.

KYM (Kiken Yochi Meeting :danger prediction meeting)

【Procedure】

1st step :Understanding the current situation
(what kind of danger is hidden?)
Every KYM member talks about what kind of danger is hidden and its reason on KY board.

The person in charge of writing itemizes the each dangerous situation on the KY board.

2nd step :Pursuit of the essence (Identification of danger points)
Focusing on a few danger points which are considered as especially important ones.

KYM (Kiken Yochi Meeting :danger prediction meeting)

3rd step :Establishment of countermeasures
(what do you do in such a situation?)

Collecting the concrete countermeasures for the focused danger points, which are possible to be carried out.

The person in charge of writing itemizes the countermeasures to be collected on the KY board.

4th step :Setting the objective (we do this way)

Focusing on one or two important points from the countermeasures to be collected, determine the objective to act.

Chanting the objective to act with finger pointing by every member for recognition and confirmation.

KYM (Kiken Yochi Meeting :danger prediction meeting)

An example of KYM scene

An example of KY board

Date: Oct. 28	KY Meeting		
Work Name: Boiler RLA			
Leader Name	S. Nakashima	Number of Workers	8
Contact information	090-7611-0022(mobile)	Health check	Good
What kind of danger is hideen?		We act the followings	
Falling from high place		Wear safety belt	
Injured with grinding machine		Check the power switch on/off	
Falling over		Watch one' step	
Sucking dust	Hitting body	Put on dust mask	Ensure the safety of the surrounding
Attention at work :	Pay attention for congested work !		
Today's action targets :	Wear safety belt ! Roger !		

5. 4) Tool Box Meeting Manual

Tool Box Meeting

【Scope】
This is applied to the meeting prior to working for workers to have the precaution against danger.

【General】
TBM is the meeting held by workers to discuss the safety prior to working in the morning and in the afternoon.
The small unite of group that is 6 members or less discusses about the scope of work, the procedures and the point of safety working.

- ✓Confirming the scope of work and its procedure for the day.
- ✓The leader for the work guides the wok members to make a speech to grasps the work members thought.
- ✓ Summarizing the discussion results, determine the action objective.

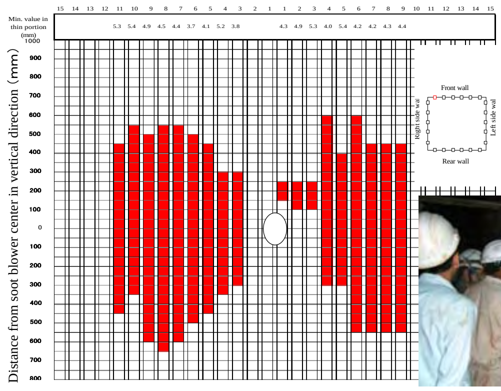
Tool Box Meeting

【Procedure 】
- ✓ Punctual TBM start by all work members
- ✓Discussion about the scope of work, the procedures and the points of safety working
- ✓Grasping the background behind the problems and danger for the work.
- ✓Discussion about the improvement plans for the problems and danger that is carried out with active and sincere participation by every worker. Determination of the objective and the items for action including 5W,1H.

Summary of Boiler RLA Demonstration

Inspection item	Japanese practice / Demo at sites	Recommendation
VT	Erosion and attrition of tubes and disorder of panel arrangement were inspected.	?
Thickness measurement	·Use of the original calibration block ·Acceptance criteria ·Grasping thickness decrease region	Study of alternative standard criteria for tube replacement such as tsr (Thickness Shell Required) was recommended.
SUS scale deposition inspection	The detection technique making use of the principle of induction is applied from the view point of efficiency and safety, besides conventional ?-ray method.	For implementation of new RLA technology, training in Japan was carried out.
Sample tube inspection	·Tube: Appearance, dimension, Hardness, Microstructure ·Scale: Appearance, Volume, Thickness, Composition	?
Creep rupture test	Residual life was evaluated by parameter method with a thousand hours creep rupture tests.	For implementation of precise RLA by creep rupture test, training in Japan was carried out.

Thickness measurement results of WW (Singrauli #6)



Summary of Boiler RLA Demonstration

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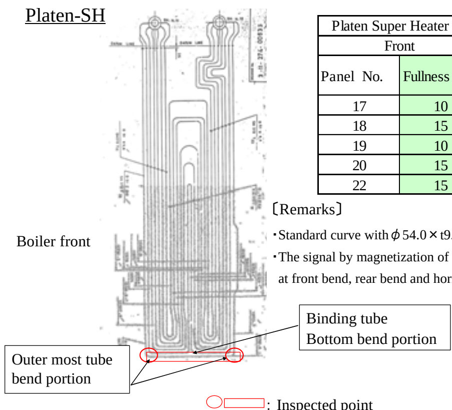
SUS scale deposition inspection results (Unchahar #2)

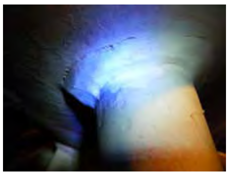


Platen Super Heater (Outermost tube bend portion)			
Front		Rear	
Panel No.	Fullness (%)	Panel No.	Fullness (%)
17	10	27	15
18	15		
19	10		
20	15		
22	15		

〔Remarks〕
- ·Standard curve with φ54.0×t9.5 was used for evaluation of fullness.
- ·The signal by magnetization of tube material with heat was recognized at front bend, rear bend and horizontal portion.

Summary of Boiler RLA Demonstration

Inspection item	Japanese practice / Demo at sites	Recommendation
DPT	・Same procedure as NTPC	・ More careful surface treatment and wiping out the penetrant


Summary of Boiler RLA Demonstration

Inspection item	Japanese practice / Demo at sites	Recommendation
DPT	・Same procedure as NTPC	・ More careful surface treatment and wiping out the penetrant
UT & TOFD (Time of flight diffraction)	Applied to the crack detection for high temperature header and pipe weld.	For implementation of new RLA technology, training in Japan was carried out.


Summary of Boiler RLA Demonstration

Inspection item	Japanese practice / Demo at sites	Recommendation
DPT	・Same procedure as NTPC	・ More careful surface treatment and wiping out the penetrant
UT & TOFD (Time of flight diffraction)	Applied to the crack detection for high temperature header and pipe weld.	For implementation of new RLA technology, training in Japan was carried out.
Boiler remaining life assessment by replica inspection	Using high magnification electron microscope, residual life was evaluated quantitatively.	・Implement RLA including OD measurement and replica before reaching evaluated life. ・For implementation of new RLA technology, training in Japan was carried out.

Summary of Boiler RLA Demonstration


General matter related to RLA	RLA is carried out focusing on the critical components.	Focusing or emphasizing on critical parts by considering creep design life from the view point of efficient inspection.
Safety	・KY（foreseeing the hazard) meeting was carried out prior to work. ・Safety shoes, safety globes, safety glasses, safety belt, spats and dust proof mask were worn during boiler inspection.	Dissemination of safety activity such as KY meeting, protective suite, indication of unsafe location is essential.

Japanese Boiler Inspection (Water wall, Furnace tube)

Water wall tube / Furnace tube

Inspection measure	Portion	Deterioration factors	Inspection interval
VT	General appearance	Burn out, distortion, swelling, ash cut, steam cut etc.	Periodic inspection (every 2years)
	General appearance building scaffolding by the burner level		Periodic inspection (every 4years)
	General appearance building scaffolding by the top of furnace at the necessary interval set.		Setting necessary interval.
VT(Endoscopy)	Water tube inside	Corrosion	Setting necessary interval.
Chemical analysis of deposit	Outside deposit	Corrosion	Periodic inspection (every 2years)
PT	Representative weld portion of fin edge	Creep-fatigue	In case of elongation of periodic inspection interval (max. 2years).
	Representative attached metal weld portion	Creep-fatigue	After 80,000 hours operation, depending on necessity
Thickness measurement	Fixed points of tube. Representative portion of ash cut and steam cut with no countermeasure	Thinning with aging. Ash cut and steam cut.	Continuous measurement depending on boiler structure and type. Erosion countermeasure necessary, in case of elongation of periodic inspection interval (max. 2years). .
Sampling tube examination	Water wall tube in high heat load portion	Scale deposit	Setting necessary interval.
Residual life assessment	Water wall tube in high heat load portion	Creep	Judge from operation and design condition, depending on necessity.

Japanese Boiler Inspection (SH, RH, Eco tube)

SH, RH, Eco tubes

Inspection measure	Portion	Deterioration factors	Inspection interval
VT	General appearance	Leak, crack, corrosion, erosion	Periodic inspection (every 2years)
Chemical analysis of deposit	Outside deposit	High temperature corrosion	Depending on necessity
Thickness measurement	Representative points of SH, RH, Eco tubes with no countermeasures for erosion.	erosion	Periodic inspection (every 2years)
	High temperature corrosion portion and portion that tends to decrease in thickness	High temperature corrosion	Continuous measurement at constant points.
	Around soot blower	Ash cut and steam cut	Periodic inspection (every 2years)
	Attrition at cross over of tubes		Setting necessary interval.
PT	Representative weld portion of fin edge	Creep fatigue	In case of elongation of periodic inspection interval (max. 2years).
	Representative dissimilar weld portion with no use of Inconel weld metal.	Creep fatigue and creep	Setting necessary interval.
	Representative attached metal weld portion	Creep fatigue	After 80,000 hours operation, depending on necessity
Sampling tube examination	Austenitic steel tube (Austenitic steal used in steam temperature 540℃ or more and metal temperature 620℃ or more).	SUS scale deposition	In case of elongation of periodic inspection interval (max. 2years).
?-ray inspection etc.	Bottom bend potion of austenitic steel tube	SUS scale deposition	Depending on necessity
Residual life assessment	Low alloy steel used in steam temperature 540℃ or more.	Creep	Judge from operation and design condition, depending on necessity.

Japanese Boiler Inspection (Steam drum, water drum)

Steam drum, Water drum

Inspection measure	Portion	Deterioration factors	Inspection interval
VT	・Drum inside with water steam separator equipments detached.	Deposit	Periodic inspection (every 2years)*
		Corrosion	
		Erosion	
Chemical analysis		Deposit	
DPT	・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

*If the weld of stub inside is smooth finished, periodic inspection every 4years

Desuper

Inspection measure	Portion	Deterioration factors	Inspection interval
Overhaul VT	Nozzle, Mixing chamber	Thermal fatigue, abrasion	Setting necessary interval.

Japanese Boiler Inspection (Header (1))

Header (Water wall header, Evaporator header, Economizer header, SH header, RH header)

Inspection measure	Portion	Deterioration factors	Inspection interval
VT	General appearance	Erosion	Periodic inspection
		Corrosion	
		Cracking	
		Leak from weld part	
VT (Endoscope)	Ligament of Furnace header, Economizer header, SH header and RH header inside (including drain and bent tube portion).	Low cycle fatigue	Include in the periodic inspection plan systematically
	Inside of Furnace header, SH header and RH header inside	Corrosion by deteriorated water condition and dead drain during outage	
	Bottom inside of Furnace headers, Economizer headers	Deposition of sludge and initiation of corrosion fatigue crack	
	Final SH header and Final RH header	Exfoliation of steam oxide scale of header inside	
	Representative 2 or more headers inside	Low cycle fatigue Erosion	Periodic inspection (every 4years)
Chemical analysis of deposit		Deposition	
	Bottom inside of Furnace headers, Economizer headers	Deposition of sludge and initiation of corrosion fatigue crack	Include in the periodic inspection plan systematically
VT, Dimension measurement of corrosion	Stub outside of Economizer header	Low temperature corrosion	
Thickness measurement	Stub tubes of Final SH header and Final RH header	Thinning by high temperature corrosion	

Japanese Boiler Inspection (Header (2))

Header (Water wall header, Evaporator header, Economizer header, SH header, RH header)

Inspection measure	Portion	Deterioration factors	Inspection interval
DPT (MPI)	Representative stubs with no flexible structure and no rounding of weld end toe	Low cycle fatigue	Periodic inspection (every 2years)
	Stub weld of furnace headers, SH headers and RH headers.	Low cycle fatigue	Include in the periodic inspection plan systematically
	Support metal weld of furnace headers, SH headers and RH headers.	Low cycle fatigue	
	Representative header stub weld	Low cycle fatigue	After 80,000 hours operation (Precise
MPI	Representative header girth weld and seam weld	Creep	
Remaining life assessment	Most damaged header or pipe beyond 450℃ among furnace headers among SH headers or main steam pipe among RH headers or hot reheat pipe.	Creep	To extend periodical inspection interval 2 year to 4year after 100,000 hours operation
	High temperature Header and pipe	Creep	Include in the periodic inspection plan systematically, taking into consideration of operation hours, start and stop times and designed life.

Thank You !

Rotating Classifiers in Coal Mill

Manufacture in Japan

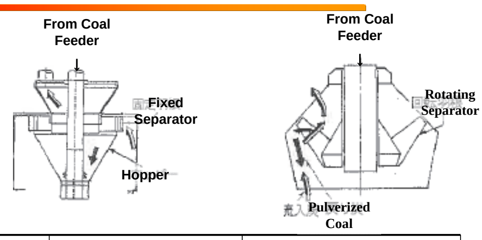
a) **Mitsubishi Heavy Industries, Ltd.: MHI**

b) **Hitachi Ltd.**

c) **IHI Corporation**

Rotating Classifiers in Coal Mill

Fixed and Rotating separator

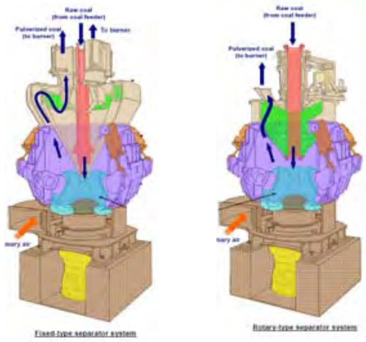


	Fixed Separator	Rotating Separator
Mechanism	- Classification by centrifugal force	- Forced classification by centrifugal force
Future	- Adjustment range of coal particular classification is limited	- Adjustment range of coal particular classification is wide

Rotating Classifiers in Coal Mill

1. MHI Type of Mill

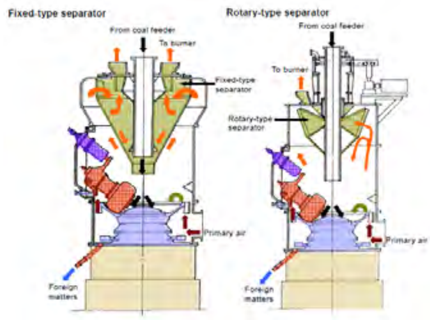
.



Rotating Classifiers in Coal Mill

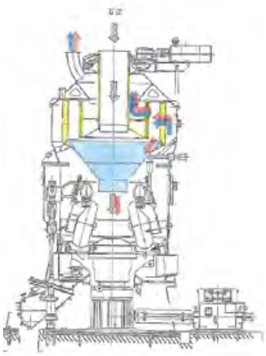
MHI Type of Mill

.



Rotating Classifiers in Coal Mill

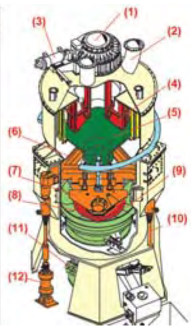
2. HITACH Type of Mill



Rotating Classifiers in Coal Mill

2. HITACH Type of Mill

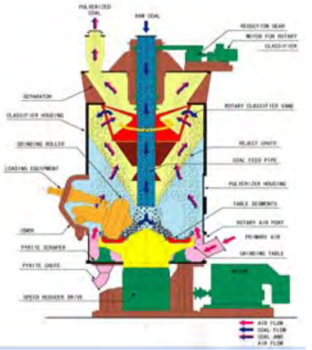
No.	Name of parts
(1)	COAL CHUTE
(2)	PULVERIZED COAL PIPE
(3)	CLASSIFIER MOTOR
(4)	ROTATING CLASSIFIER
(5)	HOPPER
(6)	PRESSURE FRAME
(7)	ROLLER BRAKET
(8)	ROLLER TIRE
(9)	GRINDING RING
(10)	LOADING ROD
(11)	GEAR BOX
(12)	HYDRAURIC CYLINDER
(13)	MAINTENANCE DOOR



Rotating Classifiers in Coal Mill

1. IHI Type of Mill

.



Slit

Air Heater

Heating Element

Type: DU, DUN, DNF, NF, FNC

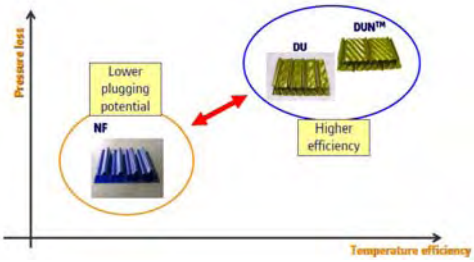
Material: Mild steel , CRLS, enamel coated steel

Thickness: 0.5, 0.6, 0.8, 1.0, 1.2mm

Height: 300 – 1500mm

Air Heater

Heating Element



Air Heater

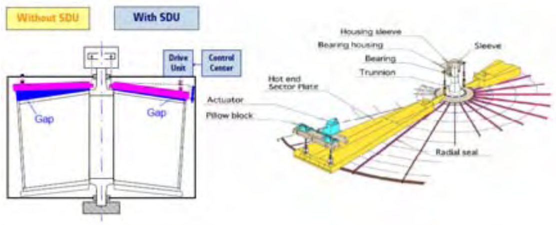
Heating Element

Element replacement record of power utilities in Japan as of 2004

Capacity	Type	Replacement Purpose
600MW	NF => DUN	Improvement of Temp. efficiency (Low temp layer : all)
700MW	DU => DUN	Maintained same efficiency (High temp layer : all)
700MW	DU => DUN	Ditto (High temp layer : all)
700MW	DU => DUN	Ditto (High temp layer : partial)
500MW	DU => DUN	Ditto (High temp layer : all)
700MW	DU => DUN	Ditto (High temp layer : partial)

Air Heater

Sector Plate Drive Unit (Automatic Leakage Control)



Control the gap at hot side radial seal by preset value at hot condition and reduce the leakage

Air Heater

Sensor Drive System track record in Japan

Major track record for Coal fired Power Plants

Capacity	Commercial Operation	Capacity	Commercial Operation
600MW	1985	500MW	1995
700MW	1989	700MW	2000
700MW	1991	700MW	2001
700MW	1992	500MW	2002
700MW	1993	600MW	2008
156MW	1994		

Air Heater

Sensor Drive System

1. One major accident occurred power utilities in Japan Last 10 years
   - Occurrence of an event

     AH trip (over load of AH drive motor)
   - Cause

     Sector Plate lower limit switch did not work

     Rotor tire and sector plate contacted and this caused over load of AH drive motor
   - Countermeasure

     Ammeter of AH drive motor is add at Central Control Room for monitoring purpose.

Condenser Assessment Methodology

Investigation method of cause for deviation of condenser pressure from the desired value

1. Increase in leak in quantity of air

The lowering of the vacuum degree occurs when leak in exceeds the extraction capacity of the vacuum pump.

Condenser Assessment Methodology

2. Decrease of cleanliness of tubes
With no increase in the leak in air amount and with the vacuum pump found to be normal, the cause of lowering of the vacuum degree is often caused by the lowering of cleanliness of the tubes.

3. Decrease of the cooling water volume
When the cooling water volume drops, an increase of temperature rise of cooling water side (ΔT), increase of CWP discharge pressure, decrease of condenser pressure loss and lowering of the condenser water chamber level occur, in case of no pump deterioration.

Condenser Assessment Methodology

4. Abnormality of the vacuum pump
When an abnormality of the vacuum pump is seen, conduct changeover testing with a spare unit and compare the respective air extraction amount and vacuum.

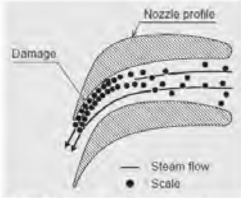
5. Increase of condenser heat load
The condenser pressure is estimated from condenser performance curve. the design heat load, on the condition that cooling water flow, tube cleanliness and heating surface, etc. are nearly design value. If the heat load increases more than the design value at a certain operation point, the condenser pressure increases.

TURBINE BLADE COATING (Boronize)

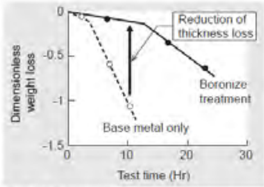
Characteristics of Boronize Treatment

- •Ensures boron alloy layer of hardness Hv 1200-1800
- •High hardness at high temperature and excellent hardwearing properties at high temperature
- •High break away resistance because of penetration intothe base metal
- •Thin layer (approximately 80 u m) of boron alloy

TURBINE BLADE COATING (Boronize)

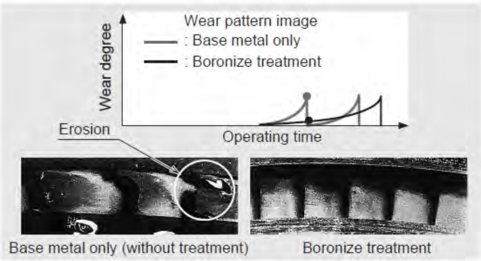


Mechanism of nozzle wear damage



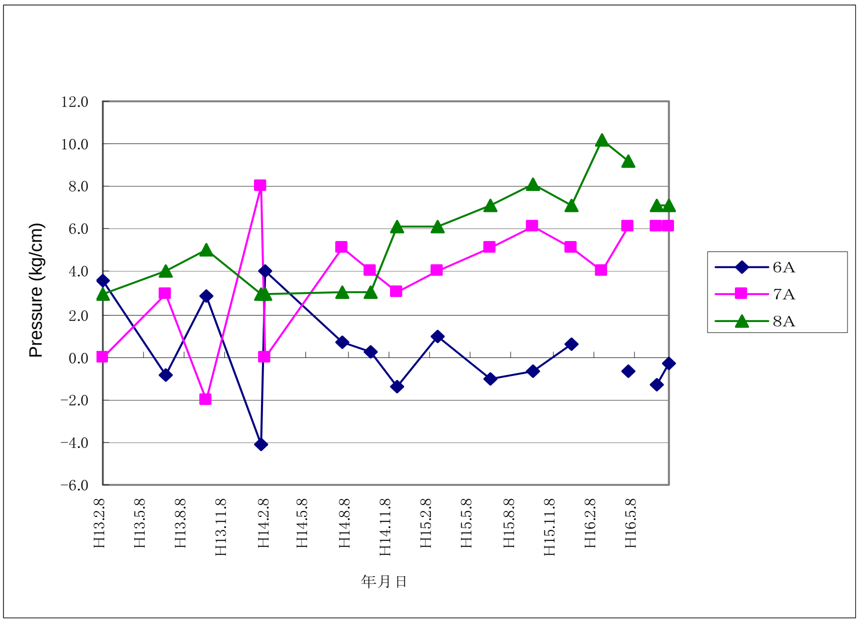
Solid particle erosion test compared

TURBINE BLADE COATING (Boronize)



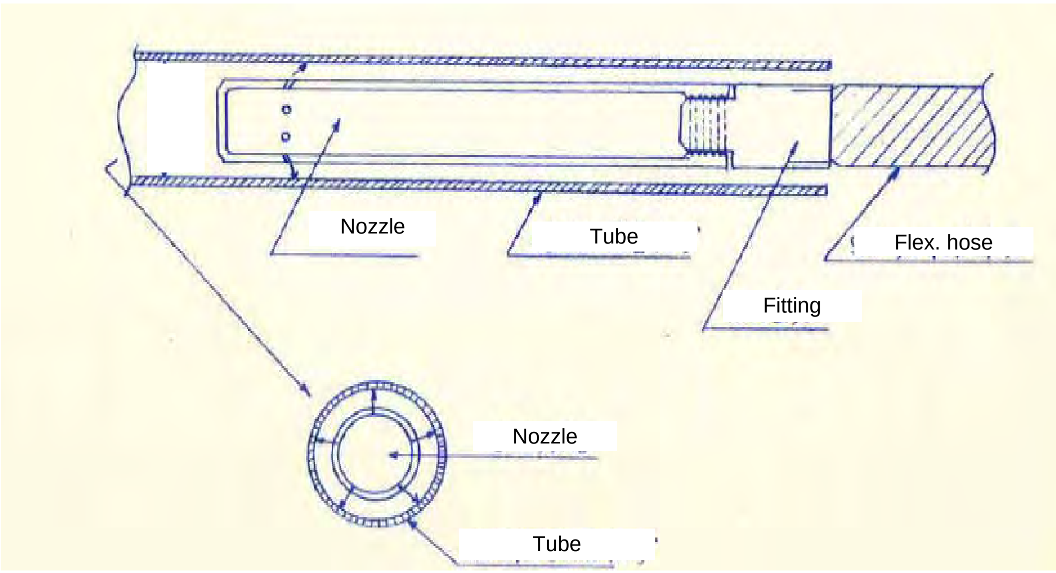
Appearance of speed-control stage nozzle

HP HTR PRESSURE LOSS (Example)



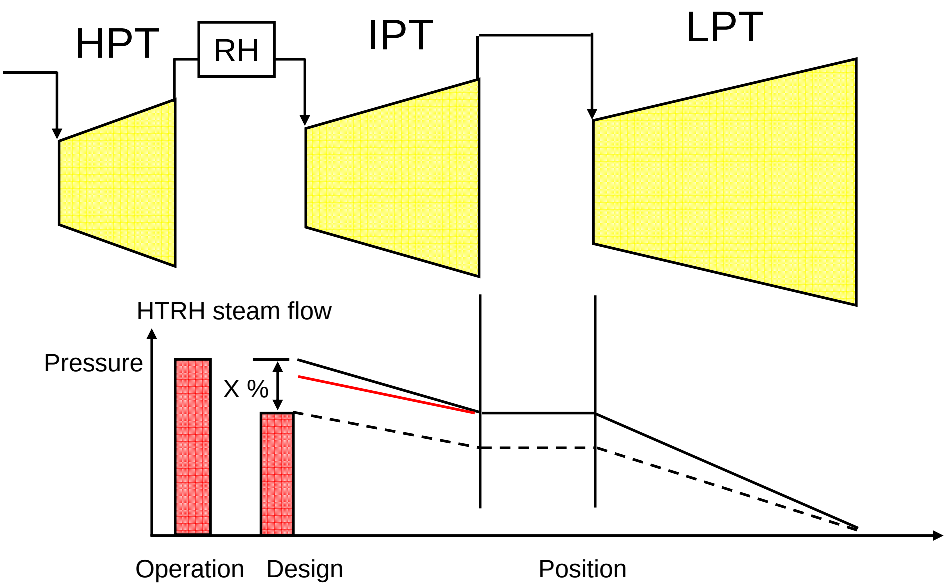
Japan International Cooperation Agency

HP HTR TUBE CLEANING (Example)



Japan International Cooperation Agency

Turbine HTRH flow vs pressure



1. Object Plant
   Singrauli #6 unit of NTPC in India.

2. Object of Test
   The unit was operated using 2 vacuum pumps (from 4～5 Years), deterioration of the vacuum (by about 10 mmHg) had been observed by operation using 2 vacuum pump. The air leak-in rate at that time under 2 pumps operation was 120 kg/ hour.
   From this reason, the leak buster tests were executed for the purpose of identifying the position, which corresponded to the air leaking abnormally into the unit.

3. Test Result
   The 130 positions in vacuum line were investigated for this time and resulted in identifying the positions corresponding to about 109 kg/hour of leaks into the unit. Among them, the major position for leak into the unit was the packing gland of BFP-T A & B. (Refer to the attached check list for details.)

No.	Helium test position	Air leak rate [Kg/h]	Detection No.
1	A BFP-T gland sealing portion (Rear)	49.3	Photo No.11
2	B BFP-T gland sealing portion (Rear)	23.5	Photo No.12
3	LP turbine gland sealing portion (Packingland and Bellow flange)	13.3	Photo No.1～5
4	HP Flush tank , Flush box-1 and Drain flush Tank B	12.3	Photo No.6～10
5	Others	14.6	
	Total	**113.0**	

4. Test Period
   Aug. 6. 2009 – Aug. 10. 2009

	Aug. 6	Aug. 7	Aug. 8	Aug. 9	Aug. 10
1. Preparation for test Equipment	▬	▬			▬
2. Verification of VP air extraction rate				▬	
3. Injection test		▬	▬	▬	▬
4. Investigation of air-leak points		▬	▬	▬	▬
5. Report and Meeting				▬	▬

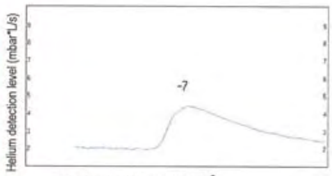
Measured by : Kawashima, Sato, Iriki and Hirose

Air leak detection photos at leak buster test

Photo-1: LP turbine packingland Generator side (Lower/Left)

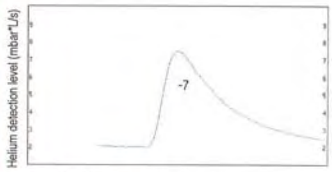

Maximum value: 5.82×10^{-7}
Approx. air leak-in rate : 1.5 kg/h

Photo-2: LP turbine packingland Turbine side (Upper/Left)

Maximum value: 4.40×10^{-7}
Approx. air leak-in rate : 1.0 kg/h

Photo-3: LP turbine packingland Turbine side (Lower/Left)

Maximum value: 7.46×10^{-7}
Approx. air leak-in rate : 2.2 kg/h

Attachment－1

NTPC Singrauli #6
Helium reaction curve

DATE : Aug. 10. 2009

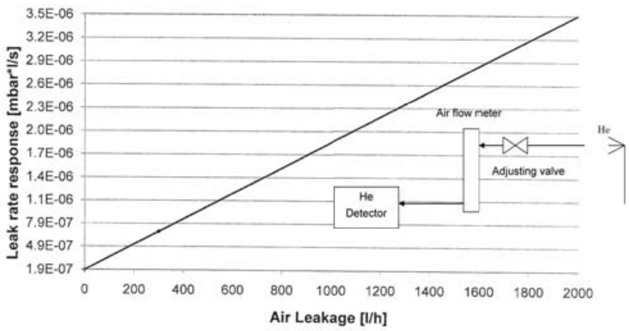
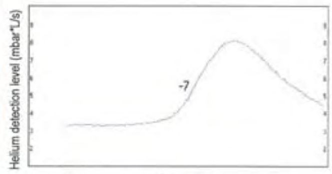
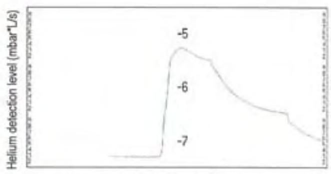


Photo-10: Drain flash tank-B (Connection pipe)

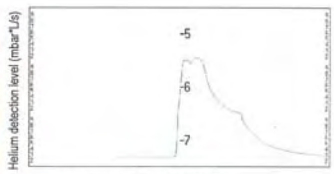
Maximum value: 8.14×10^{-7}
Approx. air leak-in rate : 2.9 kg/h

Photo-11: BFPT-A packingland

Maximum value: 3.17×10^{-5}
Approx. air leak-in rate : 49.3 kg/h

Photo-12: BFPT-B packingland

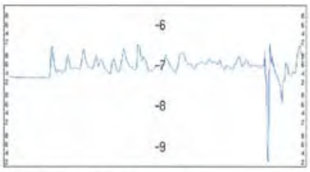



Maximum value: 1.52×10^{-5}
Approx. air leak-in rate : 23.5 kg/h

Photo-16: BFPT-B Horizontal flahge of rear casing (Right)

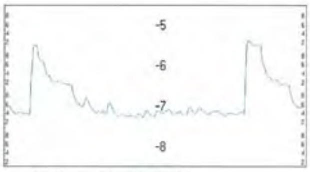
Maximum value: 6.91 x 10^{-7}
Approx. air leak-in rate : 1.8 kg/h

Photo-17: A-Vacuumpump grand seal (coupling side)



Maximum value: 1.27 x 10^{-6}
Approx. air leak-in rate : 0.2 kg/h

Photo-18: A-Vacuumpump grand seal (uncoupling side)



Maximum value: 2.18 x 10^{-5}
Approx. air leak-in rate : 3.5 kg/h

Condenser leak buster (Singrauli #6)

RESULT

1. Air ingress from gland seal packing of both A-BFPT and B-BFPT were 44% and 21% of total ingress measured respectively.

RECOMMENDATION

1. Inspect these area and conduct necessary repair.
2. After repair, carry out Helium test again to assure little air ingress.

Photo-19 Test equipments for helium reaction test

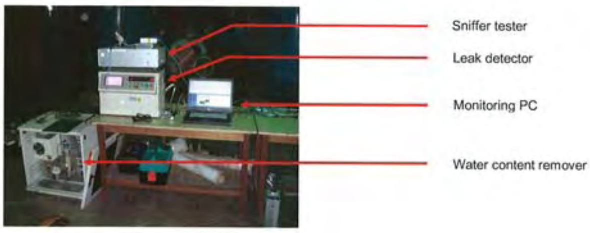


Photo-20 Helium Detection position
(Pressure gauge position for #6B vacuum pump inlet)

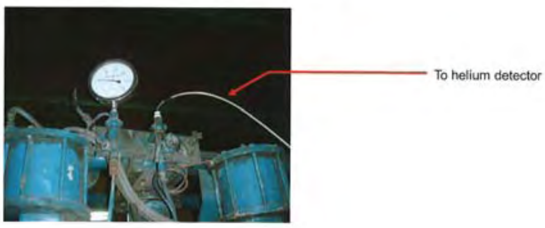


Photo-21 Injection test position
(Drain pipe of Pressure transmitter for #6B vacuum pump inlet)

Pump assessment Korba BFP-6B (T-BFP)

RESULT

1. Pump efficiency is decreased by approx. 5% from the design value.

RECOMMENDATION

1. Refurbish inner parts of the pump after economic evaluation.
2. Conduct pump test for the same pump every two years, and to carry out the test for other pumps.
3. BFP turbine efficiency can be estimated, when BFP efficiency is known.

Pump assessment Singrauli CWP I-09

RESULT

1. **Pump efficiency is decreased by approx. 11% from the design value.**

RECOMMENDATION

1. **Refurbish inner parts of the pump after economic evaluation.**
2. **Conduct pump test for the same pump every two years, and to carry out the test for other pumps.**

Pump assessment Rihand BFP-2B (M-BFP)

RESULT

1. **Pump efficiency is decreased by approx. 13% from the design value.**

RECOMMENDATION

1. **Refurbish inner parts of the pump after economic evaluation.**
2. **Conduct pump test for the same pump every two years, and to carry out the test for other pumps.**

Pump assessment Rihand CWP-2B

RESULT

1. **Pump is considered to be in acceptable condition while the efficiency is 1.6% lower than the design.**

RECOMMENDATION

1. **Conduct pump test for the same pump every two years, and to carry out the test for other pumps.**

Turbine and System Assessment
NTPC Korba #4

Workshop at Power Management Institute

Hirotugu Ohgihara – Thermal Services, ALSTOM K.K.

September 10th, 2010

Agenda

- **Objective of the Assessments**
- Project Organization
- Scope of Work
- Methodology Adopted
- Overall Executive Summary of the Findings

Objective of the Assessments

As a part of ODA program, "Study on Enhancing Efficiency of Operating Thermal Power Plants in NTPC-India", Turbine and System Assessment was implemented for NTPC Korba unit #4.

Below items are main objective of the assessment.

- Assessments of the present conditions of the turbine and related components, including critical piping systems.
- Assessments of the remaining life of the equipments / components.
- Recommendations for run/repair/replace decision of equipments / components for performance improvement from risk mitigation view point.
- Recommendations for safe & reliable operation, through identification of failure prone zones / components from risk mitigation view point.

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Agenda

- Objective of the Assessments
- **Project Organization**
- Scope of Work
- Methodology Adopted
- Overall Executive Summary of the Findings

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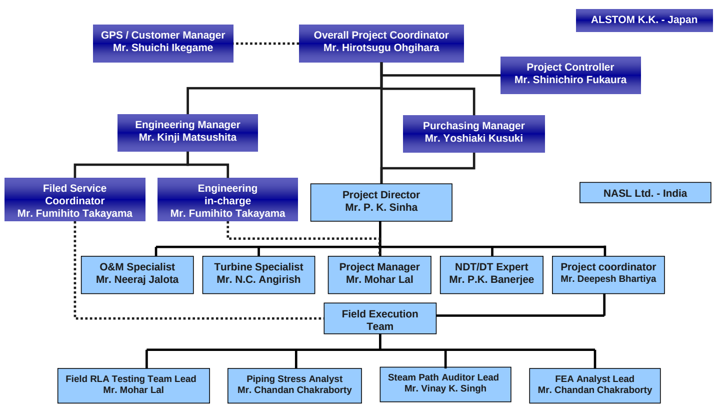
Project Organization



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Today's Participants

Mr. Hirotsugu Ohgihara	Overall Project Coordinator/BD Manager ALSTOM K.K. (Japan)
Mr. Deepesh Bhartiya	Project Coordinator NASL Ltd.
Dr. S. Shamasundar	Managing Director ProSIM R&D Pvt. Ltd.

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Agenda

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Objective of the Assessments

Project Organization

Scope of Work

Methodology Adopted

Overall Executive Summary of the Findings

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Unit Information

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- Plant: NTPC Korba Super Thermal Power Station
- Unit: #4
- Rating: 500 MW
- Turbine OEM: KWU
- Operating Hours: 198,110 hrs (as of May 2010)

- Past 10 yrs operational data is available
- Drawings available, partially missing
- The unit hasn't been implemented comprehensive conditions and residual life assessment

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Scope of Work

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- Residual Life Assessment (RLA) for 1xIP and 1xLP Turbines incl.
  - Various NDT/DT and In-situ Metallography Analysis
  - Finite Element Analysis (using ABAQUAS and FE-SAFE)
- Main Piping (MS, CRH, HRH, FW) Assessment incl.
  - Various NDT/DT and in-situ Metallography Analysis
  - Modeling and Stress Analysis (using CAESER II),
  - Finite Element Analysis (using ABAQUAS and FE-SAFE)
- Steam Path Audit (SPA) of 1xIP and 1xLP Turbines
  - Various Field Measurements
  - Modeling and Analysis (using eSTPE)

Comprehensive package for turbine and system assessment

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Agenda

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Objective of the Assessments

Project Organization

Scope of Work

Methodology Adopted

Overall Executive Summary of the Findings

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Procedures for the Assessment

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Inspection/Testing Process (field execution):

- Hot Walk Down - to capture the operating conditions
- Cold Walk Down - to capture the cold conditions
- Field Measurement/Inspection - conduct various NDT/DT tests (VI, DPT, MPI, UT, NFT, ECT, Replication (IM), Hardness, other measurements, tests, audits)

Data Analysis Process:

- Condition assessment from NDT/DT processes – collected data are analyzed for assessment of impending failures and damages.
- Remaining life assessment – based on field data, analyzed to assess remaining life. It consists of metallographic degradation analysis and finite element analysis (FEA).

Reports & Recommendations:

- Findings from field execution and data analysis result are integrated into conclusions, recommendations for Run/Repair/ Replace to secure safe operation and performance improvement.

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Data Analysis Process

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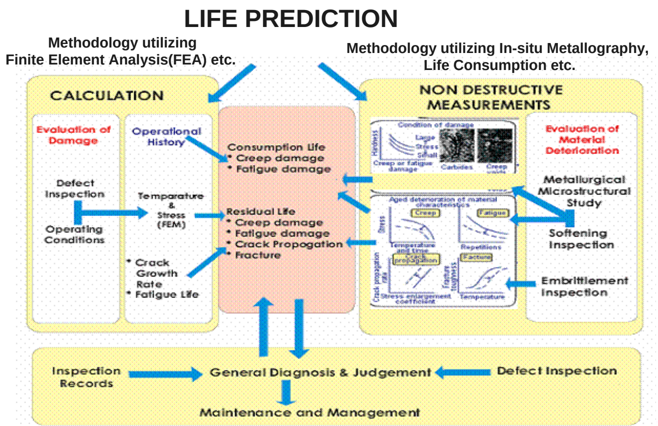

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Methodology utilizing In-situ Metallography

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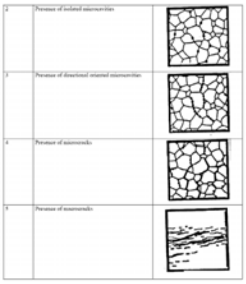
Evaluation based on Microstructural Assessment (Neubauer)& Classification (VGB guidelines):

- The level of degradation of material is classified using the above classifications for finding the level of damage.

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

- The level of damage is then checked with the creep damage classification so as to find the expended life fraction (percentage of life consumed)



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

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Methodology utilizing Larson Miller Parameters

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Evaluation based on Larson Miller Parameters:

- LMP is a means of predicting the lifetime of material vs. time and temperature using a correlative approach based on the Arrhenius rate equation.
  The value of the parameter is usually expressed as
  LMP=T(C + log t)
  C: material specific constant (often approximated as 20)
  t: exposure time (hours)
  T: temperature (K)
  The base formula is: LMP = A-B*log □. (□: hoop stress)

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Methodology utilizing Finite Element Analysis(FEA)

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In FEA, the physical system is digitally represented on a computer.
A 3D CAD FEM model of component is created & physical realities of the material and the operating conditions are prescribed upon it.
With the model, virtual system is available for analysis, and it gives the results of stress, strain, temperature, deflection in the entire 3D geometry.
The steps involved in the simulation are as follows;

- Create a 3D model and convert it in finite element mesh model.
- Physical boundary & operating conditions are mimicked for computer simulation.
- Perform FEM analysis using ABACUS software and calculate the stress, strain, temperatures etc. due to creep and fatigue effect.
- Conduct Thermo mechanical fatigue analysis using FE-SAFE software and obtain the hot spots.
- Compute creep & fatigue life and calculate the combined effect of creep-fatigue.
- Finalize remaining life based on total damage accumulated.

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Remaining Life Overview

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

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Turbine Assessment Summary (IP-Casing)

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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.

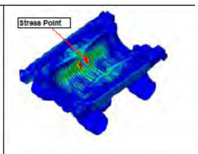
Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry.

Microstructural degradation level is II L and hardness range 168 to 200 .The expended creep life fraction is 0.181

Hardness value of casing is observed in the range of 168-172 BHN at the steam entry side, & 190-200 BHN at the steam exist side.

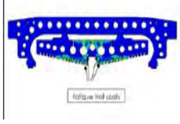
Observations:

IP Inner casing is highly stressed (530 MPa- Peak transient stress) near the inlet and first stage as shown in the figure.
The FeSafe analysis shows the probablity of crack initiation in IP casing assembly from the inlet and first stage, over a period of time.



Conclusions:

From the above Analysis and based on Miner's Rule Remaining life = 22 years.



Conclusion: **Remaining life is evaluated to > 20yrs**
Recommendation:
1) Stressed locations as marked in the figures, need to be checked and microstructure analysis should be carried out during the Overhauls
2) further RLA of the component in 5yrs

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Turbine Assessment Summary (IP-Rotor)

ALSTOM

Visual Observations reveal that the IP rotor has no significant damage.Coupling holes and coupling bolts are also in good condition.

There is no significant degradation of hardness on the rotor material.

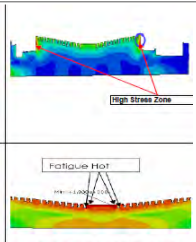
MPI,DPT & UT of Journal & Coupling Area has not revealed any defect.

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.

Observations:

IP rotor is stressed (at 360 Mpa- peak transient stress) near the inlet and last stage. Inlet becomes critical because of higher temperature and pressure of steam.



Conclusions:

From the above Analysis and based on Miner's Rule Remaining life = 16 years.

The analysis shows the probability of crack initiation in IP shaft from the steam inlet location and first stage, over a period of time. (Figure shows the details).

Conclusion: Remaining life is evaluated to 16yrs

Recommendation:

1) Stressed locations as marked in the figures, need to be checked and microstructure analysis should be carried out during the Overhauls

2) further RLA of the component in 5yrs

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Turbine Assessment Summary (LP-Casing)

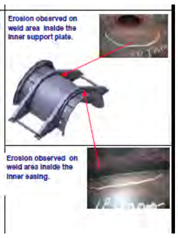
ALSTOM

Visual Observations reveal that the inner-outer casing, errosion 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.

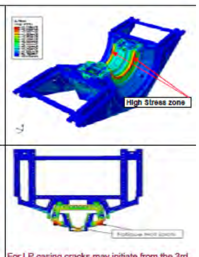
No measurable deposits found, indicating good water chemistry.

Erosion observed on weld area inside the inner support plate.



Erosion observed on weld area inside the inner casing.

In LP casing assembly, Inner casing shows the stress of 256MPa (Peak transient stress) near the third stage of the turbine.



Conclusions:

From the above Analysis and based on Miner's Rule Remaining life = 113 years.

For LP casing cracks may initiate from the 3rd stage as shown in the figure.

Conclusion: Remaining life is evaluated to > 20yrs

Recommendation:

1) Stressed locations as marked in the figures, need to be checked and microstructure analysis should be carried out during the Overhauls

2) Based on explicit observations in various locations, no immediate action is required.

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Turbine Assessment Summary (IP-Casing)

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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.

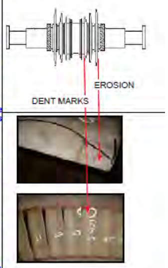
Deposit Analysis reveal presence of major oxide component. These are Iron Oxides, which is normal. No abnormal constituent like Cl, Cu etc. are present. No abnormal deposits are observed there, indicating good water chemistry.

No errosion in balancing weights observed.

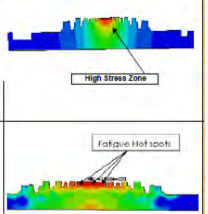
There is no significant drop observed in NFT measurements of last 03 stages free standing blades, with respect to design value.

The microstructural degradation level is 1L and the expended creep life fraction is less than 0.181.

Hardness value of rotor is found to be 268 to 278 at the inlet side and 261 to 271 at the collar region (exit side).



In LP rotor high stress (360 MPa) is observed near the inlet. This is due to higher pressure and temperature of steam at inlet.



Conclusions:

From the above Analysis and based on Miner's Rule Remaining life = 47 years.

The analysis shows the probability of crack initiation in LP shaft from the steam inlet location and first stage, over a period of time.

Conclusion: Remaining life is evaluated to > 20yrs

Recommendation:

1) Stressed locations as marked in the figures, need to be checked and microstructure analysis should be carried out during the Overhauls

2) Based on explicit observations in various locations, no immediate action is required. However the last stage moving blades of both sides needs to be replaced in the next overhaul.

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Piping Assessment Summary (MS-CRH-HPBP)

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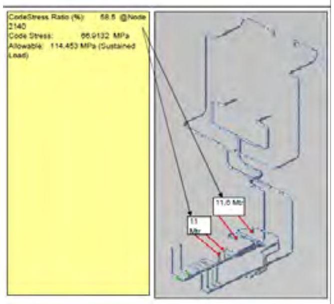
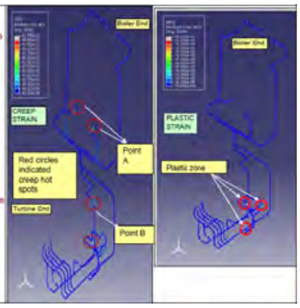


1)Maximum Stress due thermo mechanical load is 168 Mpa (localised Point A) ,average stress value is 60 to 70 MPa which is within allowable limit.& strain observed is 0.0112.(Elastic Strain 0.001 + Plastic Strain 0.00112)

2)Maximum Permanent Deformation after 25 Yrs of opern 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



Conclusion: Remaining life is evaluated to 5.91 years considering 25% safety factor to alarm the hot spot zones observed in FEA.

Recommendation: The critical locations identified be subjected to the following tests for next anual overhauling:

1. Insitu Metallography 2. Thickenss Survey.
3. Online line monitoring systems using the installation of the High temperature strain gauges a
4. EMAT - Elctromagnetic Acoustic transducer test / High frequency (20MHz) small diameter probe UT
5. Indicated hangers required to be corrected.

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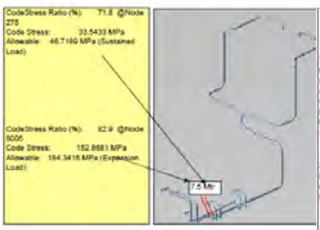
Piping Assessment Summary (HRH-LPBP)

ALSTOM



1)Maximum Stress due thermo mechanical load is 102 Mpa (localised Point A) ,average stress value is 50 to 70 MPa which is within allowable limit.& strain observed is 0.00818.(Elastic Strain 0.00712 + Pastic Strain 0.00106)

2)Maximum Permanent Deformation after 25 Yrs of opern due to Creep is 100 mm (Point A)

3) Displacement (plastic)of HRH hangers over a period of 25 years is less than 5 mm.

Conclusion: The condition of piping system is satisfactory.
Remaining life is evaluated to 13.6 years.

Recommendation: Run component fit for further operation
Re-inspection of the component is recommended after 5 years
Indicated hangers required to be corrected.

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Piping Assessment Summary (BFW)

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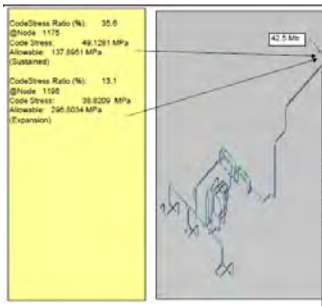
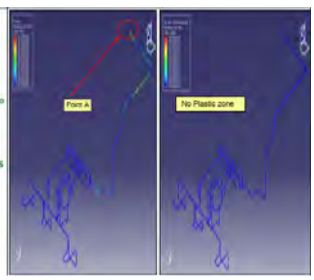


1)Maximum Stress due thermo mechanical load is 142 Mpa (localised Point A) ,average stress value is 60 to 70 MPa which is within allowable limit.& strain observed is 0.00066.(Elastic Strain 0.00066 + Plastic Strain 0.0)



Conclusion: The condition of piping system is satisfactory.
Remaining life may be concluded > 20 years.

Recommendation: Run component fit for further operation
Re-inspection of the component is recommended after 5 years
Indicated hangers required to be corrected.

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Steam Path Audit Overview

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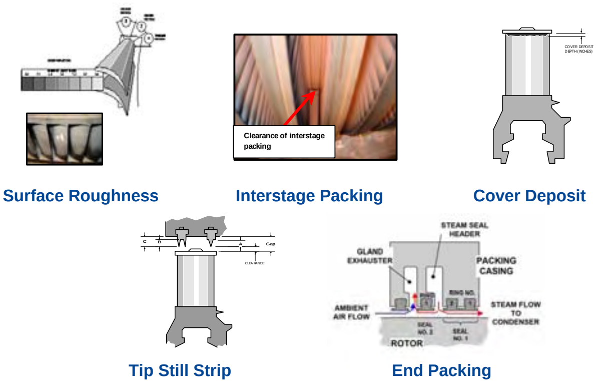

Major loss items

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Steam Path Audit Overview (total)

ALSTOM

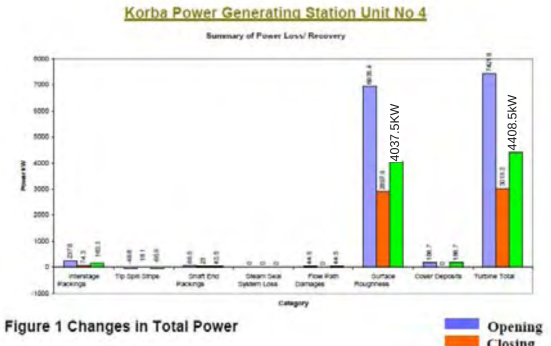

Figure 1 Changes in Total Power

Major loss & recovery from surface roughness

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Steam Path Audit Overview (total)

ALSTOM

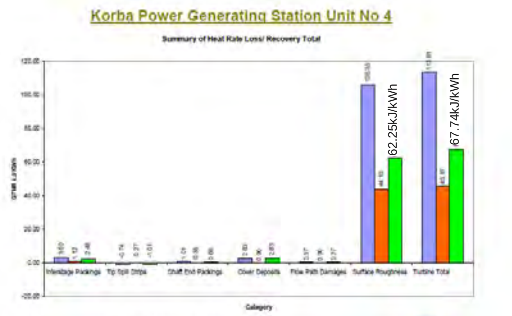

Figure 2 Changes in Total Heat Rate

Major loss & recovery from surface roughness

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Steam Path Audit Overview (IP)

ALSTOM

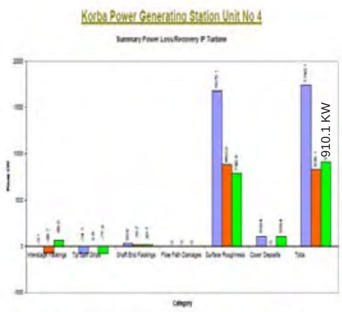

Figure 3 Changes in Power – IP Turbine

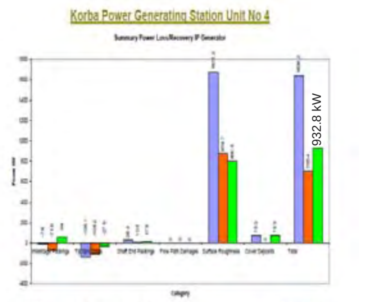

Figure 5 Changes in Power – IP Generator

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Steam Path Audit Overview (IP)

ALSTOM

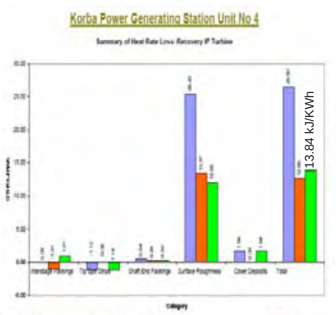

Figure 4 Changes in Heat Rate – IP Turbine

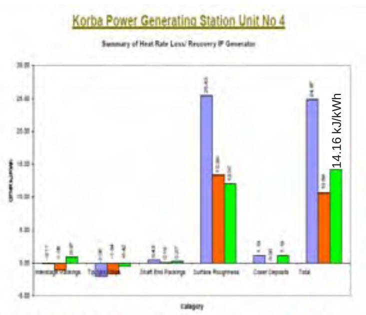

Figure 6 Changes in Heat Rate – IP Generator

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Steam Path Audit Overview (LP)

ALSTOM

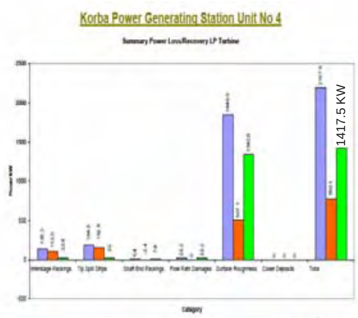

Figure 7 Changes in Power – LP Turbine

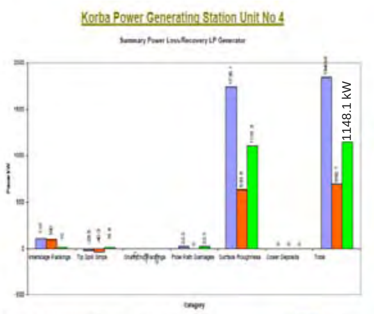

Figure 9 Changes in Power – LP Generator

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Steam Path Audit Overview (LP)

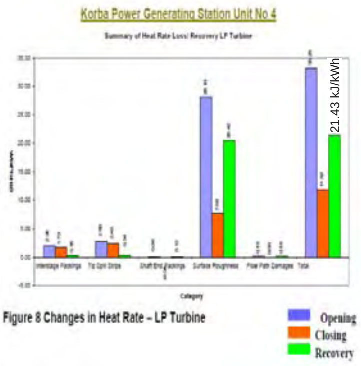

Figure 8 Changes in Heat Rate – LP Turbine

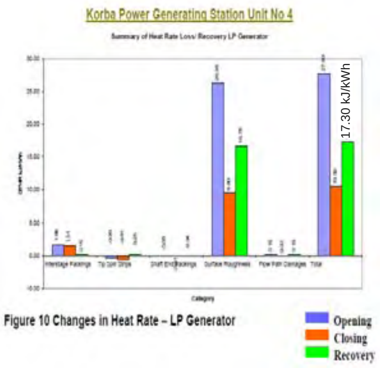

Figure 10 Changes in Heat Rate – LP Generator

Overall Conclusions

- The unit is generally in good conditions
- No significant defect is observed in turbine and piping.
- Metallographic analysis revealed the degradation level was
  - Level IIL for turbine (expended life fraction up to 18%)
  - Level IIL to IVL for piping (expended life fraction up to 44%)
- Remaining life of MS piping hot spot zone is evaluated as 5.9 yrs, taking into account 25% safety factor
- 90% of losses of turbine (output & heatrate) are come from surface roughness

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

Presentation document

< Control & Instrumentation >

Outline of Field Study

<Objectives>

To confirm the state of key facilities of Unit 3 at Unchahar power station and to investigate the feasibility of improving the reliability, operating performance and functionality of the unit through renovating or modifying its instrumentation and control systems.

The opportunities for combustion and soot blowing optimisation are a particular focus.

<Date>

Oct 26 to 29, 2009 (4days)

<Team>

JICA Study Team & Yokogawa Electric Corporation (total 6 people)

Plant description of Unchahar#3

- Unit 3, the first of two units (3 & 4) in Stage II was first synchronised in January, 1999 and declared available for commercial operation on January, 2001.
- Rated Output : 210MW
- Unit 3 has operated since 2002 with a Plant Load Factor in excess of 90% (101% in 2008!) and has been overhauled each year, except 2008.
- Operating steam conditions are fixed pressure 150 bar, 537 degrees of Celsius.
- The unit control system is provided by ABB.

Result of Field Study

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

Soot Blower Operation

- Unchahar currently have 56 wall blowers and 18 LRSB that cover convection section and AH section
- The soot blowing is mainly time based, operator initiated sequences; the wall blowers are operated once every two days, the LSRB blowers are operated once every day.
- The chosen sequence is selected based on prevailing operating conditions (steam temperatures, metal temps, AH dP etc) but the operators also look at RH/SH sprays for initiating soot blowers.

Introduction of Boiler Optimization tool

(Soot blowing & Combustion Optimization)

This information is summarized based on documents from NeuCo, Inc , USA.

In this document , there is an outline of Boiler Optimization system that includes Soot blowing optimization and Combustion optimization.

For further information, please ask NeuCo, Inc directly.
Their home page URL is as follows : http://www.neuco.net/

Overview of Comprehensive Boiler Optimization

■All NeuCo optimizers contribute to improved heat rate (by greater or lesser amounts depending on the plant's priorities.) It is important to note that reduced heat rate not only provides immediate fuel savings, it also provides CO2 reduction benefits.

■NeuCo's comprehensive Boiler Opt solution puts emphasis on balancing the air and fuel distribution in the boiler and providing the proper cleaning using the soot blowers to improve the balance of combustion, reduce variability, and assure proper heat transfer.

Expected Benefits of Optimization software

< Soot Opt>
- Improved Heat Rate
- Improved Unit Reliability
(fewer cleaning actions, better slagging and opacity control)
- Better RH & SH Steam Temperature Control
- Better Flue Gas Temperature Control
- NOx Reduction

< Combustion Opt>
- Increased Boiler Efficiency and Heat Rate
- Reduced sorbent and/or reagent usage
- Better Steam Temperature Control
- Improved Reliability
- Reduced LOI (loss of ignition)

Benefit of installation (case of Unchahar#3)

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.

Example of Soot Blower in Japan

■Usually soot blower is implemented automatically, without operator's instruction.

■Time interval setting for soot blowing is installed in plant control system.

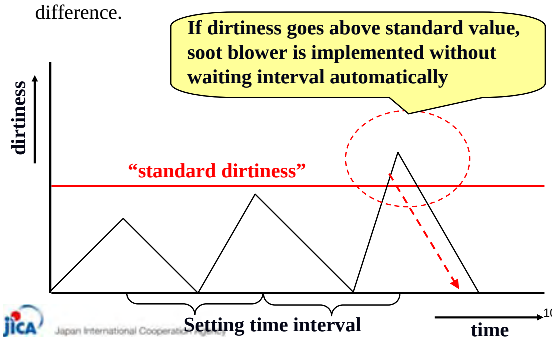
■Watching the "dirtiness" of boiler tube, there is a setting point for each boiler tube.

■Usually soot blower is carried out set time-based, however in case of becoming dirty within set time and dirtiness above set point, soot blower is carried out at this timing immediately.

■So soot blower is implemented automatically even changing the type of usage of coal.

Example of Soot Blower in Japan

" dirtiness " is comparison between difference of inlet & outlet feed water temperature and standard setting temperature difference.



Sum up for soot blower system

■As explained so far, there are 2 types of optimizing for soot blower.

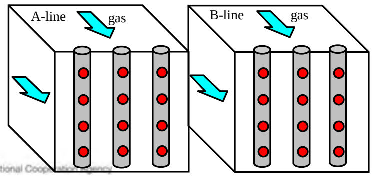
■In Japan, almost all power station are installed "intelligent soot blower" by power plant supplier.

■In USA, NeuCo's make ANN (artificial neural network) optimization software module are successful installed at more than 120 power plants. Mainly it includes ANN based combustion & soot blower model.

In Japan, never heard to install ANN technique till date.

<ref> O2 measurement in the flue gas

- For example, Misumi Power Station, ultra super critical 1000MW coal-fired plant, there are 3 probes to measure O2 outlet of economizer at each duct. There are 4 measurement spot on each probe. Total 2 ducts. So there are 24 measurement spots in all.
- The gas temperature around O2 measuring spots is approximately 350 degrees of Celsius.
- One example we are using is NGK's.
  (www.ngk.co.jp model no. MLP-10)



<ref> Control card failure

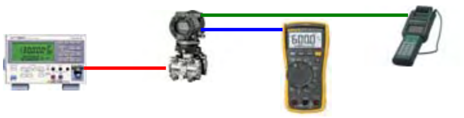
- Unit trip due to failure of control card never happen in Japan.
- Even if it happens, there are redundancy system, so switch automatically to stand-by card.
- When card failure trouble happens, alarm in the central control room tells operator to check. Then go to check the control panel room immediately to recognize which card is out of order.
- Then, inform and ask to prepare new card to OEM.
- It takes approx. a few months for OEM to prepare new card.
- No test of card during daily/overhauling maintenance, if card is reported faulty inform OEM to replace. OEM replace to new card.

Followings are recommendations for you.

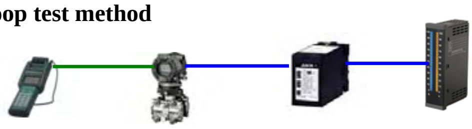
✓Keep appropriate environment for cards (temp, moisture)
✓Check the cooling fan inside of panel and filters.
  (Fan type are vertical & horizontal.)
✓Open/Close control panel door with much caution.
✓Use of panel door gasket to remove dust in each panel.

<ref> Calibration method

■Calibration



■Loop test method



Calibration is always done by subsidiary company based upon plant requirement

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

Thank you for your attention!

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

Generator Assessment

2010

Japan International Cooperation Agency

Contents

Assessment procedures

Generator part for the assessment

Stator coil insulation
Stator coil insulation is most deteriorated.

Required specification of stator

Insulator : Mica
Resin: Epoxy
Resin process: VPI (Vacuum Pressure Impregnation)

Target for the assessment

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

Target specification is the same as required specification of stator.
In Japan, small capacity generator is cooled by H2, generally.

Assessment procedures

Assessment type

Current condition assessment
Judging from the latest test results
Remaining life assessment (RLA)
Judging from lots of historical test data

Sorts of stator coil insulation diagnosis for assessment

1) Insulation resistance test (IR test)
2) Polarization index test (PI test)
3) Tan δ test
4) AC current-voltage test (Step voltage test)
5) Partial discharge test (Corona test)

When stator is cooled by water, draining and drying are required.

Assessment procedures

Required data for current condition assessment

1) Latest IR test data
2) Latest PI test data
3) Latest Tan δ test data
4) Latest AC current-voltage test data (Step voltage test)
5) Latest partial discharge test data (Corona test)

Required data for RLA

1) Multiple IR test data (Historical test data)
2) Multiple PI test data (Historical test data)
3) Multiple Tan δ test data (Historical test data)
4) Multiple step voltage test data (Historical test data)
5) Multiple partial discharge test data (Historical test data)

RLA is conducted with grasping the deterioration trend by multiple historical test data.

Essential for the assessments
- The data is reliable and accurate
- Sufficient data

Korba#6 assessment

Korba#6 assessment

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Current status of implementing assessment in Korba#6

IR test and PI test has been conducted.

Test voltage (DC V)	IR (MΩ)	Japanese criterion
200	0.0666000	
500	0.0636243	
750	0.0064650	
1000V(15 sec)	0.0601680	
1000V(1 minute)	0.0628930	50(MΩ)
1000V(8 minutes)	0.0625000	
PI	0.994	>2.0 (*1)

*1:Korba#6 PI=IR(8 min)/IR(1 min)
In Japan PI=IR(10 min)/IR(1 min)

Korba#6 does not drain and dry stator coil.
So, Korna#6 test data is meaningless for the assessment.

Recommendations for Korba#6

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1. Conducting insulation diagnosis without cooling water

It is recommended that Korba#6 conduct the insulation diagnosis without cooling water ASAP so that Korba#6 can grasp the current condition and the deterioration trend.

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Rihand#2 assessment

Rihand#2 current condition assessment

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Current status of implementing assessment in Rihand#2

IR test, PI test and Tanδ test have been conducted.

Results of IR test, PI test

Date	IR test (MΩ)		PI test
	1 minute	10 minutes	
Nov-1994	1500	11000	7.33
Nov-1999	3300	7700	2.33
Aug-2000	1500	6000	4.00
Sep-2001	800	2400	3.00
Sep-2002	20000	100000	5.00
Sep-2003	15000	60000	4.00
Oct-2004	—	—	3.92
Oct-2005	600	2500	4.17
Sep-2006	2000	6000	3.00
Oct-2007	1000	3750	3.75
NTPC Criteria	21 (*1)	—	2.0
Japanese criteria	50	—	2.0

*1 NTPC Criteria:
IR test criterion = Gen rated voltage (kV)+1

Current condition by IR test & PI test:
No problem because the results fulfill the criteria.

Rihand#2 current condition assessment

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Results of Tanδ

Voltage (kV)	R phase	Y phase	B phase	Remarks
2	1.04%	1.04%	0.96%	Estimated data (*1)
4	1.20%	1.20%	1.10%	Actual data
8	1.20%	1.40%	1.40%	Actual data
12	1.70%	1.90%	1.87%	Actual data
14.4(1.25×E/√3)	1.78%	2.13%	2.20%	Estimated data (*1)
Δtanδ	0.74%	1.08%	1.24%	=Tanδ(14.4)−Tanδ(2)
Japanese criteria	Δtanδ<2.5%			

*1: Test voltage is little bit different from Japanese one. Therefore, Tanδ(2)(Tanδ0) at 2kV and Tanδ(14.4)(Tanδ max) at 1.25×E/√3kV(E:Generator rated voltage) are estimated from Korba#2 test data using approximation formula function of Excel soft .

Current condition by Tanδ test:
No problem because the results fulfill the criteria.

Estimation of Tanδ0 & Tanδmax (R phase)

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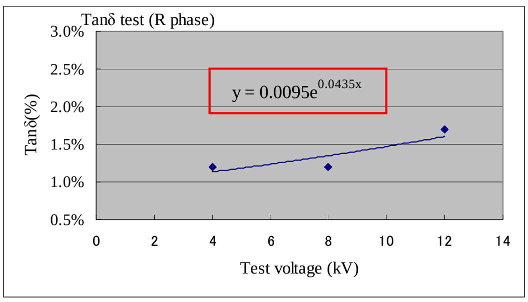
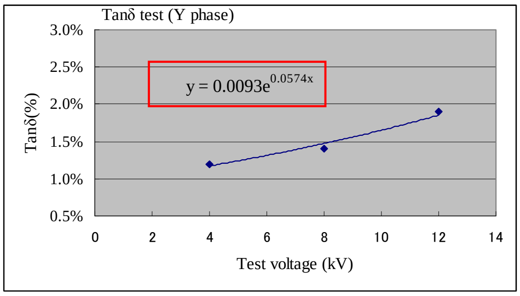


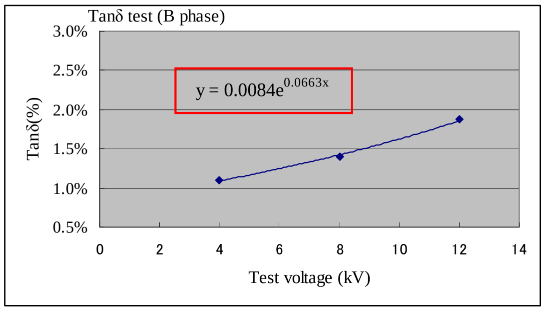
Estimation of Tan δ 0 & Tan δ max (Y phase)

12



Estimation of Tan δ 0 & Tan δ max (B phase)

13



Rihand#2 RLA

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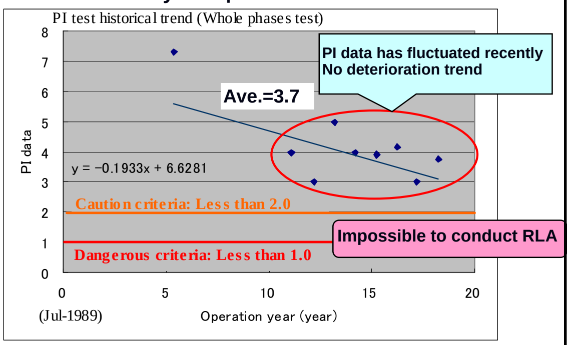
Multiple historical Tan δ data is not available. Therefore RLA is conducted by multiple historical PI test



Recommendations for Rihand#2

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1. Continue to conduct the insulation diagnosis

Japanese technical book reports that stator coil insulation strength of generator might accelerate to deteriorate after 20-25 year operation. Because Rihand#2 generator has operated for 20 years and it is possible the insulation strength accelerates to deteriorate in the future. Therefore, it is highly recommended that Rihand#2 should conduct the insulation diagnosis periodically in the future and grasp the deterioration trend.

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Singraulii#4 assessment

Singrauli#4 current condition assessment

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Current status of implementing assessment in Singrauli#4

IR, PI, Tan δ and partial discharge test have been conducted.

Results of IR test, PI test (R-phase)

	R phase		
	Megger test (MΩ)		PI
Date	1 minute	10 minutes	
Aug-1997	1700	7500	4.41
Aug-2000	1900	7000	3.68
Sep-2001	1400	5000	3.57
Nov-2004	3250	13500	4.15
Dec-2006	3100	8000	2.58
NTPC criteria	>17	—	>2
Japanese ones	>50	—	>2

Current condition by IR test & PI test (R phase):
No problem because the results fulfill the criteria.

Singrauli#4 current condition assessment (18)

Results of IR test, PI test (Y-phase)

	Y-phase		
	Megger test (MΩ)		PI
Date	1 minute	10 minutes	
Aug-1997	1700	7200	4.24
Aug-2000	1800	6000	3.33
Sep-2001	1300	3000	2.31
Nov-2004	3600	13500	3.75
Dec-2006	3500	10000	2.86
NTPC criteria	>17	—	>2
Japanese ones	>50	—	>2

Current condition by IR test & PI test (Y phase):
No problem because the results fulfill the criteria.

Singrauli#4 current condition assessment (19)

Results of IR test, PI test (B-phase)

	B-phase		
	Megger test (MΩ)		PI
Date	1 minute	10 minutes	
Aug-1997	1100	2200	2.00
Aug-2000	1750	4300	2.46
Sep-2001	1500	5000	3.33
Nov-2004	3600	12000	3.33
Dec-2006	1900	4000	2.11
NTPC criteria	>17	—	>2
Japanese ones	>50	—	>2

Current condition by IR test & PI test (B phase):
No problem because the results fulfill the criteria.

Singrauli#4 current condition assessment (20)

Tan δ test data from Singrauli#4

	R-phase			Y-phase			B-phase		
Date	1kV	3kV	5kV	1kV	3kV	5kV	1kV	3kV	5kV
Aug 1997	1.31	-	-	1.22	-	-	1.13	-	-
Aug 2000	-	-	-	-	-	-	-	-	-
Sep 2001	-	-	-	-	-	-	-	-	-
Nov 2004	1.31	-	-	1.26	-	-	1.21	-	-
Dec 2006	0.88	0.89	0.89	0.92	0.88	0.89	0.86	0.85	1

Rated voltage=15.75kV

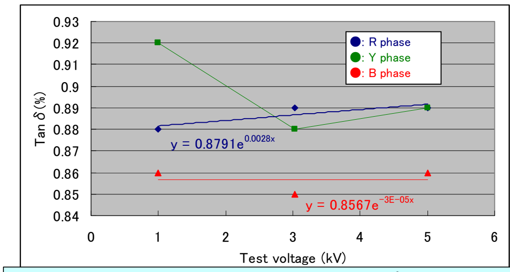
Tan δ test voltage

Item	Contents
Singrauli#4 max test voltage	7 kV (0.8×E/√3)
Japanese max test voltage	12.8kV(1.25×E/√3) or 15.57 (E)
Japanese judgment indicator	ΔTan δ =tan δ (Vmax) – Tan δ (1~2kV)

Tan δ test voltage is too low.
Singrauli#4 data does not meet Japanese judgment criteria.

Singrauliu#4 current condition assessment (21)

Results of Tan δ



Technically, the higher test voltage is, the higher tan δ data become.
But Y-phase data declines. So, these data are not reliable.

Impossible to conduct Current condition by Tan δ test:

Singrauliu#4 current condition assessment (22)

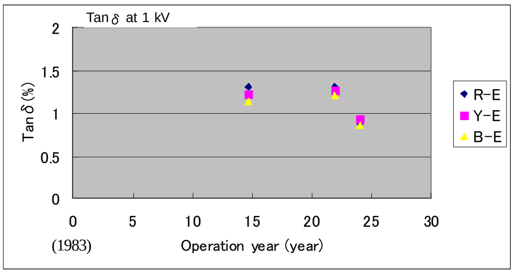
Partial discharge test

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 can not conduct the assessment by partial discharge test because there is not sufficient explanation about it from Singrauli#4.

Singrauli #4 RLA (23)

RLA by Tan δ test

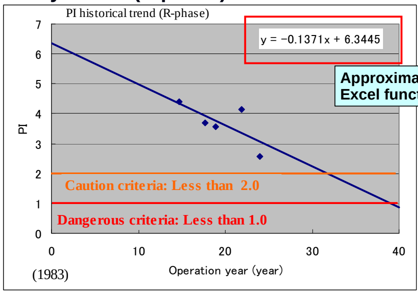


Historical Tan δ test data are conducted at low test voltage, they do not meet Japanese judgment criteria.
In addition, there is no deterioration trend.

Impossible to conduct RLA

Singrauli #4 RLA

RLA by PI test (R phase)

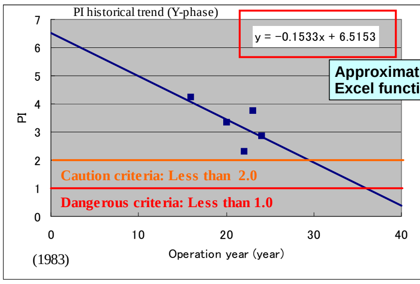


Approximation formula by Excel function

Although PI data fluctuate due to stator coil dryness, the deterioration trend is shown.

Singrauli #4 RLA

RLA by PI test (Y phase)

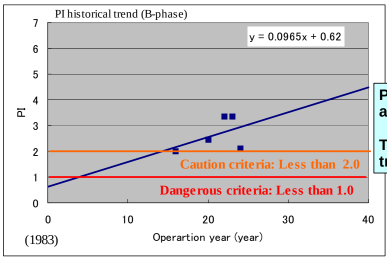


Approximation formula by Excel function

Although PI data fluctuate due to stator coil dryness, the deterioration trend is shown.

Singrauli #4 RLA

RLA by PI test (B phase)



PI data is improving according to the test data.

There is no deterioration trend.

Impossible to conduct RLA because of no deterioration trend

Singrauli #4 RLA

RLA results by PI test (R, Y phase)

Item	R phase		Y phase	
Estimated initial PI		6.3445		6.5153
ΔPI to Caution level		4.3445		4.5153
ΔPI to Dangerous level		5.3445		5.5153
Deterioration trend (PI/year)		0.1371		0.1533
Operation year & Year to Caution level	32	2015	29	2012
Operation year & Year to Dangerous level	39	2022	36	2019

RLA is conducted by approximation formula by Excel function

Recommendations for Singrauli#4

1. Continue to conduct insulation diagnosis
   As for R phase and Y phase, PI data tends to decrease although PI data depends on dryness of generator stator.
   As for B phase, the PI does not show the deterioration trend.
   It is recommended to continue to conduct insulation diagnosis test in the future and to monitor trend of deterioration.
2. Get reliable and accurate test data
   It is recommended to review test data enough, and to get proper test data.

Status of conducting insulation diagnosis test

Plant	IR	PI	S-V	Tan δ	PD	Remarks
Korba#6	△*1	△*1	−	−	−	
Singrauli#4	○	○	−	○*2	○*3	
Rihand#2	○	○	−	○	−	
Japan	○	○	(○)*4	○	○	

S-V: Step-voltage test PD:Partial discharge test

*1: Test with cooling water is meaningless.

*2: Max test voltage is low.

*3: Measurement data is different from Japanese one

*4: Some OEMs do, the others do not in Japan.

Insulation diagnosis is totally evaluated by all the tests in Japan.

Sample reports in Japanese plant

Frequency of stator coil insulation diagnosis

Basically, once per 10 years
Recently it tends to be extended according to the condition based on experience

Sorts of stator coil insulation diagnosis for assessment

1) Insulation resistance test (IR test)
2) Polarization index test (PI test)
3) Tan δ test
4) AC current-voltage test (Step voltage test)
5) Partial discharge test (Corona test)

Test implementation

By the manufacturer

In Japan, the assessment of stator coil insulation is comprehensively evaluated considering whole these tests.

Sample reports in Japanese plant

Generator specification

Items	Specification
Rated capacity	417MVA
Power factor	0.9 (lag)
Frequency	60Hz
Rotating speed	3600rpm
Rated voltage	22kV
Rated current	10943A
Cooling (Stator)	Water
Cooling (Rotor)	H2
Stator insulation	Mica + epoxy resin (VPI)
Start operation	1973
Manufacturer	X manufacturer

Setting maximum test voltage

Required draining & drying cooling water

Required specification for insulation diagnosis

Setting maximum test voltage

Sample reports in Japanese plant

Preparation work

- Stator coil cooling water is drained and dried
- Every phase is disconnected.
- Conduct IR test and PI test to confirm whether stator coil insulation is in good condition for conducting insulation diagnosis

Each phase diagnosis
- Required to disconnect phases
- Possible to confirm which phase is bad, if bad condition

Whole phases diagnosis
- Not required to disconnect phases
- Impossible to confirm which phase is bad, if bad condition

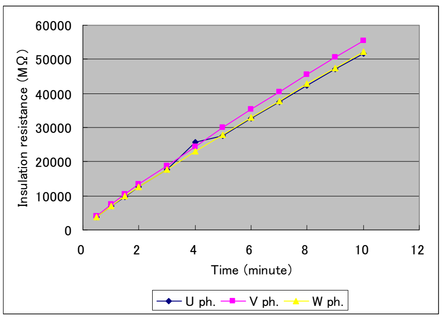
Sample reports in Japanese plant

IR test & PI test

Charging time	Insulation resistance (MΩ)			Reference
(minute)	U phase	V phase	W phase	
0.5	3750	4090	3880	
1.0	6890	7420	7030	
1.5	9760	10490	9900	
2.0	12480	13390	12610	
3.0	17590	18850	17690	
4.0	25700	24400	23100	
5.0	27700	29900	27900	
6.0	32700	35300	33000	
7.0	37600	40500	37900	
8.0	42400	45600	42800	
9.0	47100	50700	47500	
10.0	51700	55500	52300	Criteria
PI test	7.5	7.48	7.44	≥2.0
Evaluation	Good	Good	Good	

If PI result is bad, insulation diagnosis is canceled or dry stator coil more and improve PI.

Sample reports in Japanese plant



Check point
No fluctuation, No decline

Sample reports in Japanese plant

Setting test voltage

Test voltage is set considering draft step-voltage test result & & generator operation years

Generator rated voltage=22kV

Setting test voltage by draft step-voltage test

Draft test voltage : AC 1.0kV to 12kV
Result : No surge point (Pi1) →Pi1≧12kV
Available max. test voltage formula: =Pi1×3.5×0.7 =29.4(kV)

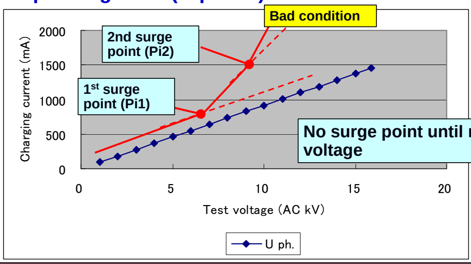
Setting test voltage by generator operation years

The manufacturer sets the max. test voltage at 1.25 × E/ √3 (15.9kV) according to the manufacturer manual when 15 years have passed since the generator started operation.

The lower max. test voltage is set because it is essential to avert the negative impact on the stator coil insulation due to conducting the diagnosis test.

Sample reports in Japanese plant (36)

Step-voltage test (U-phase)



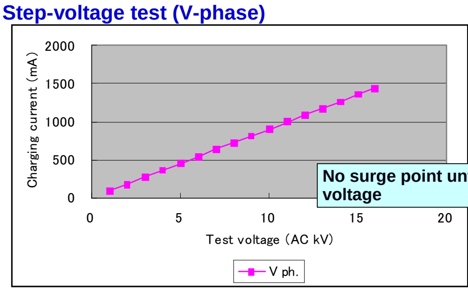
Check point

Whether there are Pi1, Pi2?

Whether ΔI (charging current increase ratio) is less than 5%?

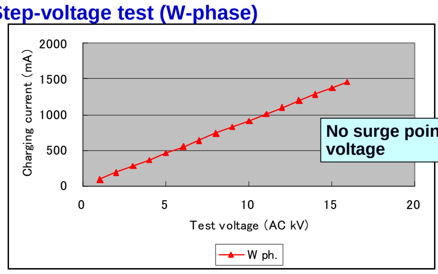
Sample reports in Japanese plant (37)

Step-voltage test (V-phase)



Sample reports in Japanese plant (38)

Step-voltage test (W-phase)



Evaluation item	U phase	V phase	W phase	Criteria
ΔI (%)	0	0	0	<5%(at 12.7kV)
Pi1 (kV)	NE Pi1	NE Pi1	NE Pi1	>12.7kV (E/)
Pi2 (kV)	—	—	—	>22kV (E)

Sample reports in Japanese plant (39)

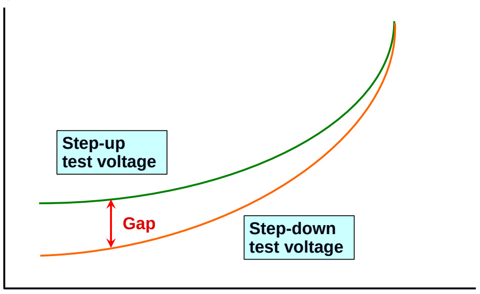
Tanδ test

Voltage (kV)	U phase	V phase	W phase	Reference
2.0	1.43	1.33	1.31	
5.0	1.49	1.36	1.36	Step-up test voltage
8.0	1.58	1.43	1.44	
11.0	1.81	1.67	1.72	
14.0	2.10	1.94	2.00	
15.9	2.25	2.09	2.18	
14.0	2.12	1.97	2.02	
11.0	1.85	1.70	1.72	Step-down test voltage
8.0	1.60	1.46	1.47	
5.0	1.50	1.37	1.37	
2.0	1.46	1.33	1.33	Criteria
Tan δ 0	1.43	1.33	1.31	—
ΔTan δ	0.82	0.76	0.87	<2.5
Capacitance(μF)	0.2450	0.2420	0.2430	—
Evaluation	Good	Good	Good	

In Japan, Tanδ is measured at both step-up and step-down voltage.

Sample reports in Japanese plant (40)

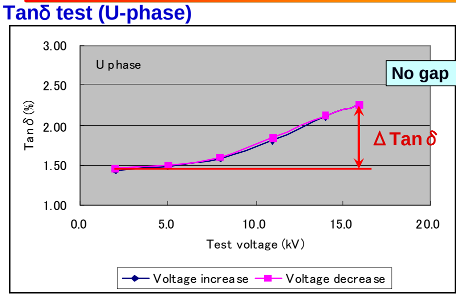
Tanδ test



If there is a obvious gap between step-up and step-down, there is something wrong with the insulation

Sample reports in Japanese plant (41)

Tanδ test (U-phase)

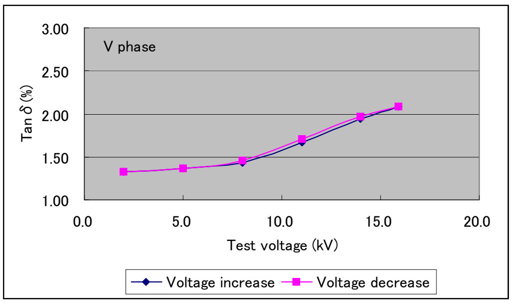


Check point

- Whether there is an obvious gap between step-up and step-down ?
- How many difference between Tanδ max and Tanδ0? (ΔTanδ)

Sample reports in Japanese plant

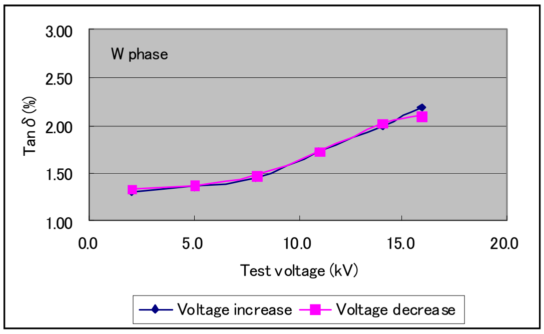
Tanδ test (V-phase)



Technically, the higher test voltage is, the higher Tan δ becomes.

Sample reports in Japanese plant

Tanδ test (W-phase)



Sample reports in Japanese plant

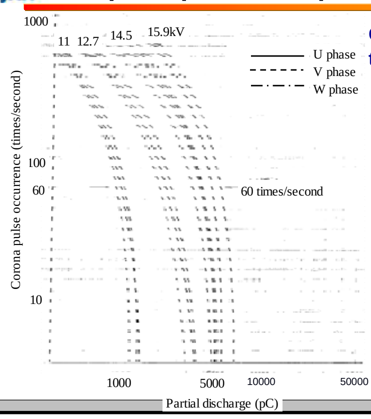
Partial discharge test

- Partial discharge test was conducted by 2 different frequency ranges, a wide range (10kHz-4MHz) and a low frequency range (10kHz-200kHz).
- The test voltage is 11.0kV, 12.7kV (Judgment voltage: E/√3), 14.5kV, 15.9kV

The result

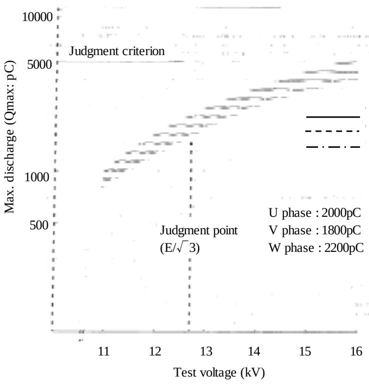
	U phase	V phase	W phase	Criteria
Wide range	2000pC	1800pC	2200pC	< 5000 pC
Low frequency	3500pC	3200pC	3600pC	<10000pC
Evaluation	Good	Good	Good	

Sample reports in Japanese plant



Corona pulse – test voltage (Wide range)

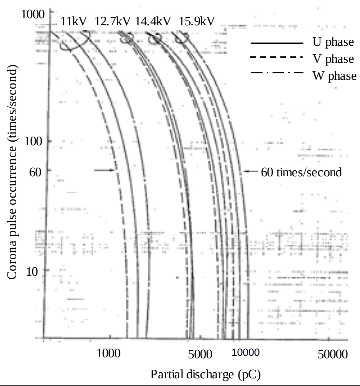
Sample reports in Japanese plant



Qmax – test voltage (Wide range)

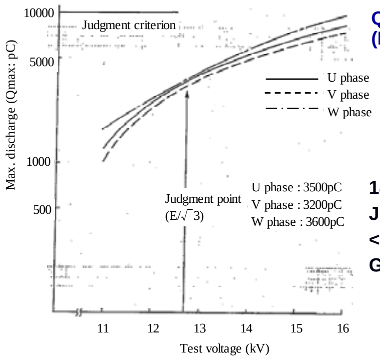
1800-2200 (pC)
(Judgment criterion
< 5000 pC, 60times/s)
Good condition

Sample reports in Japanese plant



Corona pulse – test voltage (Low-frequency range)

Sample reports in Japanese plant



Qmax – test voltage (Low-frequency range)

1800-2200 (pC)

Judgment criterion

< 5000 pC, 60times/s)

Good condition

Sample reports in Japanese plant

Test	Judgment items		Bad criteria	Evaluation point	Result
PI	PI (at 1000V)	H2 cool	≤1.5	Bad condition or Dry more	
		Water cool	≤2.0		
Step-voltage	Pi1		≤12.7kV(E/√3)	10	0
	Pi2		≤22kV(E)		
	ΔI	at E	≥12.0%	5	0
		at 1.25E/√3	≥5.0%	5	0
Tanδ	Tanδ in	at 2kV	—		
	ΔTanδ	at E	≥6.5%	5	0
		at 1.25E/√3	≥2.5%	5	0
Partial discharge)	Qmax (WR range) (1 time/1Hz)	at E/√3	>5000pC	5	0
			>10000pC	10	0
	Qmax (LF range) (1 time/1Hz)	at E/√3	>10000pC	5	0
			>20000pC	10	0
Total evaluation The largest point is added as the evaluation point.			Good	<5	0
			Attention	5≤	
			Bad condition	15 <	

Sample reports in Japanese plant

No negative impact check

After conducting all the tests, check tests were conducted to confirm whether the tests didn't give negative impact to stator coil insulation.

Step-voltage test

	Charging current (mA)	
	Former test	Check test
U phase	1458	1430
V phase	1431	1452
W phase	1451	1443

	IR test (MΩ) (1 minute)	
	Former test	Check test
U phase	6890	7000
V phase	7420	7510
W phase	7030	7100

Step-voltage test and IR test were conducted.

Check test data are similar to the former ones.

Therefore, there is no negative impact to stator coil insulation due to conducting insulation diagnosis test.

Sample reports in Japanese plant

Whole phase check

After checking no negative impact and connecting each phase each other, whole phases check (whole phase PI test) was conducted so that the generator can start operation again.

Whole phases PI test result

	IR (MΩ)
1 minute	2810
10 minutes	20070
PI test	7.14

Whole phases PI test result is good condition. Therefore, the generator is ready to operate again without problem.

Sample reports in Japanese plant

Final Evaluation

18 years has passed since the target generator started operation. Although this test results were good condition, the deterioration speed would vary largely by the operation condition such as operation time, frequency of start-stop, load change, temperature in operation. Therefore, it is important to conduct insulation diagnosis periodically and grasp the deterioration trend.

Moreover, according to the latest Japanese study result, the insulation might accelerate to deteriorate after 20-25 year operation. Therefore, it is highly recommended that periodical insulation diagnosis should be conducted in the near future.

End

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

Generator Transformer Assessment

2010

Japan International Cooperation Agency

Contents

1. GT Assessment procedures

Required specification & Target GT

GT part for the RLA

Coil insulation paper
Coil insulation paper is most deteriorated.

Required specification of GT

Oil immersed transformer
Insulation paper : craft paper
Sealed type
No absorbent in oil

Target for the assessment

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

Target specification is the same as required specification of stator.

Assessment method

Assessment type

Current condition assessment
Judging from the latest test data
Remaining life assessment (RLA)
Judging from lots of historical test data

Sorts of GT assessment

1) Insulation resistance test (IR test)
2) Dissolved gas analysis (DGA)
3) Furfural analysis
4) CO+CO2 analysis

Required data for assessment

Required test data for current condition assessment

1) Latest IR test data
2) Latest DGA test data
3) Latest accumulated CO+CO2 data
4) Latest furfural analysis data

Required data for RLA

1) Multiple accumulated CO+CO2 data
2) Multiple furfural analysis data

RLA is conducted with grasping the deterioration trend by multiple historical test data.

Essential for the assessments
- The data is reliable and accurate
- Sufficient data

NTPC DGA Criteria

NTPC utilizes IEEE standard C57, 104-1991 as NTPC criteria.

Status	H2	CH4	C2H2	C2H4	C2H6	CO	CO2	TCG
Condition-1	<100	<120	<35	<50	<65	<350	<2500	<720
Condition-2	101-700	121-400	36-50	51-100	66-100	351-570	2501-4000	721-1920
Condition-3	701-1800	401-1000	51-80	101-200	101-150	571-1400	4001-10000	1921-4630
Condition-4	>1800	>1000	>80	>200	>150	>1400	>10000	>4630

Condition 1
TCG below this level indicates the transformer is operating satisfactorily. Any individual combustible gas exceeding specified levels should prompt additional investigation.

Condition 2
TCG within this range indicates greater than normal combustible gas level. Any individual combustible gas exceeding specified levels should prompt additional investigation. Action should be taken to establish a trend. Fault(s) may be present.

Condition 3
TCG within this range indicates a high level of decomposition. Any individual combustible gas exceeding specified levels should prompt additional investigation. Immediate action should be taken to establish a trend. Fault(s) are probably present.

Condition 4
TCG within this range indicates excessive decomposition. Continued operation could result in failure of the transformer.

Japanese DGA Criteria

According to Electric Technology Research Association (Japan) criteria

Gas	Caution 1 level	Caution 2 level	Abnormal level
CO2	As deterioration diagnosis		
CO	≧ 300	(1) C_2H_2 : ≧ 0.5 or (2) Both C_2H_4 : ≧ 10 and TCG : ≧ 500	(1) C_2H_2 : ≧ 5 or (2) Both C_2H_4 ≧ 100 & TCG at least 700 or (3) Both C_2H_4 ≧ 100 & TCG increase ≧ 70 ppm/month
H_2	≧ 400		
CH_4	≧ 100		
C_2H_6	≧ 150		
C_2H_4	≧ 10		
C_2H_2	-		
TCG*	≧ 500		

Caution 1 : The level that transformer is out of normal condition although it is not judged to be abnormal and dangerous condition

Caution 2 : The level that transformer becomes abnormal condition gradually

Abnormal : The level that transformer is clearly abnormal condition. (aggravating further from Caution 2 level)

CO+CO2 analysis & Furfural analysis

1. Principle

- Various organic substances are produced by chemical changes of the cellulose.
- Cellulose is main ingredient of insulation paper and is indicator of insulation paper strength. (Insulation paper strength = DP)

Inorganic	H_2O, CO, CO_2
Hydrocarbon	Methane, ethane, propane, propylene
Alcohol	Ethyl alcohol, furfuryl alcohol
Aldehyde/ Ketone	Acetaldehyde, furfural, 5-methylfurfural, 5-hydroxymethyl-2-furfural, acetone, methyl ethyl ketone
Acid	Formic acid, 2-furan carboxylic acid, acidum tartaricum, butyric acid
Others	Furan methyl carboxylic acid, acetic ether ($CH_3COOC_2H_5$), furan (C_4H_4O), 2-acetyl furan

▭ Deep relation with insulation paper strength = DP

CO,CO2 and Furfural are closely related with insulation paper strength
Remaining life diagnosis is conducted with the relation.

NTPC current status & NTPC criteria

NTPC current status

NTPC has not introduced CO+CO2 analysis yet.
NTPC has introduced furfural analysis recently.

NTPC criteria

(1) DP criterion

	NTPC criterion	Japanese criterion
Ave. DP of RLA	200	450

According to Japanese technical book, when the Ave. DP of transformer insulation paper is from 150 to 250, the insulation paper might be broken by even normal electromagnetic force which occurs by transformer energizing inrush current.

(2) Furfural conversion formula

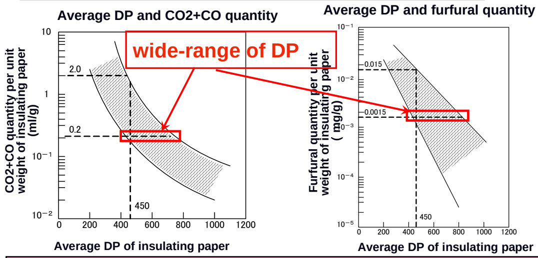
NTPC utilizes conversion formula of EPRI as NTPC manual.

Log(Furfural density)＝1.51－0.0035×Ave. DP

Japanese criteria of CO+CO2, furfural analysis

Japanese criteria

	Caution level	Dangerous level
CO2+CO analysis	0.2 (ml/g)	2.0 (ml/g)
Furfural analysis	0.0015 (mg/g)	0.015 (mg/g)



CO+CO2 analysis: (CO+CO2 volume)/(insulation paper weight)
Furfural analysis: (furfural weight)/(insulation paper weight)

The reasons for the wide-range of DP

The criteria of CO+CO2 analysis and furfural analysis are developed from actual DP measurement of Japanese transformer (Tr)

But the insulation paper weight varies between transformers even if the capacity, specification are the same.

When (CO+CO2 or furfural) per insulation paper weight is the same, Tr with less insulation paper weight has less lifetime than Tr with more insulation paper weight.

That is one of the reasons for the wide-range of DP.

And initial DP is different between transformers (mainly because of the OEM quality)

Tr with lower initial DP reach lifetime faster than Tr with higher initial DP.

That is one of the reasons for the wide-range of DP.

Requirements and precondition for CO+CO2 analysis

(12)

Requirements for CO+CO2 analysis

	Required Items	Unit	Remarks
A1	Accumulated CO+CO2 density in insulation oil	vol ppm (mL/kL)	With measurement date Multiple test results are required for RLA Accurate oil treatment historical records are required.
A2	Insulation oil volume	kL	A2 or (A3/A4) is required
A3	Insulation oil weight	kg	A2 or (A3/A4) is required
A4	Insulation oil gravity	g/mL	
A5	Insulation paper weight	kg	Not including press board weight
A6	History of insulation oil treatment		Inc. oil change, filtration, deaeration

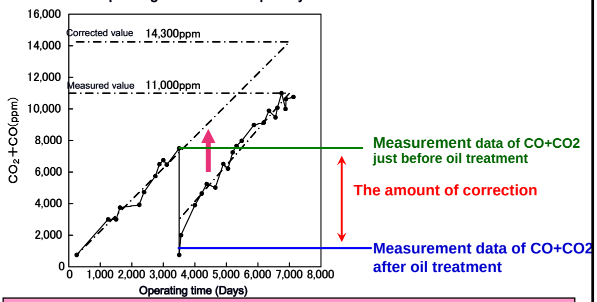
Precondition

Transformer must be sealed type

When insulation oil treatment is conducted, CO and CO2 remove from insulation oil. CO+CO2 analysis requires accumulated CO+CO2. Therefore, CO+CO2 analysis requires the history of insulation oil treatment.

Correction of accumulated CO+CO2

(13)



When insulation oil treatment is conducted, CO and CO2 remove from insulation oil. Therefore, Correction of accumulated CO+CO2 is required for the analysis

How to calculate the data for CO+CO2 analysis

(14)

Step 1: Calculate CO+CO2 volume in oil

CO+CO2 in oil (B1: mL)
=(Measurement data of CO+CO2)(A1:vol ppm)×
(insulation oil volume)(A2:kL)

Step 2: Calculate CO+CO2 per insulation paper weight

CO+CO2 per insulation paper weight (C1:mL/g)
=CO+CO2 in oil (B1: mL) / (insulation paper weight)(A5: g)

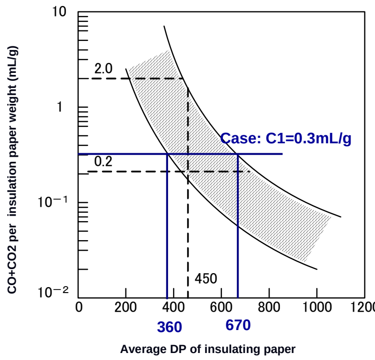
Step 3: Correction of accumulated CO+CO2 per insulation paper weight

Implement the correction of accumulated CO+CO2 when insulation oil treatment has been conducted,

Please pay attention for matching "unit".

DP estimation by CO+CO2 analysis

(15)



When CO+CO2 per Insulation paper weight =0.3(mL/g), DP estimation is from 360 to 670.

Requirements and precondition for furfural analysis

(16)

Requirements for furfural analysis

	Required Items	Unit	Remarks
A1	Furfural density in insulation oil	mg/L	With measurement date Multiple test results are required for RLA
A2	Insulation oil volume	L	A2 or (A3/A4) is required
A3	Insulation oil weight	kg	A2 or (A3/A4) is required
A4	Insulation oil gravity	g/mL	
A5	Insulation paper weight	kg	Not including press board weight
A6	History of insulation oil change		Even when insulation treatments excluding oil change are implemented, furfural remains in insulation oil.

Precondition

No absorbent in insulation oil

Even when insulation treatments excluding oil change are implemented, furfural remains in insulation oil.

How to calculate the data for furfural analysis

(17)

Step 1: Calculate furfural in oil

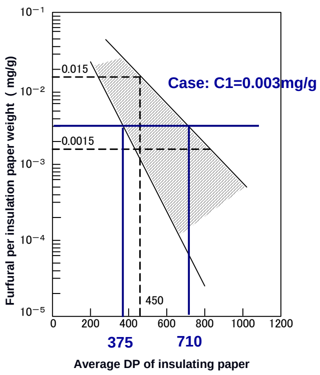
Furfural in oil (B1: mg)
=(Measurement data of furfural)(A1:mg/L)×
(insulation oil volume)(A2:L)

Step 2: Calculate furfural per insulation paper weight

Furfural per insulation paper weight (C1:mg/g)
=Furfural in oil (B1: mg) / (insulation paper weight)(A5:g)

Please pay attention for matching "unit".

4. DP estimation



When furfural per insulation paper weight =0.003(mg/g), DP estimation is from 375 to 710.

Korba#6 assessment

Korba#6 DGA data

DGA results (R phase)

Date	Months from last test	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Apr-1990		387	3	0	2	51	0	34	47	477		Abnormal level *1
Nov-1990	7.0	11	8	0	0	0	0	82	819	101	-53.7	
Feb-1995	52.1	80	17	0	30	0	10	15	1723	152	1.0	
Sep-1995	6.7	75	16	0	22	0	23	10	1855	146	-0.9	
Jun-2000	58.1	85	56	50	58	0	28	381	2853	658	8.8	Caution level-2
Oct-2000	4.4	84	54	52	84	0	12	398	3606	684	6.0	Caution level-2
Jul-2005	57.8	20	60	22	66	0	28	450	3810	646	-0.7	Caution level-2
Oct-2005	2.6	16	70	20	70	0	30	440	3890	646	0.0	Caution level-2
Jan-2006	2.9	42	60	16	67	0	25	420	3710	630	-5.5	Caution level-2
Apr-2006	3.5	32	62	2	118	0	60	262	4135	536	-26.9	Caution level-1
Jul-2006	3.1	23	15	1	50	0	10	130	1906	229	-99.0	
Oct-2006	2.6	29	24	1	26	0	8	128	1903	216	-4.9	
Apr-2007	6.6	16	30	2	38	0	5	91	1597	182	-5.2	
Jul-2007	2.3	12	42	0	45	0	10	75	2062	184	0.9	
Oct-2007	3.2	102	24	0	31	0	9	34	1394	200	4.9	
Dec-2007	1.8	91	35	0	51	0	12	43	2111	232	17.8	
Mar-2008	3.1	70	30	0	29	0	8	40	1922	177	-17.6	
Aug-2008	5.3	60	20	0	25	0	7	25	1229	137	-7.5	
Dec-2008	4.1	41	13	1	21	0	18	45	1084	139	0.5	
Feb-2009	1.9	30	11	0	40	0	15	98	1191	194	28.4	

Korba#6 DGA data

DGA results (Y phase)

Date	Months from last test	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Apr-1990		40	0	0	0	0	0	16	412	56		
Nov-1990	7.0	31	0	0	0	0	0	42	1148	73	2.4	
Feb-1995	52.1	0	15	4	27	0	0	5	2914	51	-0.4	
Sep-1995	6.6	10	15	10	26	0	15	43	3200	119	10.3	Caution level-1
May-2000	57.0	55	95	1	61	0	16	275	4744	503	6.7	Caution level-1
Nov-2000	5.9	55	93	2	61	0	12	290	4822	513	1.7	Caution level-1
Jul-2005	57.3	23	90	3	145	0	45	320	4405	626	2.0	Caution level-1
Oct-2005	2.6	30	80	5	140	0	40	330	4390	625	-0.4	Caution level-1
Jan-2006	2.9	40	70	3	130	0	75	290	4210	608	-5.8	Caution level-1
Apr-2006	3.5	30	62	2	113	0	56	262	4130	525	-23.7	Caution level-1
Jul-2006	3.1	20	30	1	30	0	15	120	2310	216	-99.7	
Oct-2006	2.6	30	27	1	27	0	13	115	2196	213	-1.1	
Jan-2007	2.8	21	23	1	44	0	14	109	2233	212	-0.4	
Jul-2007	6.1	5	51	0	49	0	17	149	3331	271	9.7	
Oct-2007	3.2	12	31	1	49	0	13	73	3044	179	-28.5	
Jan-2008	3.7	80	81	0	80	0	27	205	3310	473	80.2	
May-2008	3.1	53	73	13	74	0	24	191	3160	428	-14.7	Caution level-1
Jul-2008	2.9	61	14	0	16	0	15	61	1259	167	-91.0	
Jan-2009	6.0	42	16	1	66	0	32	91	2013	248	13.5	
Mar-2009	1.8	33	49	0	65	0	25	103	2291	275	15.3	
Oct-2008	-5.0	51	21	1	19	0	12	82	1311	186	17.9	

Korba#6 DGA data

DGA results (B phase)

Date	Months from last test	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Apr-1990		44	3	0	0	0	0	123	650	170		
Nov-1990	7.0	25	10	0	0	0	0	67	904	102	-9.7	
Mar-2000	113.3	95	60	55	68	0	40	390	4460	708	5.3	Caution level-2
Jun-2000	3.5	95	65	52	68	0	42	393	4492	715	2.0	Caution level-2
Sep-2000	3.0	93	68	50	69	0	40	398	4510	718	1.0	Caution level-2
Jul-2005	59.2	25	75	22	116	0	136	440	5495	814	1.6	Caution level-2
Oct-2005	2.6	30	70	20	110	0	130	460	5425	820	2.3	Caution level-2
Jan-2006	2.9	44	60	15	102	0	20	450	5390	691	-44.0	Caution level-2
Apr-2006	3.5	40	53	13	93	0	16	430	5210	645	-13.1	Caution level-2
Jul-2006	3.1	20	22	3	50	0	11	190	2410	296	-112.6	
Oct-2006	2.6	33	22	1	37	0	17	180	2330	290	-2.3	
Jan-2007	2.8	26	24	0	33	0	12	170	2243	265	-8.9	
Jul-2007	6.1	12	56	0	58	0	19	139	3092	284	3.1	
Oct-2007	3.2	108	30	0	41	0	12	47	2003	238	-14.2	
Dec-2007	1.8	93	71	0	76	0	24	154	2324	418	100.0	
Mar-2008	3.0	63	51	0	66	0	10	104	2065	294	-41.3	
May-2008	2.6	53	50	2	80	0	32	101	1475	318	9.2	
Jul-2008	2.2	61	11	2	61	0	30	183	2010	348	13.6	
Oct-2008	2.8	55	8	2	81	0	12	175	2117	333	-5.4	
Jan-2009	2.6	39	8	1	54	0	21	171	2243	294	-15.2	

Assessment of DGA results

R phase

Each analyzed gas has had no big change and been less than the judgment criteria recently, although C2H4, CO, TCG had become Caution level-1 or Caution level-2 from 2000 to 2006. Therefore, the transformer is assessed as normal condition.

Y phase

Each analyzed gas has had no big change and been less than the judgment criteria recently, although CO, C2H2, TCG had become Caution level-1 mainly from 2000 to 2006. Therefore, the transformer is assessed as normal condition.

B phase

Each analyzed gas has had no big change and been less than the judgment criteria recently, although C2H4, CO, TCG had become Caution level-1 or Caution level-2 from 2000 to 2006.Therefore, the transformer is assessed as normal condition.

Obtained data for CO+CO2 analysis from Korba#6

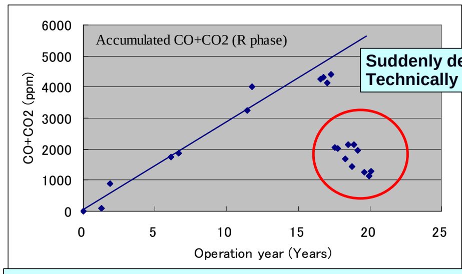
	Required Items	Unit	Data
A1	Accumulated CO+CO2 density in insulation oil	vol ppm (mL/kL)	Next page
A2	Insulation oil volume	kL	23.4
A3	Insulation oil weight	kg	—
A4	Insulation oil gravity	g/mL	—
A5	Insulation paper weight	kg	303
A6	History of insulation oil treatment		Nil

Sealed performance is good and Korba#6 has not conducted oil treatment.

Therefore, correction of accumulated CO+CO2 is not required.

Accumulated CO+CO2 = CO+CO2 measurement data

Accumulated CO+CO2 in oil (R phase)



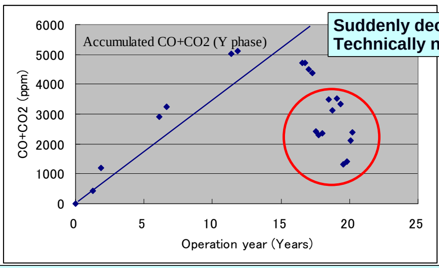
Suddenly decline
Technically not consistent

Korba#6 GT is sealed type and the CO+CO2 technically increases as it operate.

Red circled data are unreliable.

Therefore, The assessment is conducted using reliable data only. (excluding red circled data)

Accumulated CO+CO2 in oil (Y phase)



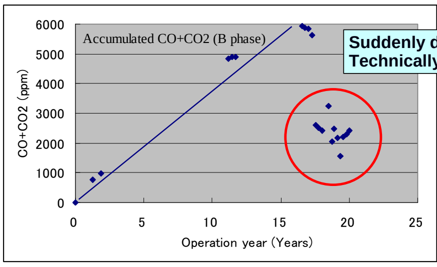
Suddenly decline
Technically not consistent

Korba#6 GT is sealed type and the CO+CO2 technically increases as it operate.

Red circled data are unreliable.

Therefore, The assessment is conducted using reliable data only. (excluding red circled data)

Accumulated CO+CO2 in oil (B phase)



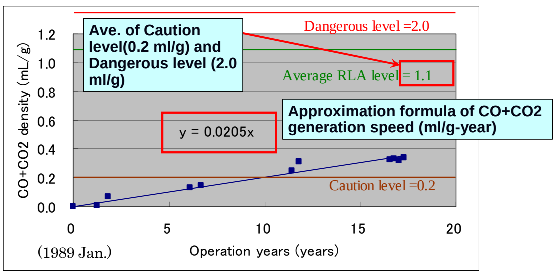
Suddenly decline
Technically not consistent

Korba#6 GT is sealed type and the CO+CO2 technically increases as it operate.

Red circled data are unreliable.

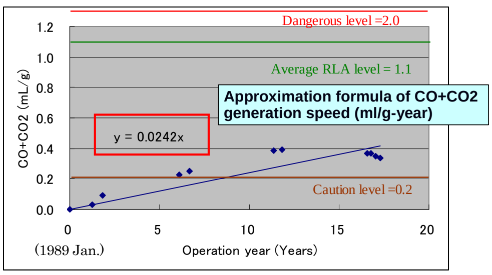
Therefore, The assessment is conducted using reliable data only. (excluding red circled data)

Estimation of CO+CO2 generation speed (R phase)



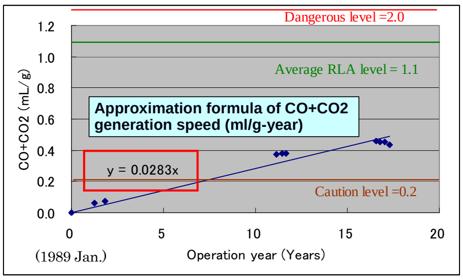
The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

Estimation of CO+CO2 generation speed (Y phase)



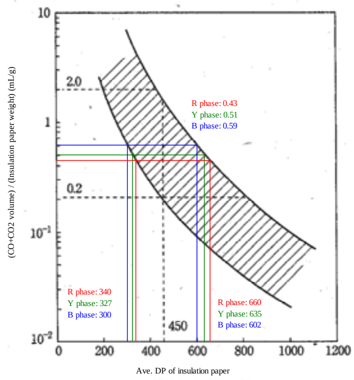
The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

Estimation of CO+CO2 generation speed (R phase) (30)



The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

DP estimation by CO+CO2 analysis (31)



Assessment of CO+CO2 analysis (Korba#6) (32)

		R phase	Y phase	B phase
Trend	CO+CO2 generating speed (mL/g year)	0.0205	0.0242	0.0283
Current condition (Jan 2010)	CO+CO2 (mL/g) (Jan 2010)	0.4305	0.5082	0.5943
	DP	340-660	327-635	300-602
	Evaluation	Caution level	Caution level	Caution level
RLA	Operation years until Ave. lifetime point	53.7	45.5	38.9
	Estimating year to Ave. lifetime point	2042 Sep.	2034 Jul.	2027 Dec.

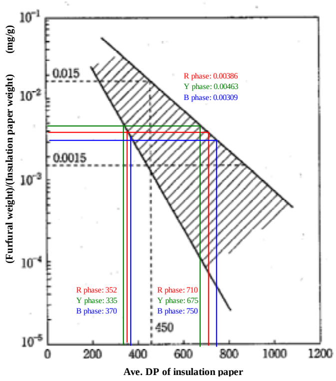
Obtained data for furfural analysis from Korba#6 (33)

	Required Items	Unit	R phase	Y phase	B phase
A1	Furfural density	mg/L	0.05	0.06	0.04
A2	Insulation oil volume	L	23400		
A3	Insulation oil weight	kg	22000		
A4	Insulation oil gravity	g/mL	—		
A5	Insulation paper weight	kg	303		
A6	History of insulation oil change		Nil		

Korba#6 has never implemented the insulation oil change.
The measurement data becomes furfural generating weight from starting operation to furfural measurement day.

Korba#6 has measured furfural once and the RLA by furfural analysis might be unreliable, but the current condition assessment in Jan.-2010 and the RLA is conducted by calculating the furfural generation speed.

DP estimation by furfural analysis (34)



Assessment of furfural analysis (Korba#6) (35)

		R phase	Y phase	B phase
Trend	Furfural generating speed (mg/g year)	0.000185	0.000222	0.000148
Current condition (Jan 2010)	Furfural (mg/g) (Jan 2010)	0.00389	0.00467	0.00312
	DP	352-710	335-675	370-750
	Evaluation	Caution level	Caution level	Caution level
RLA	Operation years until Ave. lifetime point	44.5	37.1	55.7
	Estimating year to Ave. lifetime point	Jul-2033	Feb-2026	Aug-2044

Recommendations for Korba#6

1. **Accurate measurement**

   It is recommended that Korba#6 get the proper test data.

2. **Conducting furfural analysis in the future**

   Korba#6 has conducted the test only once. It recommended that Korba#6 continue to conduct the test periodically so that Korba#6 can grasp furfural generation trend and improve the accuracy of the RLA.

Rihand#2 assessment

Rihand#2 DGA data

DGA results (R phase)

Date	Months from last test	H2	CH4	C2H4	C2H6	C2H2	C3H8	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Jan-1989		**Start operation**										
Oct-1991	34.3	15	5	2	5	0	0	32	326	59	1.7	
Jul-1995	45.0	42	5	5	1	0	0	40	533	93	0.8	
Jan-1996	6.1	40	5	3	5	0	7	37	563	97	0.7	
Jun-1996	5.4	**Oil filtration**										
Jun-1999	36.3	40	45	22	20	0	10	120	450	260	7.2	Caution level-1
Dec-1999	6.3	**Oil filtration**										
Feb-2000	2.5	25	3	4	3	0	4	82	292	120	48.0	
Aug-2001	17.3	20	57	1	15	0	10	238	1087	341	12.8	
Aug-2001	0.7	**Oil filtration**										
Jul-2002	11.1	10	42	6	18	0	8	302	1165	386	34.9	Caution level-1
Sep-2002	2.4	**Oil filtration**										
Sep-2005	36.3	55	12	0	8	0	2	147	810	224	6.2	
Sep-2005	0.1	**Oil filtration**										
Aug-2007	23.4	29	19	0	7	0	1	246	2005	285	12.2	
Oct-2007	2.0	**Oil filtration**										
Nov-2007	1.0	5	0	1	1	0		101	474	112	112.0	Abnormal level
Mar-2008	3.1	23	10	1	1	0	1	310	468	346	74.7	Abnormal level
Jun-2008	3.2	15	18	0	0	0	0	120	387	153	-60.3	
Sep-2008	3.2	25	10	0	2	0	1	139	767	177	7.5	
Dec-2008	3.0	45	8	5	4	0	9	121	832	192	4.9	
Mar-2009	3.0	40	5	2	1	0	1	111	805	160	-10.5	

Korba#6 DGA data

DGA results (Y phase)

Date	Months from last test	H2	CH4	C2H4	C2H6	C2H2	C3H8	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Jan-1989	-	**Start operation**										
Jul-1991	-	22	5	0	0	0	0	91	607	118	-	
Dec-1994	41.4	26	0	1	4	0	0	55	1355	86	-0.8	
Aug-1995	8.4	**Oil filteration**										
Oct-1995	2.0	20	0	0	0	0	0	0	198	20	10.0	
Aug-1997	22.2	20	25	10	22	0	13	16	350	106	3.9	Caution level-1
Sep-1997	1.2	**Oil filteration**										
Aug-1999	23.0	87	40	2	18	0	10	136	719	293	12.7	
Dec-1999	4.3	**Oil filteration**										
Sep-2000	9.7	10	0	0	0	0	0	33	353	43	4.4	
Jul-2002	21.9	17	50	1	7	0	13	305	1220	393	16.0	Caution level-1
Sep-2002	2.4	**Oil filteration**										
Sep-2005	36.3	15	20	2	3	0	0	230	1120	270	7.4	
May-2006	7.6	**Oil filteration**										
Aug-2006	3.1	62	16	1	1	0	0	80	650	160	51.1	
Nov-2007	15.8	10	15	1	3	0	1	185	474	215	3.5	
Mar-2008	3.1	11	10	1	2	0	1	110	459	135	-25.5	
Jun-2008	3.2	10	15	0	0	0	0	90	235	115	-6.3	
Sep-2008	3.2	40	11	0	4	0	2	134	952	191	23.8	
Dec-2008	3.0	65	9	0	2	0	1	123	991	200	3.0	
Mar-2009	3.0	24	7	1	0	0	1	109	834	142	-19.1	

Korba#6 DGA data

DGA results (B phase)

Date	Months from last test	H2	CH4	C2H4	C2H6	C2H2	C3H8	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Aug-1991	-	32	4	0	4	0	0	181	835	237		
Dec-1994	40.6	25	0	3	1	0	20	60	1087	109	-3.2	
Aug-1995	8.4	**Oil filteration**										
Jan-1996	5.3	10	0	0	6	0	5	0	253	21	3.9	
Aug-1997	18.8	35	82	35	34	0	70	133	1473	389	19.5	Caution level-1
Sep-1997	1.2	**Oil filteration**										
Nov-1999	26.3	74	75	3	29	0	13	152	1164	346	13.2	
Dec-1999	1.1	**Oil filteration**										
Aug-2001	19.8	15	22	5	21	0	2	198	1401	263	13.3	
Jul-2002	11.8	32	73	0	47	0	6	142	950	300	3.1	
Sep-2002	2.4	**Oil filteration**										
Jul-2003	9.5	50	13	0	10	0	8	109	627	190	20.1	
Sep-2003	2.3	**Oil filteration**										
Jun-2006	33.0	90	8	4	8	0	0	80	302	190	5.8	
Nov-2007	18.2	12	3	2	4	0	1	15	362	37	-8.4	
Mar-2008	3.1	11	5	0	1	0	1	26	390	44	2.2	
Jun-2008	3.2	35	5	0	0	0	0	31	254	71	8.4	
Sep-2008	3.2	60	7	1	6	0	1	42	251	117	14.4	
Dec-2008	3.0	41	5	0	4	0	1	48	424	99	-5.9	
Mar-2009	3.0	31	3	0	0	0	0	46	455	80	-6.3	

Assessment of DGA results (Rihand#2)

R phase

The TCG increase ratio had become Dangerous level in Nov. 2007 and Mar.-2008. Nov.-2007 is just after conducting filtration treatment of the insulation oil. Therefore, maybe the TCG remained in the oil without removing the TCG sufficiently. In addition, because each analyzed gas has had no big change and been less than the judgment criteria recently, the transformer is assessed as normal condition.

Y phase

Each analyzed gas has had no big change and been less than the judgment criteria recently, although C2H4 (Aug-1997) and CO (Jul-2002) had become Caution level-1.Therefore, the transformer is assessed as normal condition.

B phase

Each analyzed gases has had no big change and been less than the judgment criteria recently, although C2H4 (Aug-1997) had become Caution level-1.Therefore, the transformer is assessed as normal condition.

Obtained data for CO+CO2 analysis from Rihand#2 (42)

	Required Items	Unit	Data	Remarks
A1	Accumulated CO+CO2 density in insulation oil[*1]	vol ppm (mL/kL)	Refer to next Table	
A2	Insulation oil volume	kL	37800	
A3	Insulation oil weight	Kg	32432	
A4	Insulation oil gravity	g/mL	-	
A5	Insulation paper weight	Kg	(305.5)	Precondition
A6	History of insulation oil treatment		Refer to next Table blue marked	

Insulation paper weight is essential for conducting CO+CO2 analysis. But it is not available in Rihand#2 GT. The insulation paper weight is estimated by utilizing Korba#6 GT data

Sealed performance is bad and Rihand#2 has conducted oil treatment often.
Therefore, correction of accumulated CO+CO2 is required.

Obtained data for CO+CO2 analysis from Rihand#2 (43)

R phase

Date	Operation years	CO+CO2 (ppm)	Accumulated CO+CO2	Gap with last test	CO+CO2 (mL/g)	Remarks
Jul-1989	0.0	0	0	0	0.000	Initial data
Oct-1991	2.3	358	358	358	0.044	
Jul-1995	6.0	573	573	215	0.071	
Jan-1996	6.5	600	600	27	0.074	
Jun-1996	7.0	759	759	159		Correction
Jun-1996	7.0	0	759	0	0.094	Filtering
Jun-1999	9.9	570	1,329	570	0.164	
Dec-1999	10.5	758	1,517	188		Correction
Dec-1999	10.5	0	1,517	0	0.188	Filtering
Feb-2000	10.7	374	1,891	374	0.234	
Aug-2001	12.1	1325	2,842	951	0.352	
Aug-2001	12.2	1346	2,863	21		Correction
Aug-2001	12.2	0	2,863	0	0.354	Filtering
Jul-2002	13.1	1467	4,330	1,467	0.536	
Sep-2002	13.3	1538	4,401	71		Correction
Sep-2002	13.3	0	4,401	0	0.545	Filtering
Sep-2005	16.2	957	5,358	957	0.663	
Sep-2005	16.3					
Aug-2007	18.2					
Oct-2007	18.3					
Oct-2007	18.3					
Nov-2007	18.4					
Mar-2008	18.7					
Jun-2008	18.9					
Sep-2008	19.2					

When oil filtration is conducted, CO, CO2 in oil are moved away (Measurement =0)

CO+CO2 generating speed=363ppm/year

Long span from oil filtration to the previous test
Correction is conducted considering the CO+CO2 increase during the span.
Correction=Ave. generation speed × the span

Despite sealed type, oil treatment has been conducted so often.

Obtained data for CO+CO2 analysis from Rihand#2 (44)

Y phase

Date	Operation years	CO+CO2 (ppm)	Accumulated CO+CO2 (ppm)	Gap with last test	CO+CO2 (mL/g)	Remarks
Jul-1989	0.0	0	0	0	0.000	Initial data
Jul-1991	2.0	698	698	698	0.086	
Dec-1994	5.4	1410	1410	712	0.174	
Aug-1995	6.1	1652	1652	242		Correction
Aug-1995	6.1	0	1652	0	0.204	Filtering
Oct-1995	6.3	198	1850	198	0.229	
Aug-1997	8.1	366	2018	168	0.250	
Sep-1997	8.2	401	2053	35		Correction
Sep-1997	8.2	0	2053	0	0.254	Filtering
Aug-1999	10.1	855	2908	855	0.360	
Dec-1999	10.5	979	3032	124		Correction
Dec-1999	10.5	0	3032	0	0.375	Filtering
Sep-2000	11.3	386	3418	386	0.423	
Jul-2002	13.1	1525	4557	1139	0.564	
Sep-2002	13.3	1593	4625	68		Correction
Sep-2002	13.3	0	4625	0	0.572	Filtering
Sep-2005	16.2					
May-2006	16.9					
May-2006	16.9					
Aug-2006	17.1					
Nov-2007	18.4					
Mar-2008	18.7					
Jun-2008	18.9					
Sep-2008	19.2					

When oil filtration is conducted, CO, CO2 in oil are moved away (Measurement =0)

CO+CO2 generating speed=352ppm/year

Long span from oil filtration and the previous test
Correction is conducted considering the CO+CO2 increase during the span.
Correction=Ave. generation speed × the span

Despite sealed type, oil treatment has been conducted so often.

Obtained data for CO+CO2 analysis from Rihand#2 (45)

B phase

Date	Operation years	CO+CO2 (ppm)	Accumulated CO+CO2 (ppm)	Gap with last test	CO+CO2 (mL/g)	Remarks
Jul-1989	0.0	0	0	0	0.000	Initial data
Aug-1991	2.1	1,016	1,016	1,016	0.126	
Dec-1994	5.4	1,147	1,147	131	0.142	
Aug-1995	6.1	1,413	1,413	266		Correction
Aug-1995	6.1	0	1,413	0	0.175	Filtering
Jan-1996	6.6	253	1,666	253	0.206	
Aug-1997	8.1	1,606	3,019	1353	0.374	
Sep-1997	8.2	1,645	3,058	39		Correction
Sep-1997	8.2	0	3,058	0	0.378	Filtering
Nov-1999	10.4	1,316	4,374	1316	0.541	
Dec-1999	10.5	1,351	4,409	35		Correction
Dec-1999	10.5	0	4,409	0	0.546	Filtering
Aug-2001	12.1	1,599	6,008	1599	0.743	
Jul-2002	13.1	1,092	5,501	-507	0.681	
Sep-2002	13.3	1,168	5,577	76		Correction
Sep-2002	13.3					
Jul-2003	14.0					
Sep-2003	14.2					
Sep-2003	14.2					
Jun-2006	16.9					
Nov-2007	18.4					
Mar-2008	18.7					
Jun-2008	18.9					
Sep-2008	19.2	293	6,679	8	0.826	

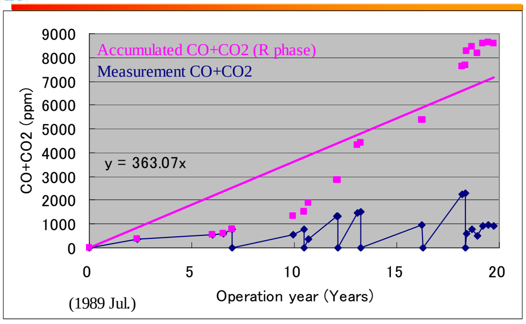
When oil filtration is conducted, CO, CO2 in oil are moved away (Measurement =0)

CO+CO2 generating speed=385ppm/year

Long span from oil filtration and the previous test
Correction is conducted considering the CO+CO2 increase during the span.
Correction=Ave. generation speed × the span

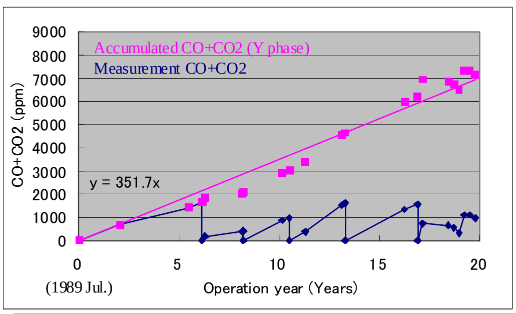
Despite sealed type, oil treatment has been conducted so often.

CO+CO2 generation in oil (R phase) (46)



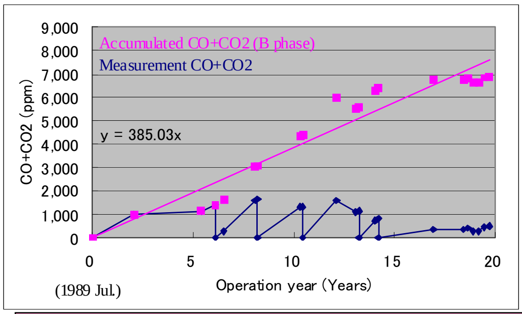
There is no big fluctuation in the data and the graph is consistent with the technical theory, although the data fluctuate a little bit.

CO+CO2 generation in oil (Y phase) (47)



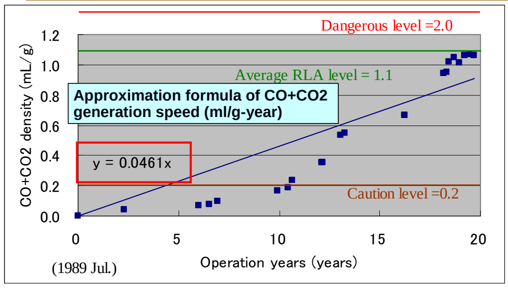
There is no big fluctuation in the data and the graph is consistent with the technical theory, although the data fluctuate a little bit.

CO+CO2 generation in oil (B phase) 48



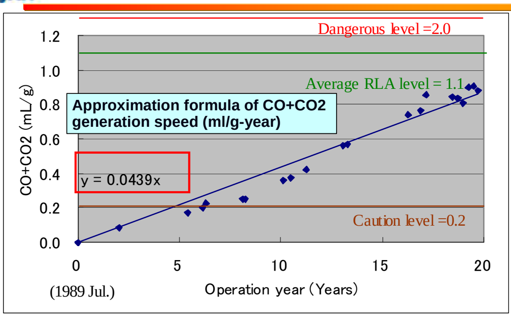
There is no big fluctuation in the data and the graph is consistent with the technical theory, although the data fluctuate a little bit.

Estimation of CO+CO2 generation speed (R phase) 49



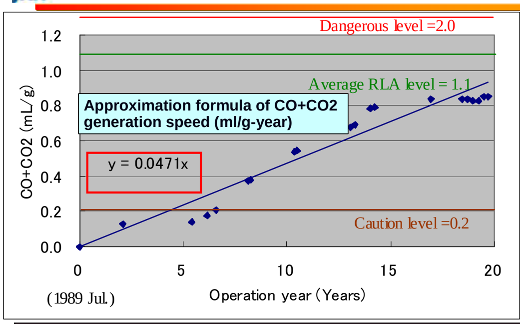
The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

Estimation of CO+CO2 generation speed (Y phase) 50



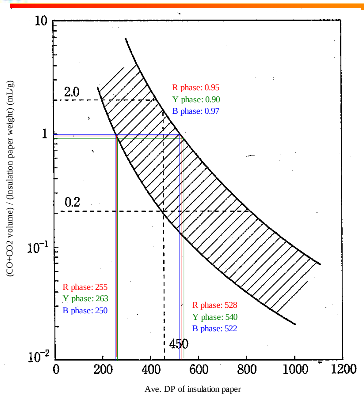
The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

Estimation of CO+CO2 generation speed (B phase) 51



The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

DP estimation by CO+CO2 analysis 52



Assessment of CO+CO2 analysis (Rihand#2) 53

		R phase	Y phase	B phase
Trend	CO+CO2 generating speed (mL/g year)	0.0461	0.0439	0.0471
Current condition (Jan 2010)	CO+CO2 (mL/g)	0.95	0.90	0.97
	DP	255-528	263-540	250-522
	Evaluation	Caution level	Caution level	Caution level
RLA	Operation years until Ave. lifetime point	23.9	25.1	23.4
	Estimating year to Ave. lifetime point	May-2013	Jul-2014	Nov-2012

Although transformer lifetime is approximately 40~50 years generally in Japanese power plant, Rihand#2 GTs lifetimes are estimated to be short relatively.

Obtained data for furfural analysis from Rihand#2

54

	Required Items	Unit	R phase	Y phase	B phase
A1	Furfural density	mg/L	1.14	0.5	0.5
A2	Insulation oil volume	L	37800		
A3	Insulation oil weight	kg	32432		
A4	Insulation oil gravity	g/mL	—		
A5	Insulation paper weight	kg	(305.5)		
A6	History of insulation oil change		Nil		

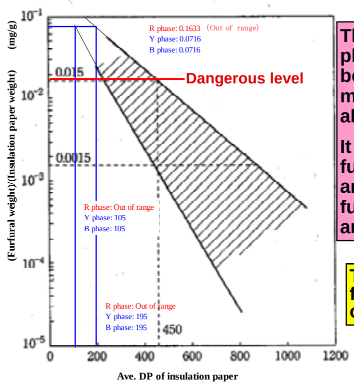
Insulation paper weight is essential for conducting furfural analysis. But it is not available in Rihand#2 GT. The insulation paper weight is estimated by utilizing Korba#6 GT data

Rihand#2 has never implemented the insulation oil change and the measurement data becomes furfural generating weight from starting operation to furfural measurement day.

Rihand#2 has measured furfural once and the RLA by furfural analysis might be unreliable, but the current condition assessment in Jan.-2010 and the RLA is conducted by calculating the furfural generation speed.

DP estimation by furfural analysis

55



The lifetime at all the phases had already passed because the furfural measurement data are abnormally high.

It is estimated that the furfural measurement data are unreliable because the furfural measurement data are abnormally high.

The assessment by furfural analysis is omitted.

Recommendations for Rihand#2

56

1. Grasp current condition and deterioration trend

It is difficult for JICA-ST to judge whether GT deteriorates actually.

Sampling the insulation paper actually and measuring the DP are effective measures for confirming that. But sampling the insulation paper actually is difficult for many power plants. When it is difficult for Rihgand#2 to sample the insulation paper, it is recommended the followings.

- Shorten the cycle of conducting DGA
- Evaluate furfural analysis by accurate and reliable measurement data.

It is essential for NTPC to consult with OEM before taking the actions/countermeasures.

Recommendations for Rihand#2

57

2. Accurate measurement

The furfural measurement data are abnormally high.

It is recommended thatRihand#2 get the proper and accurate data.

3. Moisture in oil

Rihand#2 is required to implement insulation treatment so often due to moisture in the insulation oil although Rihand#2 GTs are sealed type.

Study team is wondering that there is some seal-break at the insulation oil cooler. it is recommended that Rihand#2 should conduct the cooler leak check and take the countermeasures if there is a leak.

58

Singrauli#6 assessment

Singrauli#6 DGA data

59

DGA results (R phase)

Date	from last test	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1		≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2				≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level				≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Mar 2000	**Oil filtering**											
Apr 2000	-	7	3	3	2	0	2	9	199	26		
Jul 2000	3.0	29	12	15	11	0	5	33	512	105	26.0	Caution level-1
Jan 2001	6.1	25	57	44	31	0	31	89	807	277	28.0	Caution level-1
Dec 2001	11.1	32	109	72	50	0	52	202	1586	517	21.6	Caution level-1
May 2002	**Oil filtering**											
Jun 2002	6.1	10	5	7	4	0	3	38	635	67	11.0	
Oct 2002	4.1	30	15	40	45	0	15	95	810	240	42.5	Caution level-1
Jun 2004	20.3	30	63	44	31	0	16	109	790	293	2.6	Caution level-1
Jan 2005	7.1	20	52	50	31	0	15	139	908	307	2.0	Caution level-1
May 2005	4.0	70	60	60	42	0	20	80	892	332	6.3	Caution level-1
Jan 2006	8.2	27	15	62	53	0	5	81	835	243	-10.9	Caution level-1
Apr 2006	3.0	40	32	66	52	0	25	105	1110	320	25.7	Caution level-1
Jun 2006	**Oil filtering**											
Dec 2006	8.1	33	8	5	7	0	2	61	343	116	14.3	
May 2007	5.0	20	26	32	26	0	18	51	535	173	11.3	Caution level-1
Nov 2008	18.3	61	50	25	21	0	12	76	666	245	3.9	Caution level-1
Feb 2009	3.1	62	26	11	22	0	19	87	787	227	-5.9	Caution level-1

Assessment of DGA results (Singrauli#6R) (60)

The C2H4 has become Caution level-1 continuously. Because the TCG increase ratio has had no big change, the transformer is estimated to have no serious problem.

But it is recommended that Singrauli#6 should continue to conduct DGA in relatively short term and grasp the trend because it is Caution level-1.

Obtained data for CO+CO2 analysis from Singrauli#6 (61)

	Required Items	Unit	Data	Remarks
A1	Accumulated CO+CO2 density in insulation oil	vol ppm (mL/kL)		
A2	Insulation oil volume	kL	31.719	
A3	Insulation oil weight	kg	27500	
A4	Insulation oil gravity	g/mL	0.867	
A5	Insulation paper weight	kg	(303)	Precondition
A6	History of insulation oil treatment		Refer to Table 8.4.6-39 blue marked	

Insulation paper weight is essential for conducting CO+CO2 analysis. But it is not available in Singrauli#6 GT. The insulation paper weight is estimated by utilizing Korba#6 GT data

Sealed performance is bad and Rihand#2 has conducted oil treatment often.

Therefore, correction of accumulated CO+CO2 is required.

Obtained data for CO+CO2 analysis from Singrauli#6 (62)

Singrauli #6R GT started operation in 1987 Jul. But there is no test data until 2000 Mar.

Date	Operation years	CO+CO2 (ppm)	Accumulated CO+CO2 (ppm)	Gap with last test	CO+CO2 (mL/g)	Remarks
Mar-2000	0	0	0	-	0.0000	Filtering
Apr-2000	0.04	208	208	208	0.0218	
Jul-2000	0.29	545	545	337	0.0571	
Jan-2001	0.80	896	896	351	0.0938	
Dec-2001	1.71	1788	1788	892	0.1872	
May-2002	2.12	2017	2017	229	0.2111	Correction
May-2002	2.13	0	2017	0	0.2111	Filtering
Jun-2002	2.21	673	2690	673	0.2816	
Oct-2002	2.55	905	2922	232	0.3059	
Jun-2004	4.22	899	2916	-6	0.3053	
Jan-2005	4.80	1047	3064	148	0.3207	
May-2005	5.13	972	2989	-75	0.3129	
Jan-2006	5.80	916	2933	-56	0.3070	
Apr-2006	6.05	1215	3232	299	0.3383	
Jun-2006	6.21	1307	3324	92	0.3479	Correction
Jun-2006	6.21	0	3324	0		Filtering
Dec-2006	6.72	404				
May-2007	7.13	586				
Nov-2008	8.64	742				
Feb-2009	8.89	874				

When oil filtration is conducted, CO, CO2 in oil are moved away (Measurement =0)

CO+CO2 generating speed=557ppm/year

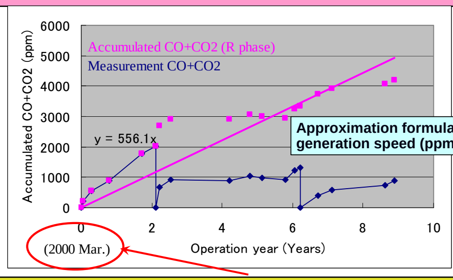
Long span from oil filtration and the previous test

Correction is conducted considering the CO+CO2 increase during the span.

Correction=Ave. generation speed × the span

CO+CO2 generation in oil (R phase) (63)

There is no big fluctuation in the data and the graph is consistent with the technical theory, although the data fluctuate a little bit.

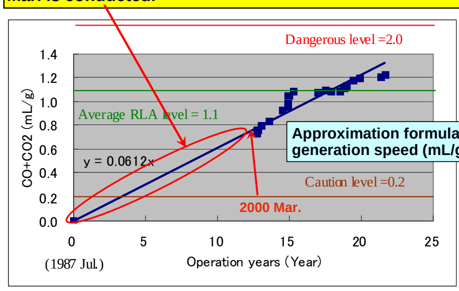


Approximation formula of CO+CO2 generation speed (ppm/year)

Singrauli #6R GT started operation in 1987 Jul. Correction of accumulated CO+CO2 between 1987 Jul. and 2000 Mar. is required.

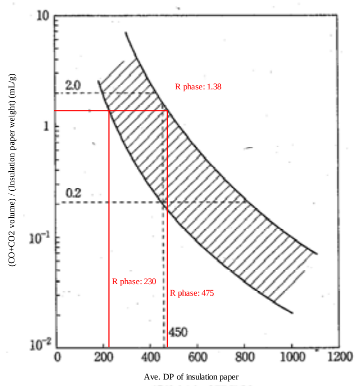
CO+CO2 generation in oil (R phase) (64)

Correction of accumulated CO+CO2 between 1987 Jul. and 2000 Mar. is conducted.



Approximation formula of CO+CO2 generation speed (mL/g-year)

DP estimation by CO+CO2 analysis (S-#6R) (65)



Assessment of CO+CO2 analysis (Singrauli#6R)

66

		R phase
Trend current condition (Jan 2010)	$CO+CO_2$ generating speed (mL/g year)	0.0612
	$CO+CO_2$ (mL/g) (Jan 2010)	1.38
	DP	230-475
	Evaluation	Caution level
	Operation years until Ave. lifetime	18
RLA	Estimating year to Ave. lifetime	Jun-2005
	Operation years until Dangerous level	32.7
	Estimating year to Dangerous level	Sep-2019

Although transformer lifetime is approximately 40~50 years generally in Japanese power plant, Singrauli#6 GT lifetimes are estimated to be short relatively.

Obtained data for furfural analysis from Singrauli#6

67

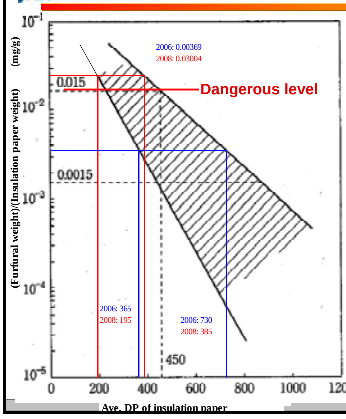
	Required Items	Unit	Data	Remarks
A1	Furfural density (Sep-2006)	mg/L	0.03	1st test
A1	Furfural density (Sep-2008)	mg/L	0.27	2nd test
A2	Insulation oil volume	L	31719	Big gap abnormally
A3	Insulation oil weight	kg	27500	
A4	Insulation oil gravity	g/mL	0.867	
A5	Insulation paper weight	kg	(303)	
A6	History of insulation oil change		Nil	

Insulation paper weight is essential for conducting furfural analysis. But it is not available in Singrauli#6 GT. The insulation paper weight is estimated by utilizing Korba#6 GT data

Singrauli#6 has never implemented the insulation oil change and the measurement data becomes furfural generating weight from starting operation to furfural measurement day.

DP estimation by furfural analysis (S-#6R)

68



The lifetime had already passed because the furfural measurement data are abnormally high. (2008)

It is estimated that the furfural measurement data are unreliable because there is the big gap between 2006 data and 2008 data.

Assessment of furfural analysis (Singrauli#6R)

69

		Sep-2006	Sep-2008
Trend	Furfural generating speed (mg/g year)	0.000164	0.001334
Current condition (Jan 2010)	Furfural (mg/g) (Jan 2010)	0.00369	0.03004
	DP	365-730	195-385
	Evaluation	Caution level	Dangerous level
	Operation years until Ave. RL[*1]	50.4	6.2
RLA	Estimating year to Ave. RL	Nov-2037	Sep-1993
	Operation years until Dangerous level	91.6	11.2
	Estimating year to Dangerous level	Feb-2079	Oct-1998

The lifetime at all the phases had already passed because the furfural measurement data are high. (2008)

The results are unreliable because there is the big gap between 2006 data and 2008 data.

Recommendations for Singrauli#6R

70

1. Grasp current condition and deterioration trend

It is difficult for JICA-ST to judge whether;

- GT deteriorates actually
- The assessment is wrong due to the inaccuracy of the assessment data.

Sampling the insulation paper actually and measuring the DP are effective measures for confirming that. But sampling the insulation paper actually is difficult for many power plants. When it is difficult for Rihgand#2 to sample the insulation paper, it is recommended the followings.

- Shorten the cycle of conducting DGA
- Evaluate furfural analysis by accurate and reliable measurement data.

It is essential for NTPC to consult with OEM before taking the actions/countermeasures.

Recommendations for Singrauli#6

71

2. Accurate measurement

As for the assessment by furfural analysis, there is a big gap of furfural measurement data between 2006's and 2008's. It is recommended that Singrauli#6 get the proper data.

3. Moisture in oil

Singrauli#6 is required to implement insulation treatment so often due to moisture in the insulation oil although Singrauli#6R GT is sealed type.

Study team is wondering that there is some seal-break at the insulation oil cooler. it is recommended that Singrauli#6R GT should conduct the cooler leak check and take the countermeasures if there is a leak.

Recommendations when NTPC purchases a new Oil immersed transformer

Please get the following transformer information from OEM so that NTPC can conduct assessment accurately in the future.

- **Insulation paper weight**
- **Initial DP**

And it is preferable;

- **GT is OFAF, not OFWF, if possible**
  (For preventing moisture from entering to oil)

5. Korba#6 assessment (2010, 3rd year)

Korba#6R DGA Result

Date	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1	≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2			≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level			≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Apr-1990	387	3	0	2	51	0	34	47	477		Abnormal level *1
Nov-1990	11	8	0	0	0	0	82	819	101	-53.7	
Feb-1995	80	17	0	30	0	10	15	1723	152	1.0	
Sep-1995	75	16	0	22	0	23	10	1855	146	-0.9	
Jun-2000	85	56	50	58	0	28	381	2853	658	8.8	Caution level-2
Oct-2000	84	54	52	84	0	12	398	3606	684	6.0	Caution level-2
Jul-2005	20	60	22	66	0	28	450	3810	646	-0.7	Caution level-2
Oct-2005	16	70	20	70	0	30	440	3890	646	0.0	Caution level-2
Jan-2006	42	60	16	67	0	25	420	3710	630	-5.5	Caution level-2
Apr-2006	32	62	2	118	0	60	262	4135	536	-26.9	Caution level-1
Jul-2006	23	15	1	50	0	10	130	1906	229	-99.0	
Oct-2006	29	24	1	26	0	8	128	1903	216	-4.9	
Apr-2007	16	30	2	38	0	5	91	1597	182	-5.2	
Jul-2007	12	42	0	45	0	10	75	2062	184	0.9	
Oct-2007	102	24	0	31	0	9	34	1394	200	4.9	
Dec-2007	91	35	0	51	0	12	43	2111	232	17.8	
Mar-2008	70	30	0	29	0	8	40	1922	177	-17.6	
Jun-2008	71	2	2	8	0	0	127	1865	210	10.8	
Aug-2008	60	20	0	25	0	7	25	1229	137	-32.7	
Jul-2009	21	81	1	76	0	31	111	1869	321	16.8	
Dec-2009	18	61	2	58	0	21	109	1916	269	-9.8	
Mar-2010	25	32	0	33	0	2	92	1790	184	-26.8	
Jun-2010	21	49	3	91	0	4	112	1896	280	30.0	

Korba#6Y DGA Result

Date	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1	≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2			≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level			≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Apr-1990	40	0	0	0	0	0	16	412	56		
Nov-1990	31	0	0	0	0	0	42	1148	73	2.4	
Feb-1995	0	15	4	27	0	0	5	2914	51	-0.4	
Sep-1995	10	15	10	26	0	15	43	3200	119	10.3	Caution level-1
May-2000	55	95	1	61	0	16	275	4744	503	6.7	Caution level-1
Nov-2000	55	93	2	61	0	12	290	4822	513	1.7	Caution level-1
Jul-2005	23	90	3	145	0	45	320	4405	626	2.0	Caution level-1
Oct-2005	30	80	5	140	0	40	330	4390	625	-0.4	Caution level-1
Jan-2006	40	70	3	130	0	75	290	4210	608	-5.8	Caution level-1
Apr-2006	30	62	2	113	0	56	262	4130	525	-23.7	Caution level-1
Jul-2006	20	30	1	30	0	15	120	2310	216	-99.7	
Oct-2006	30	27	1	27	0	13	115	2196	213	-1.1	
Jan-2007	21	23	1	44	0	14	109	2233	212	-0.4	
Jul-2007	5	51	0	49	0	17	149	3331	271	9.7	
Oct-2007	12	31	1	49	0	13	73	3044	179	-28.5	
Jan-2008	80	81	0	80	0	27	205	3310	473	80.2	Abnormal level
May-2008	53	73	13	74	0	24	191	3160	428	-14.7	Caution level-2
Jul-2008	61	14	0	16	0	15	61	1259	167	-90.0	
Jul-2009	26	72	1	70	0	25	287	2390	481	27.2	
Dec-2009	31	57	1	60	0	23	267	2223	439	-7.9	
Mar-2010	21	30	2	52	0	2	212	1966	319	-37.9	
Jun-2010	18	28	1	51	0	2	233	2411	333	4.4	

Korba#6B DGA Result

Date	H2	CH4	C2H4	C2H6	C2H2	C3S	CO	CO2	TCG	TCG increase	Remarks
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm/month	
Caution level-1	≧400	≧100	≧10	≧150	≧0.5		≧300		≧500		
Caution level-2			≧10		≧0.5				≧500		C2H4≧10+TCG≧500 or C2H2≧0.5
Abnormal level			≧100						≧700	≧70	C2H4≧100+TCG≧700 or ΔTCG≧70ppm/month
Apr-1990	44	3	0	0	0	0	123	650	170		
Nov-1990	25	10	0	0	0	0	67	904	102	-9.7	
Mar-2000	95	60	55	68	0	40	390	4460	708	5.3	Caution level-2
Jun-2000	95	65	52	68	0	42	393	4492	715	2.0	Caution level-2
Sep-2000	93	68	50	69	0	40	398	4510	718	1.0	Caution level-2
Jul-2005	25	75	22	116	0	136	440	5495	814	1.6	Caution level-2
Oct-2005	30	70	20	110	0	130	460	5425	820	2.3	Caution level-2
Jan-2006	44	60	15	102	0	20	450	5390	691	-44.0	Caution level-2
Apr-2006	40	53	13	93	0	16	430	5210	645	-13.1	Caution level-2
Jul-2006	20	22	3	50	0	11	190	2410	296	-112.6	
Oct-2006	33	22	1	37	0	17	180	2330	290	-2.3	
Jan-2007	26	24	0	33	0	12	170	2243	265	-8.9	
Jul-2007	12	56	0	58	0	19	139	3092	284	3.1	
Oct-2007	108	30	0	41	0	12	47	2003	238	-14.2	
Dec-2007	93	71	0	76	0	24	154	2324	418	100.0	Abnormal level
Mar-2008	63	51	0	66	0	10	104	2065	294	-41.3	
May-2008	53	50	2	80	0	32	101	1475	318	9.2	
Jun-2008	61	11	2	61	0	30	183	2010	348	13.6	
Jul-2009	20	33	1	66	0	29	166	2283	315	-2.9	
Dec-2009	26	13	2	56	0	13	141	2012	251	-12.1	
Mar-2010	36	11	0	38	0	2	133	1898	220	-9.8	
Jun-2010	31	49	2	78	0	1	145	1999	306	26.9	

Review of Korba#6 DGA

■R phase
Each analyzed gas has had no big change and been less than the judgment criteria. Therefore, the transformer is assessed as normal condition.

■Y phase
Each analyzed gas has had no big change and been less than the judgment criteria recently, although TCG increase per month (Jan. 2008) had become Abnormal level and C2H4 (May. 2008) had become Caution level-2. Therefore, the transformer is assessed as normal condition.

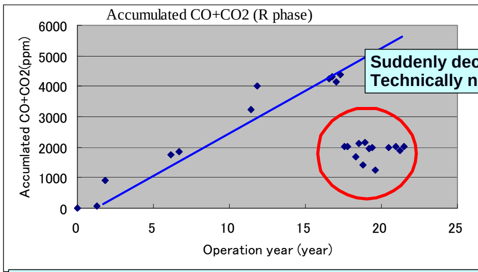
■B phase
Each analyzed gas has had no big change and been less than the judgment criteria recently, although TCG increase per month (Dec. 2007) had become Abnormal level. Therefore, the transformer is assessed as normal condition.

Obtained data for CO+CO2 analysis from Korba#6

	Required Items	Unit	Data
A1	Accumulated CO+CO2 density in insulation oil	vol ppm (mL/kL)	Next page
A2	Insulation oil volume	kL	23.4
A3	Insulation oil weight	kg	—
A4	Insulation oil gravity	g/mL	—
A5	Insulation paper weight	kg	303
A6	History of insulation oil treatment		Nil

Sealed performance is good and Korba#6 has not conducted oil treatment.
Therefore, correction of accumulated CO+CO2 is not required.
Accumulated CO+CO2 = CO+CO2 measurement data

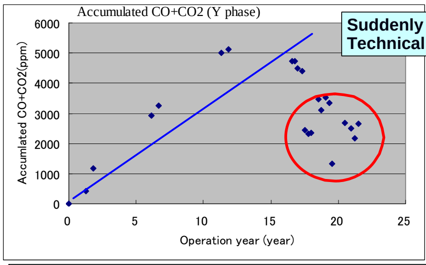
Accumulated CO+CO2 in oil (R phase)



Korba#6 GT is sealed type and the CO+CO2 technically increases as it operates.

Red circled data are unreliable.
Therefore, The assessment is conducted using reliable data only. (excluding red circled data)

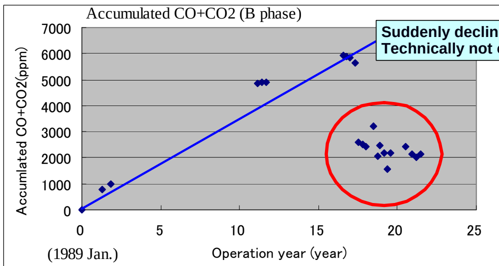
Accumulated CO+CO2 in oil (Y phase)



Korba#6 GT is sealed type and the CO+CO2 technically increases as it operate.

Red circled data are unreliable.
Therefore, The assessment is conducted using reliable data only. (excluding red circled data)

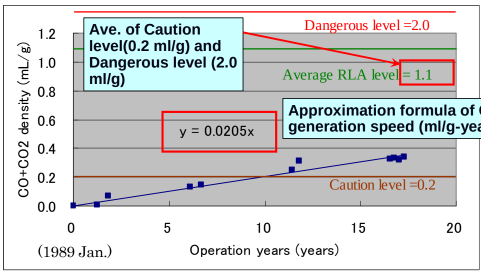
Accumulated CO+CO2 in oil (B phase)



Korba#6 GT is sealed type and the CO+CO2 technically increases as it operate.

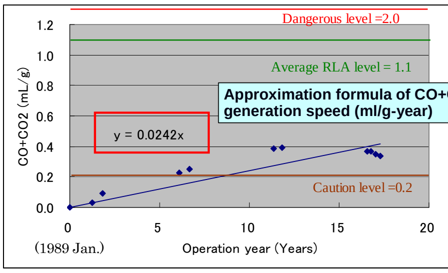
Red circled data are unreliable.
Therefore, The assessment is conducted using reliable data only. (excluding red circled data)

Estimation of CO+CO2 generation speed (R phase)



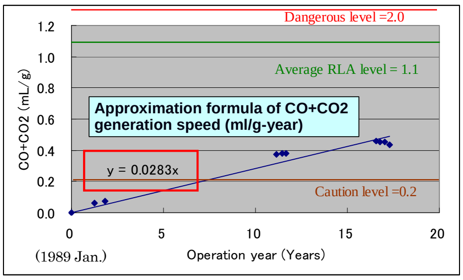
The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

Estimation of CO+CO2 generation speed (Y phase)



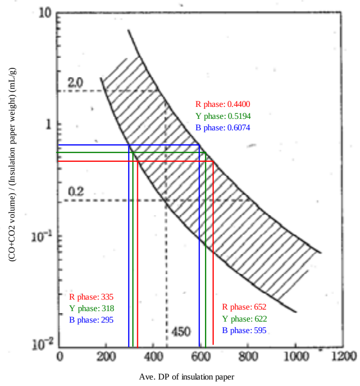
The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

Estimation of CO+CO2 generation speed (R phase) 84



The generation speed of CO+CO2 per insulation paper weight is estimated by approximation formula function of Excel soft and the current condition & the RLA are estimated.

DP estimation by CO+CO2 analysis 85



Assessment of CO+CO2 analysis (Korba#6) 86

		R phase	Y phase	B phase
Trend	CO+CO2 generating speed (mL/g year)	0.0205	0.0242	0.0283
Current condition (Jan 2010)	CO+CO2 (mL/g) (Jan 2010)	0.4400	0.5194	0.6074
	DP	335-652	318-622	295-595
	Evaluation	Caution level	Caution level	Caution level
RLA	Operation years until Ave. lifetime point	53.7	45.5	38.9
	Estimating year to Ave. lifetime point	2042 Sep.	2034 Jul.	2027 Dec.

Obtained data for furfural analysis from Korba#6 87

	Required Items	Unit	R phase	Y phase	B phase
A1	Furfural density (Nov. 2009)	mg/L	0.05	0.06	0.04
A1	Furfural density (June 2010)	mg/L	0.06	0.07	0.05
A2	Insulation oil volume	L	23400		
A3	Insulation oil weight	kg	22000		
A4	Insulation oil gravity	g/mL	—		
A5	Insulation paper weight	kg	303		
A6	History of insulation oil change		Nil		

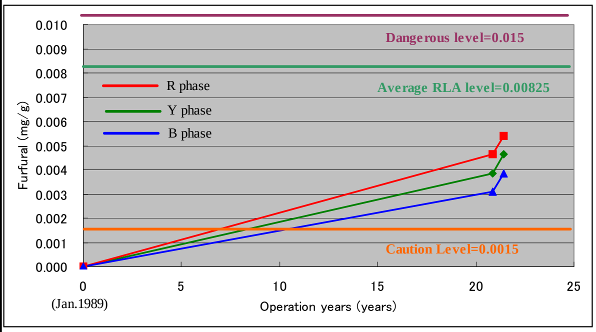
Korba#6 has never implemented the insulation oil change. The measurement data becomes furfural generating weight from starting operation to furfural measurement day.

2010 data is little bit larger than 2009 data.

Furfural data of 2009's and 2010's 88

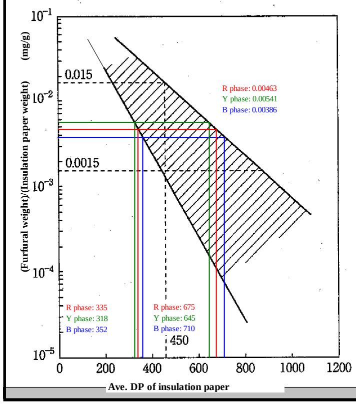
Start operation		Insulation paper weight			303 kg
Jan 1989		Oil volume			23400 L
Phase	Date	Operation years	Furfural (mg/L)	Furfural*1 (mg/g)	Remarks
R phase	Nov. 2009	20.86	0.05	0.00386	Caution level
	June 2010	21.46	0.06	0.00463	Caution level
Y phase	Nov. 2009	20.86	0.06	0.00463	Caution level
	June 2010	21.46	0.07	0.00541	Caution level
B phase	Nov. 2009	20.86	0.04	0.00309	Caution level
	June 2010	21.46	0.05	0.00386	Caution level

Furfural generating trend 89



Because 2010 data is little bit larger than 2009 data, furfural generating speed increases.

DP estimation by furfural analysis



DP estimation by 2010 June data.

Assessment of furfural analysis (Korba#6)

		R phase	Y phase	B phase
Trend	Furfural generating speed (mg/g year)	0.000220	0.000259	0.000184
Current condition (Jan 2010)	Furfural (mg/g) (June 2010)	0.00463	0.00541	0.00386
	DP	335-675	318-645	352-710
	Evaluation	Caution level	Caution level	Caution level
RLA	Operation years until Ave. lifetime point	38.2	32.8	45.9
	Estimating year to Ave. lifetime point	Mar-2027	Oct-2021	Nov-2034

Recommendations for Korba#6

Although the result of furfural analysis shows that furfural generation speed seems to become fast at every phase, it is estimated that there is no serious problem because the span between 2nd test and 1st test is short and the difference between 2nd furfural measurement data and 1st one is 0.001 mg/L, which might be a measurement deviation.

That means that it is not confirmed which test data is reliable, 1st test data or 2nd test one.

Therefore, it is recommended that Korba#6 continue to conduct the test periodically so that NTPC can grasp furfural generation trend and improve the accuracy of the RLA.

End

Analysis of present performance and performance decrease

General
Differences in the Implementation of the Performance Test

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: EEM Group Implementation: EEM Group
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

Analysis of present performance and performance decrease

General
Differences in the Implementation of the Performance Test
Sampling

Fig. 6.13-1 Coal Sampling Plastic Bag

Fig. 6.13-2 Fly Ash Extraction Valve for Sampling

Fig. 6.13-3 Fly Ash Sampling Storage Bin

Review and Improvement of Past and Present O&M Procedure

NTPC (India)	Study Team (Japan)
➢ Patrol: 3 times / 1 shift	➢ Patrol: 1 times / 1 shift
➢ 8 local operator/ 2units	➢ 3 to 4 local operator/ 2units
➢ Each station does not have Simplified Simulator.	➢ Each station has Simplified Simulator.
➢ Maintenance (in house)	➢ Maintenance (by subsidiary company: (J Power case)
➢ Periodic inspections works conducted 24h/day	➢ Periodic inspections works conducted 8-12h/day
➢ Boiler RLA conducted every 5 years	➢ Boiler RLA is conducted 100,000 hrs operation time. It is conducted by the RLA result after that.
➢ Performance test frequencies are depend on system	➢ Performance test/once a year

Review and Improvement of Past and Present O&M Procedure

Findings

Study team found some safety and health problems during field works.

- House keeping in boiler field is not well conducted.
(Broken pieces of iron plates and wires and ash accumulates everywhere.
- Workers need to wear face masks in dusty critical areas
- 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.

Review and Improvement of Past and Present O&M Procedure

Recommendations
1) Patrols

Review and Improvement of Past and Present O&M Procedure

Marking on indicators and Thermo-label

Review and Improvement of Past and Present O&M Procedure

Regulation of entry and exit of enclosed area

Review and Improvement of Past and Present O&M Procedure

Safety management

It is advisable to thoroughly educate all employees from managers to workers about the importance of safety and re-emphasize the necessity of putting on safety gear for them.

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

The Economic & Financial Analysis Overview

October, 2010

Katsumi Yoshida

Kyushu Electric Power

Introduction (1/6)

1. Objectives

- To clarify the economic and financial impact cased by implementation of the technical improvement proposals

2. Scope

- Focusing on items which would be expected to have a certain value of economic increment due to implementation recommendations of technical assessment

Introduction (2/6)

Scope*: Current items for Financial Analysis

Plant (# =Unit)	***Korba #6***	***Singrauli #4***	***Rihand #2***	**Unchahar #3**
Boiler	Air Heater Renovation (SDU/FRS)	Air Heater Renovation (SDU/FRS)		
Turbine	Turbine Seal Fin Replacement	Turbine Seal Fin Replacement	Turbine Seal Fin Replacement	
Control System	—	—	—	New System for Optimization of Combustion & Soot blowers

*About these all items, we conducted Economic & Financial Analysis. In this presentation we pick up several items as example.

Introduction (3/6)

3. Method

Economic & Financial

- Firstly, with the Cost Benefit Analysis, we evaluate the actual economic volume of incremental profit. Then, by NPV approach we clarify the value of investment in terms of the Cost of Capital.

Environmental Value-CO2

- Secondly, regarding the environmental value added by the reduction of CO2 emissions that would arise from the proposed technical improvements, introduced later

Introduction (4/6)

Assumption for this Analysis

- 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 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.

Introduction (5/6)

Assumption for this Analysis

- 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.

Introduction (6/6)

Cost of Capital

- The cost of capital is the cost of a company's finance (e.g. interest on debt and dividend on stock).
- We assumed current NTPC's cost of capital to be 7% following recent actual expenditure on Interest & Finance Cost and Divided. (Source of figures in the table below is page 20 of NTPC's 33rd Annual Report)
- As a result of discussions about the expected cost of capital in the near future with CenPEEP, **we have set the cost of capital as 12% for the following DCF Approach analysis**.

Cost Benefit Analysis (1/4)

1-1 Method of CBA

◆*Concept*

Cost Benefit Analysis (CBA) compares the incremental profit (such as the reduction of fuel costs through the plant efficiency improvement) gained by the implementation of the improvement with the initial cost of implementation.

If there are any extra expenses or costs caused by the implementation (such as the materials, maintenance and/or scrapping property), CBA recognizes these things as negative factors for incremental profit. CBA also considers lifetime assessment for new equipment

Cost Benefit Analysis (2/4)

1-2 Method of CBA

CBA's Criteria is Simple
➢Possibility of **Incremental Profit**

◆*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

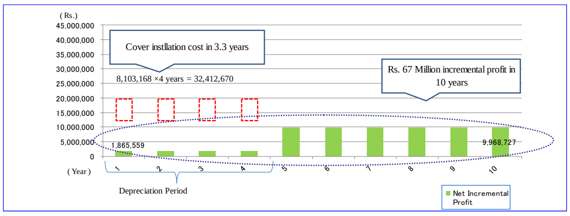
* CBA is based on a practical accounting policy, so, in accordance with the existence of the depreciation cost related to the implementation, we should carefully evaluate the incremental profit.

Cost Benefit Analysis (3/4)

2-1 CBA Practice

Korba #6 : AH Seal by SDU

The implementation which make efficiency 0.5% improvement, the plant will expect that Rs.67 million incremental profit in 10 years and recovery of Rs. 32.4 million investment in 3.3years



** Degradation of efficiency improvement while operation period is included for CBA above.*

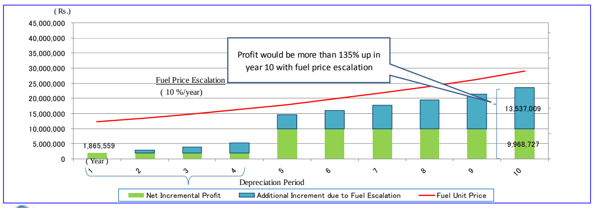
Cost Benefit Analysis (4/4)

2-2 CBA Practice

Korba #6 : AH Seal by SDU

◆Sensitivity Analysis- Fuel Unit Price

As one of the possible cases, if the fuel unit price will be escalated 10% per year (compounded), the plant will expect a huge cost benefit – incremental profit to be doubled in 10 years (Total: from Rs.67 to 126Mil.).



DCF Approach (1/3)

DCF Approach

The value of future cash flows should be discounted using the assumed Cost of Capital. This is called "DCF" -Discounted Cash Flow Approach that we can use to find out the realistic investment value.

NPV - Net Present 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 one of the standard DCF financial analysis methods called "NPV" -Net Present Value, to evaluate the excess or shortfall of cash flows, in present value terms, once an investment has been made

$$DPV = \frac{FV}{(1+i)^n}$$

DPV = Discounted Present Value
FV = Future Value
i = Discount Rate

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = C_0 + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \dots + \frac{C_n}{(1+r)^n}$$

C_0= Initial Investment
* Negative number because of cash outflow f or investment
r = Discount Rate

IRR

DCF Approach (2/3)

IRR-Internal Rate of Return

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.

$$C_0 + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \frac{C_3}{(1+r)^3} + \dots + \frac{C_n}{(1+r)^n} = 0$$

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0$$

C_0= Initial Investment
* Negative number because of cash outflow for investment

r = Internal Rate of Return

BCR

DCF Approach (3/3)

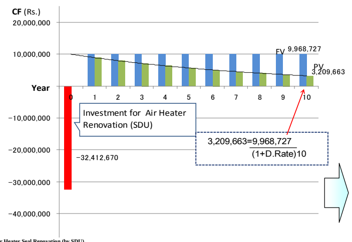
BCR- Benefit Cost Ratio

We also conduct "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.

Leverage effect of Investment !!

$$\text{BCR} = \frac{\text{Total Future Cash inflow (Discounted as Present Value)}}{\text{Initial Investment}}$$

DCF Approach Case Study "*Korba #6 – Air Heater Renovation by SDU*"



Findings by DCF Approach

- Sum of the present values (PVs) is Rs.56.3Mil (A)
  (As a nominal, Rs.99.7Mil in 10 years.)
- <u>NPV is Rs. 23.9Mil</u>
  (=A-Rs.32.4Mil for Investment)
- IRR is 28.2% (high rate of return, over Cost of Capital 12%)
- BCR is 1.7(good investment value)
- <u>PO is 3.3 years (short recovery)</u>

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										

Conclusion of Financial Analysis(1/2)

Plant Unit		Korba #6 500 MW	Singrauli #4 200 MW	Rihand #2 500 MW	Unchahar #3 210 MW
Items		Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Turbine Seal Fin (TSF)	System for Optimization(CI)
Assumption	Lifetime of Improvement Item	(AH-S) 10 years (AH-F) 10 years (TSF) 6 years	(AH-S) 10 years (AH-F) 10 years (TSF) 6 years	(TSF) 6 years	(CI) 10 years
Assumption	Installation Cost (*Relative Value*)	(AH-S) medium (AH-F) medium (TSF) medium	(AH-S) medium (AH-F) medium (TSF) low	(TSF) low	(CI) high
Accompanied O&M Cost		(AH-F) low	(AH-F) low	—	(CI) high
CBA (Cost Benefit Analysis)	Net Incremental Profit(Relatively)	(AH-S) big (AH-F) big (TSF) small	(AH-S) medium (AH-F) medium (TSF) small	(TSF) medium	(CI) negative
CBA (Cost Benefit Analysis)	POA	(AH-S) 3.3 years (AH-F) 3.9 years (TSF) 4.1 years	(AH-S) 5.6 years (AH-F) 7.0 years (TSF) 2.6 years	(TSF) 0.8 years	(CI) NA
CBA (Cost Benefit Analysis)	Discout Rate (Cost of Capital)	12%	12%	12%	12%
DCF (Discounted Cash Flow Approach Analysis)	NPV	(AH-S) big (AH-F) big (TSF) negative	(AH-S) small (AH-F) negative (TSF) small	(TSF) medium	(CI) negative
DCF (Discounted Cash Flow Approach Analysis)	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) higher than 12%	(TSF) much higher than 12%	(CI) NA (IRR is negative)
DCF (Discounted Cash Flow Approach Analysis)	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% stand for "Good Investment". Short recovery (POA:3.3), No accompanyng cost <u>Excellent</u> (AH-F) Huge NPV, IRR much higher than 12% stand for "Good Investment". Short recovery (POA:3.9), No accompanyng cost <u>Excellent</u> (TSF) NPV is Negative, so it could not be Recommended. If we make some practical efforts (e.g. Rreduction of installation cost by20%, and/or extend life time), NPV would be positive and we might choose this proposal.	(AH-S) A cnertain volume of NPV, IRR little higher than 12% stand for "acceptable". Recovery Period is not Short (POA:5.6), No accompanyng cost <u>Good</u> (AH-F) NPV is Negative, so it could not be Recommended. If we make some practical efforts (e.g. Rreduction of installation cost by20%, and/or extend life time), NPV would be positive and we might choose this proposal. (TSF) A cnertain volume of NPV, IRR higher than 12% stand for "acceptable". Recovery Period is t Short (POA:2.6)t <u>Good</u>	(TSF) Goodly volune of NPV, IRR much higher than 12% stand for "Good Investment". Rapid Recovery (POA:0.8), No accompanyng cost <u>Excellent</u>	(CI) Due to huge installation cost and expensive accompanying mentenance fee, this item would not be a profitable. Even after depreciation period, incremental profit and NPV would be negative

From the view point of finance, recommendable items

Excellent

1st option
Turbine Seal Fin at Rihand #2

2nd option
Air Heater Seal by SDU at Korba #6

3rd option
Air Heater Seal by FRS at Korba #6.

Good options
Turbine Seal Fin at Singrauli #4
Air Heater Seal by SDU at Singrauli #4

Not Recommended
Other items with Negative NPV

Conclusion of Financial Analysis(2/2)

Plant Unit		Korba #6 500 MW	Singrauli #4 200 MW	Rihand #2 500 MW	Unchahar #3 210 MW
Items		Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Air Heater by SDU(AH-S) Air Heater by FRS(AH-F) Turbine Seal Fin (TSF)	Turbine Seal Fin (TSF)	System for Optimization(CI)
Assumption	Lifetime of Improvement Item	(AH-S) 10 years (AH-F) 10 years (TSF) 6 years	(AH-S) 10 years (AH-F) 10 years (TSF) 6 years	(TSF) 6 years	(CI) 10 years
Assumption	Installation Cost (*Relative Value*)	(AH-S) medium (AH-F) medium (TSF) medium	(AH-S) medium (AH-F) medium (TSF) low	(TSF) low	(CI) high
Accompanied O&M Cost		(AH-F) low	(AH-F) low	—	(CI) high
CBA (Cost Benefit Analysis)	Net Incremental Profit(Relatively)	(AH-S) big (AH-F) big (TSF) small	(AH-S) medium (AH-F) medium (TSF) small	(TSF) medium	(CI) negative
CBA (Cost Benefit Analysis)	POA	(AH-S) 3.3 years (AH-F) 3.9 years (TSF) 4.1 years	(AH-S) 5.6 years (AH-F) 7.0 years (TSF) 2.6 years	(TSF) 0.8 years	(CI) NA
CBA (Cost Benefit Analysis)	Discout Rate (Cost of Capital)	12%	12%	12%	12%
DCF (Discounted Cash Flow Approach Analysis)	NPV	(AH-S) big (AH-F) big (TSF) negative	(AH-S) small (AH-F) negative (TSF) small	(TSF) medium	(CI) negative
DCF (Discounted Cash Flow Approach Analysis)	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) higher than 12%	(TSF) much higher than 12%	(CI) NA (IRR is negative)
DCF (Discounted Cash Flow Approach Analysis)	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% stand for "Good Investment". Short recovery (POA:3.3), No accompanyng cost <u>Excellent</u> (AH-F) Huge NPV, IRR much higher than 12% stand for "Good Investment". Short recovery (POA:3.9), No accompanyng cost <u>Excellent</u> (TSF) NPV is Negative, so it could not be Recommended. If we make some practical efforts (e.g. Rreduction of installation cost by20%, and/or extend life time), NPV would be positive and we might choose this proposal.	(AH-S) A cnertain volume of NPV, IRR little higher than 12% stand for "acceptable". Recovery Period is not Short (POA:5.6), No accompanyng cost <u>Good</u> (AH-F) NPV is Negative, so it could not be Recommended. If we make some practical efforts (e.g. Rreduction of installation cost by20%, and/or extend life time), NPV would be positive and we might choose this proposal. (TSF) A cnertain volume of NPV, IRR higher than 12% stand for "acceptable". Recovery Period is t Short (POA:2.6)t <u>Good</u>	(TSF) Goodly volune of NPV, IRR much higher than 12% stand for "Good Investment". Rapid Recovery (POA:0.8), No accompanyng cost <u>Excellent</u>	(CI) Due to huge installation cost and expensive accompanying mentenance fee, this item would not be a profitable. Even after depreciation period, incremental profit and NPV would be negative

Findings

- ✓ <u>Leverage Effect 1</u> :*Unit Capacity is important to get incremental profit on the same volume of the investment.*
- ✓ <u>Leverage Effect 2</u> :*Unit CBA (Evaluating Net Incremental Profit) should be compared with the magnitude of each implementation cost.*
  (Because cash is limited)
- ✓ <u>Influence of Fuel Unit Price & PLF:</u> *Even a small Fuel Price escalation will have a huge effect on profit in the long term. Keeping high PLF is basic for earnings*

Environmental Value Added Analysis

Concept

Evaluation of the environmental value added would be conducted by finding the reduction of CO2 emissions. The method for this analysis is simple and similar to the one used for the cost benefit analysis in the previous slide. This evaluation considers total CO2 Emission reduction in each item's lifetime with due regard for degradation effect

Formula

<u>CO2 Emission/Unit</u> (kg -CO2/kWh) =
Fuel Consumption Rate (kg / kWh) × Carbon Content of Fuel (%) × Relative Atomic Weight (44/12)

<u>CO2 Emission</u> (kg-CO2) = CO2 Emission/Unit (kg-CO2/kWh) × Generation (kWh)

Cost Benefit of Emission Reduction

Environmental Value Added Analysis

How to evaluate CBER !?

Furthermore we evaluate Cost benefit for the CO2 emission reduction (CBER). This is calculated by dividing the volume of the emission-reduction by the cost of investment (If there are any accompanying incremental costs or expenses due to the implementation, they would be considered part of the cost of investment)

Cost Benefit for the CO2 Emission Reduction

= Investment / CO2 Reduction (for lifetime)

Conclusion 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)
CO2 Reduction *(for lifetime)* *(Relative Value)*	(AH-S) big (AH-F) big (TSF) medium	(AH-S) medium (AH-F) medium (TSF) small	(TSF) small	(CI) medium
Reduction Cost Rate *(Rs./t-CO2)* *(Relative Value)*	(AH-S) <u>low</u> (AH-F) <u>low</u> (TSF) <u>high</u>	(AH-S) <u>medium</u> (AH-F) <u>medium</u> (TSF) <u>high</u>	(TSF) <u>medium</u>	(CI) <u>high</u>
Financial Comments	(AH-S) With a goodly volume of Reduction, Cost is relatively low <u>Excellent</u> (AH-F) With a goodly volume of Reduction, Cost is relatively low <u>Excellent</u> (TSF) Although a medium volume of Reduction, Cost is relatively expensive <u>Carefull examination about the cost-balance would be necessary.</u>	(AH-S) With a certain volume of Reduction, Cost is relatively medium <u>Good</u> (AH-F) With a certain volume of Reduction, Cost is relatively medium <u>Good</u> (TSF) Although a small volume of Reduction, Cost is relatively expensive <u>Carefull examination about the cost-balance would be necessary.</u>	(TSF) Although a small volume of Reduction, Cost is relatively medium <u>Good</u>	(CI) Although a certain volume of Reduction, Cost is relatively expensive <u>Carefull examination about the cost-balance would be necessary.</u>

Thank You !

The results of the economic and financial evaluation in this presentation are our Study Team's current views and briefs in accordance with data currently available, and subject to a number of risks, uncertainties and other factors that may cause actual results to differ materially from this study. That's why, in the NTPC's actual decision making process of the implementation of our Study Team's technical proposal, you should carefully utilize the evaluation methods and its result in this report on your own risk and responsibilities.

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

September 2010

JICA Study Team

JICA Japan International Cooperation Agency

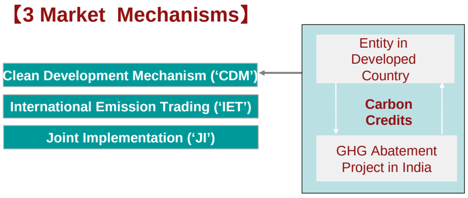
CONTENTS

1. Outline of CDM and PREPARATION OF PDD Draft

Kyoto protocol

- Emission reduction targets for Developed countries
- GHG emission reduction by 5 % below 1990 levels in 2008-2012 commitment period

【3 Market Mechanisms】

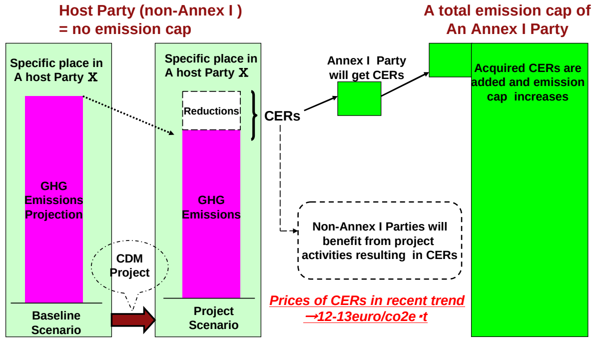


- Carbon credits are measured in terms of Certified Emission Reduction ('CER')
- One CER equals 1 MT CO_2 e (equivalent)

Source：Ministry of Economy, Trade and Industry, Japan "About an international trend over the issue of climate change"

1. Outline of CDM and PREPARATION OF PDD Draft

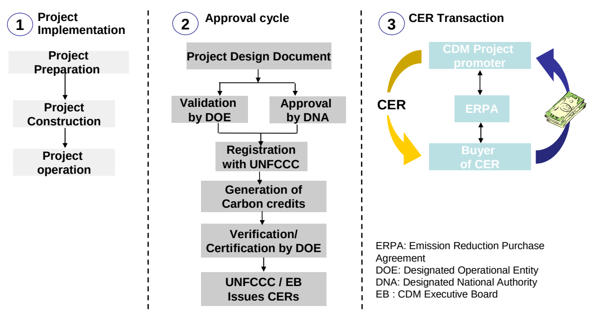
CDM : project activities and emission cap



Source：Ministry of the Environment, Japan "CDM CHARTS Ver.9.0"

1. Outline of CDM and PREPARATION OF PDD Draft

CDM project Cycle



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

1. Outline of CDM and PREPARATION OF PDD Draft

Sections of PDD

- The CDM PDD consists of 5 sections , the sections are as mentioned below.

･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

1. Outline of CDM and PREPARATION OF PDD Draft

Selection of Methodology

Large scale Approved Methodologies -AM0061 and AM0062

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

Sources: United Nations Framework Convention on Climate Change (Methodologies for CDM project activities)

1. Outline of CDM and PREPARATION OF PDD Draft

Small scale CDM (SSC)

Simplified modalities and procedures are applicable to small-scale CDM

Type I	Type II	Type Ⅲ
AMS* I	AMS *II	AMS * Ⅲ
Renewable energy project activities within a maximum output capacity of 15 MW (or an appropriate equivalent)	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 (or an appropriate equivalent)	Emission reductions of less than or equal to 60 kt CO_2 equivalent annually

・AMS (Approved Methodology Small-scale CDM)

Sources: United Nations Framework Convention on Climate Change (Methodologies for CDM project activities)

1. Outline of CDM and PREPARATION OF PDD Draft

Commission of the work of CDM Consultant

➢**Title of the Study**

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

➢**The Contractor**

Ernst &Young Pvt .Ltd.

➢**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

1. Outline of CDM and PREPARATION OF PDD Draft

Thermal power generation units and energy efficiency improvement measures

➢ **Finalized thermal power generation unit and energy efficiency improvement measures**

Thermal power generation unit	Proposed energy efficiency improvement measures	
	Initial measures 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

2. Summary of PDD Drafts

PDD Draft (Singrauli)-Overview

Section A	General Description of small scale project activity
A.1	**Title of the small scale project activity**
Air Pre-Heater performance improvement at NTPC Plant, Singrauli, Uttar Pradesh	
A.2	**Description of the small-scale project activity**
Project Description 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	

2. Summary of PDD Drafts

PDD Draft (Singrauli)-Overview

Section A	General Description of small scale project activity
A.3	**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	
A.4	**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 (FRS) 2.Adoption of Sector Plate Drive Unit (SDU)	

2. Summary of PDD Drafts

PDD Draft (Singrauli)-Overview

Section B	Application of a baseline and monitoring methodology
B.1	**Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity**
Type - Title - Reference -	II - Energy Efficiency Improvement Projects A.M.S II B "Supply side energy efficiency improvements - generation" A.M.S II B (Version 9, EB 33)
B.2	**Justification of choice of project category**

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

•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
•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 technologies or measures may be applied to existing stations or be part of a new facility.

The project activity conforms to the above measures as follows:

•The Boiler unit in the project activity uses coal (fossil fuel) steam generation and subsequently, for electricity generation.
•The total thermal energy savings by the project activity would be within 180 GWhth
•The energy efficiency measures are being implemented in the existing boiler of # 4.

2. Summary of PDD Drafts

PDD Draft (Singrauli)-Overview

Section B	Application of a baseline and monitoring methodology
B.3	**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

B.4	**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 will be calculated as the product of the gross heat rate in the boiler, multiplied by the emission coefficient (IPCC Value) of 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.

B.5	**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)**

Investment Barrier
Technological barrier

Barrier to prevailing Barrier
The project activity being undertaken has not been implemented in India and would face prevailing practice barrier. 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.

2. Summary of PDD Drafts

PDD Draft (Singrauli)-Overview

Section C	Duration of the project activity and crediting period

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

Section D	Environmental Impact Assessment

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.

Section E	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. Summary of PDD Drafts

PDD Draft (Korba)-Overview

Section A	General Description of small scale project activity
A.1	**Title of the small scale project activity**

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

A.2	**Description of the small-scale project activity**

Project Description

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

2. Summary of PDD Drafts

PDD Draft (Korba)- Overview

Section A	General Description of small scale project activity
A.3	**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

A.4	**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(FRS)
2.Adoption of Sector Plate Drive Unit (SDU)

2. Summary of PDD Drafts

PDD Draft (Korba)- Overview

Section B	Application of a baseline and monitoring methodology
B.1	**Title and reference of the approved baseline and monitoring methodology applied to the small-scale project activity**
Type - Title - Reference -	II - Energy Efficiency Improvement Projects A.M.S II B "Supply side energy efficiency improvements - generation" A.M.S II B (Version 9, EB 33)
B.2	**Justification of choice of project category**

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

•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
•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 technologies or measures may be applied to existing stations or be part of a new facility.

The project activity conforms to the above measures as follows:

•The Boiler unit in the project activity uses coal (fossil fuel) steam generation and subsequently, for electricity generation.
•The total thermal energy savings by the project activity would be within 180 GWhth
•The energy efficiency measures are being implemented in the existing Boiler of # 6.

2. Summary of PDD Drafts

PDD Draft (Korba)- Overview

Section B	Application of a baseline and monitoring methodology
B.3	**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

B.4	**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 will be calculated as the product of the gross heat rate in the boiler, multiplied by the emission coefficient (IPCC Value) of 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

B.5	**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)**

Investment Barrier
Technological barrier

Barrier to prevailing Barrier
The project activity being undertaken has not been implemented in India and would face prevailing practice barrier. 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.

2. Summary of PDD Drafts

PDD Draft (Korba)-Overview

Section C	Duration of project activity and crediting period

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

Section D	**Environmental Impact Assessment**

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.

Section E	**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.

2. Summary of PDD Drafts

PDD Draft (Rihand)-Overview

Section A	General Description of small scale project activity
A.1	**Title of the small scale project activity**

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

A.2	**Description of small-scale project activity**

Project Description

The energy efficiency measures would improve the overall efficiency of the boiler feed water pump system 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.

2. Summary of PDD Drafts

PDD Draft (Rihand)-Overview

Section A	General Description of small scale project activity
A.3	**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

A.4	**Technical Description of the small scale 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:

2. Summary of PDD Drafts

PDD Draft (Rihand)-Overview

Section B	Application of a baseline and monitoring methodology
B.1	**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.2	**Justification of choice of project category**

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

•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
•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 technologies or measures may be applied to existing stations or be part of a new facility.

The project activity conforms to the above measures as follows:

•The Boiler unit in the project activity uses coal (fossil fuel) steam generation and subsequently, for electricity generation.
•The total thermal energy savings by the project activity would be within 180 GWhe.
•The energy efficiency measures are being implemented in the existing Boiler feed water pump of # 2.

2. Summary of PDD Drafts

PDD Draft (Rihand)-Overview

Section B	Application of a baseline and monitoring methodology
B.3	**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.

B.4	**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.

B.5	**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)**

Investment Barrier
a financially more viable alternative to the project activity would have led to higher GHG emissions, that is, demonstrating the project IRR is lower than the benchmark rate of returns

Technological barrier
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.

2. Summary of PDD Drafts

PDD Draft (Rihand)-Overview

Section C	Duration of project activity and crediting period
Expected Operational Lifetime of the Project activity : XX years The project activity uses a fixed crediting period of 10 years	
Section D	**Environmental Impact Assessment**
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.	
Section E	**Stakeholders ' comments**
The local stakeholders' consultation was not implemented according to request of NTPC.	

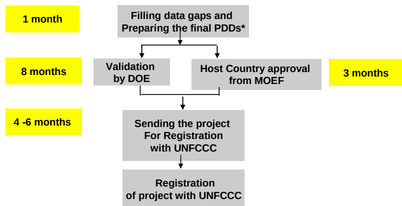
3. Planning of schedule of preparatory works

Time estimate for the Way forward

- **CDM Documentation:**
  - Final Project Design Document (PDD)
  - Preparation of Project Idea Note (PIN)
  - **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.
- **Host country approval prior to request for registration**
  - Preparation and submission of requisite documents and presentation at the Indian DNA.
  - **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.
- **Validation by DOE**
  - Web hosting of PDD on UNFCCC website for global stakeholder consultation.
  - Site visit by DOE to the plant
  - Preparation of Draft Validation Report including clarification, Corrective action requests (CARs), etc.
  - Issue final Validation Report after satisfactory closure of clarifications, CARs, etc. and submission of project to UNFCCC for CDM registration
  - **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.
- **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.

3. Planning of schedule of preparatory works

Way Forward

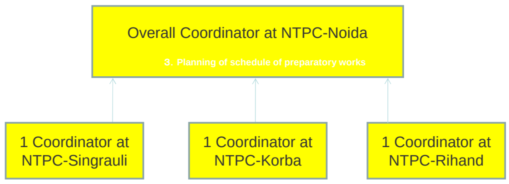


Activity	Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CDM Documentation															
Host country approval prior to request for registration															
Validation by DOE															
Registration of CDM project with UNFCCC															

3. Planning of schedule of preparatory works

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



3. Planning of schedule of preparatory works

CDM Transaction Cost

- Consultant fixed fee and success fee(% of the CDM revenues received by the project proponent):
  - PDD, PCN development
  - Facilitating Host Country Approval
  - Facilitating Validation
  - Facilitating Registration
- Validation Fee (one time):
  - Charged by third party validator
  - One time fee, typically range from 10 – 12 Lacs
- UNFCCC registration fee (one time):
  - < 15,000 CER's per annum, nil
  - > 15,000 CER's per annum, 0.1 $ per CER up to 15,000 CER's and 0.2 $ per CER's beyond 15,000 CER's
- 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
- Verification fee (for every verification)
  - Charged by third party verifier
  - To be paid for every periodic verification, typically range from 7 – 10 lacs

3. Planning of schedule of preparatory works

CDM Projects- Indian Experience

Since the establishment of the Indian DNA (Designated National Authority) in 2003, it has approved a significant number of projects. 530 Indian projects have been registered by the CDM executive board, which account for about 22.45% of all the registered projects

Total Projects Registered -India	530
Number of CDM projects approved by MoEF-India	1,561

Various reasons for the slow registration process of CDM projects

- Stringent guidelines and procedural requirements at UNFCCC
- Stringent validation of the project activity by the DOE

3. Planning of schedule of preparatory works

CDM Projects- Indian Experience

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:

oPrior consideration for 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

oBaseline Data:

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

oDemonstration 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.

oMonitoring 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.

Thank You !

8.3 モデルユニット選定調査票

Table 4-1

Name of Power Plant (Unit No):	
Location:	
Commercial Operation Date:	
Boiler Manufacture:	
Turbine Manufacture:	
Fuel (Coal analysis)	Attached sheet Coal Design coal and present coal
Design condition	Ambient temp. ℃ Ambient pressure hPa Relative humidity %

Items	No	Operation Data(100%Load)	Design Data(100%Load)	
1. General				
(1)Equipment				
1)Turbine				
100%Load Output(MW)	1	MW	MW	
Main Steam Pressure (MSP) / Temperature (MST)	2	MPa ℃	MPa ℃	
Reheat Steam Pressure (RSP)/Temperature (RST)	3	MPa ℃	MPa ℃	
Turbine Type / Length of Final stage blade	4	—		
2)Boiler				
100%Load Main Steam / Reheat Steam Flow	5	/ t/h	/ t/h	
Superheater outlet steam pressure / temperature	6	MPa ℃	MPa ℃	
Reheater outlet steam pressure / temperature	7	MPa ℃	MPa ℃	
Economizer inlet feed water pressure / temperature	8	MPa ℃	MPa ℃	
Boiler Type	9	—	Natural circulation / Forced circulation	
Burner layout	10	—	Corner / Front / Opposed	
Coal Mill (unit)/reserver (unit)	11	Unit (reserve unit)	Unit (reserve unit)	
(2)Plant Operation				
1)Annual operation time	12	Operation time: hrs	Operation time: hrs	
2)Rated load operation time	13	hrs	hrs	
3)Partial load operation time	14	hrs	hrs	
4)Annual generated power output(MWh)	15	MWh	MWh	
5)Annual Net electric power (MWh)	16	MWh	MWh	
6) Total operation time	17	hrs		
7) Number of Hot Start	18			
8) Number of Warm Start	19			
9) Number of Cold start	20			
2. Technical data				
(1)Heat rate and Auxiliary power consumption				
1)Heat rate (LHV base)				
Plant heat rate	21	Gross kJ/kWh Net kJ/kWh	Gross kJ/kWh Net kJ/kWh	
Coal consumption for Goss generation (standard Coal)	22	㎏/kWh	㎏/kWh	
Coal consumption for Net generation (standard Coal)	23	㎏/kWh	㎏/kWh	
Boiler efficiency (LHV/HHV)	24	%	%	
Turbine efficiency				
・Turbine Plant efficiency	25	%	%	
・HP Turbine internal efficiency	26	%	%	
・IP/LP Turbine internal efficiency	27	IP % LP %	IP % LP %	
2)Auxilry Power consumption			Name plate / data	100% Load / data
Coal mill	28	100% Load Power consumption kW	kW	kW
Primary air fan (PAF)	29	100% Load Power consumption kW	kW	kW
Forced draft fan (FDF)	30	100% Load Power consumption kW	kW	kW
Induced draft fan (IDF)	31	100% Load Power consumption kW	kW	kW
BFP(Motor driven)	32	100% Load Power consumption kW	kW	kW
Circulation Water Pump (CWP)	33	100% Load Power consumption kW	kW	kW
(2)Annual Fuel consumption(ton)				
Coal	34	Standard t	Standard t	
Oil(as Auxiliary Fuel)	35	t	t	
(3)Boiler data				
1)Percentage of excess air				
Economizer outlet	36	%	%	
Air preheater outlet	37	%	%	
2)Air preheater inlet air / gas temperature	38	/ ℃	/ ℃	
3)Air preheater outlet gas temperature(leak correction)	39	℃	℃	
4)Air preheater outlet air temperature (1ry / 2ry)	40	/ ℃	/ ℃	
5)Differencial pressure of Air preheater	41	kPa	kPa	
6)Combustible in refuse in Fly ash	42	%	%	
7)Economizer inlet feed water flow	43	t/h	t/h	
8)BFP outlet water pressure / temperature	44	MPa ℃	MPa ℃	
9)Auxiliary steam flow	45	t/h	t/h	
10)Stack inlet gas temperature	46	℃	℃	
11)Coal fineness	47	mm under %	mm under %	
12)Coal mill inlet air temperature (primary air)	48	℃	℃	
13)Coal mill outlet air temperature	49	℃	℃	
14)Air/Coal	50			
15)Air preheater outlet air flow (1ry / 2ry)	51	/ kg/h	/ kg/h	
16)Air preheater inlet air flow	52			
17) SH outlet flue gas temperature (1ry/2ry/3ry)	53	℃	℃	
17) RH outlet flue gas temperature (1ry/2ry)	54	℃	℃	
(4)Turbine data				
1)HP Turbine inlet steam pressure / temperature	55	MPa ℃	MPa ℃	
2)HP Turbine exhaust steam pressure / temperature	56	MPa ℃	MPa ℃	
3)IP Turbine inlet steam pressure / temperature	57	MPa ℃	MPa ℃	
4)Extraction pressure / temperature				
1st Extraction pressure / temperature	58	MPa ℃	MPa ℃	
2nd Extraction pressure / temperature	59	MPa ℃	MPa ℃	
3rd Extraction pressure / temperature	60	MPa ℃	MPa ℃	
4th Extraction pressure / temperature	61	MPa ℃	MPa ℃	
5th Extraction pressure / temperature	62	MPa ℃	MPa ℃	
6th Extraction pressure / temperature	63	MPa ℃	MPa ℃	
7th Extraction pressure / temperature	64	MPa ℃	MPa ℃	
8th Extraction pressure / temperature	65	MPa ℃	MPa ℃	
5)Last stage Feed water heater out let temperature	66	℃	℃	
6)Condenser vacuum	67	mmHg	mmHg	

Table 4-1

7)Condenser cooling water temperature inlet / outlet	68	inlet ℃ outlet ℃	inlet ℃ outlet ℃
8)Condenser cooling method	69	Surface type cooling	Surface type cooling
(5) Turbine efficiency enhancement modification			
1)Modification record	70		
2)Scope and its year	71		
3)Result	72	%	%
3. Steam supply (Yes /No)	73		

4. Economical data (parameter)		
(1)Fuel price (standard coal base)	74	Rs/t
(2)Electrical tariff	75	Rs/kWh

5. Information of Power Plant operation		
(1)Cause of shut down trouble and its time	76	Attached sheet 1
(2)Main list of trouble equipments	77	Attached sheet 2
(3)Improvement record	78	Attached sheet 3
(4)environmental criteria of power plant	79	Dust: mg/m3N SOx: mg/m3N NOx: mg/m3N
(5)Environmental protection equipment	80	Dust: SOx: NOx:
(6)Cooling water temperature record	81	Attached sheet

6. I & C information			
(1)Cause of shut down trouble and its time	82	Attached sheet 1	
(2)Main list of trouble equipments	83	Attached sheet 2	
(3)Improvement record	84	Attached sheet 3	
(4)I&C equipment	85	Year: Replace:	
1)Boiler control system	86	Type: (DCS Elec-analogue Air-analogue)	Cabinet nos:
2)Burner control system	87	Type: (DCS PLC WiredLogic Electromagneti	Cabinet nos:
3)Boiler sequence control system	88	Type: (DCS PLC WiredLogic Electromagneti	Cabinet nos:
4)Boiler protection	89	Type: (DCS PLC WiredLogic Electromagneti	Cabinet nos:
5)Boiler local control system	90	Type: (DCS Elec-analogue Air-analogue)	Cabinet nos:
6)flue-gas De-NOx system	91	Type: (DCS Elec-analogue Air-analogue)	Cabinet nos:
7)flue-gas De-SOx system	92	Type: (DCS Elec-analogue Air-analogue)	Cabinet nos:
8)Turbine governor control system	93	Type: (DEH Mechanical type)	Cabinet nos:
9)Turbine start and stop control system	94	Type: (DCS PLC Electromagnetism Ry)	Cabinet nos:
10)Turbine sequence control system	95	Type: (DCS PLC Electromagnetism Ry)	Cabinet nos:
11)Turbine protection	96	Type: (DCS PLC Electromagnetism Ry)	Cabinet nos:
12)Turbine local control system	97	Type: (DCS Elec-analogue Air-analogue)	Cabinet nos:
13)Unit CPTR	98	Y/N Function;( )	Cabinet nos:

7. Control method			Equip ○yes ×no ◇Other	automatization ○yes ×no	Condition / pending Control mode:(Auto/Manual)
(1)Load control	①BT coordinated control system	99			
	②Conventional	100			
(2)Feed water control system		101			
(3)Draft control	①Air flow control(FDF)	102			
	②Air flow control(O2)	103			
	③Furnace pressure control(IDF)	104			
	④WB damper control	105			
(4) MST control	Spray control system	106			
(5)RST control	Spray control system	107			
(6)Fuel control	①Coal feed control system	108			
	②HO flow control	109			
	③LO flow control	110			
(7)startup system	①Boiler bypass system	111			
	②Turbine bypass system	112			
(8)Local control	①Deaerator level control	113			
	②Deaerator pressure control	114			
	③Heater level control	115			
	④GAH out let gas temperature co	116			
(9)Burner control	①Automatic burner ignition	117			
	②Coal feed control	118			
(10)DeNOX control		119			
(11)DeSOx control		120			
(12)Others	①soot blower control	121			

INVESTIGATION SHEET : Coal TOR 4

NO.	Item	unit	Coal name				
			Design	Present-1	Present-2	Present-3	Present-4
1	Inherent moisture (AD)	%					
2	Volatile (AD)	%					
3	Fixed carbon (AD)	%					
4	Ash (AD)	%					
5	Total	%					
6	HHV	kJ/kg					
7	Fuel ratio						
8	Surface water	%					
9	C	%					
10	H	%					
11	S	%					
12	N	%					
13	O	%					
14	H_2O	%					
15	Ash	%					
16	Total	%					
	AD:Air dry						
	Ash fusion, reducing						
17	IT	℃					
18	ST	℃					
19	HT	℃					
20	FT	℃					
	Ash fusion, oxidizing						
21	IT	℃					
22	ST	℃					
23	HT	℃					
24	FT	℃					
	Ash mineral analysis						
25	SiO_2	%					
26	Al_2O_3	%					
27	Fe_2O_3	%					
28	CaO	%					
29	MgO	%					
30	Na_2O	%					
31	K_2O	%					
32	TiO_2	%					
33	MnO	%					
34	SO_3	%					
35	P_2O_5	%					

INVESTIGATION SHEET : Generator

TOR 4

Questionnaire about Generator for selecting power station
Object: Generator (stator coil)

	Questionnaire	Reply
1	Generator specification	
	(1) Type	
	(1) Rated output (MW or MVA)	
	(2) Rated voltage (kV)	
	(3) Rated current (A)	
	(4) Frequency (Hz)	Design : Present operation :
	(5) Power factor	Design : Present operation :
	(6) Stator specification	
	a. Insulation class	
	a. Cooling system	H2 cooling, Air cooling or Water cooling
	b. Insulation material	
	c. Type of resin	
	d. Resin process method	
	(7) Manufacturer (country)	
2	Operation record	
	(1) Year of operation	
	(2) Accumulated number of generator start-stop	
	(3) Accumulated operation time (hour)	
	(4) Operation mode	Base-load, Middle-load or Peak-load
3	Operation monitoring data (①Just after starting commercial operation and ②Now)	①:Exist or Nil ②:Exist or Nil
4	Insulation resistance test (megger testing) data in the past 5 years	Exist or Nil

5	History of implementing Polarization index test (PI test)	
	(1) 1st test	Exist or Nil
	(2) 2nd test	Exist or Nil
	(3) 3rd test	Exist or Nil
	(4) 4th test	Exist or Nil
	(5) 5th test	Exist or Nil
6	History of implementing Tan δ test	
	(1) 1st test	Exist or Nil
	(2) 2nd test	Exist or Nil
	(3) 3rd test	Exist or Nil
	(4) 4th test	Exist or Nil
	(5) 5th test	Exist or Nil
7	History of implementing AC voltage-current test	
	(1) 1st test	Exist or Nil
	(2) 2nd test	Exist or Nil
	(3) 3rd test	Exist or Nil
	(4) 4th test	Exist or Nil
	(5) 5th test	Exist or Nil
8	History of implementing Partial discharge test	
	(1) 1st test	Exist or Nil
	(2) 2nd test	Exist or Nil
	(3) 3rd test	Exist or Nil
	(4) 4th test	Exist or Nil
	(5) 5th test	Exist or Nil
9	Records of accident	
10	Records of refurbishment	

INVESTIGATION SHEET : Main Transformer

Questionnaire about Transformer for selecting power station
Object: Main transformer

	Questionnaire	Reply
1	Transformer specification	
2	Transformer specification (insulation oil storage type)	Open type or Closed type (Sealed type)
3	Coolant (Insulator)	Oil or SF6 Gas
4	Absorbent for insulation oil	Exist or Nil
3	Year of starting operation	
4	Accumulated operation time (hour)	
5	Records of implementing gas analysis of transformer insulation oil	
	(1) 1st test	Exist or Nil
	(2) 2nd test	Exist or Nil
	(3) 3rd test	Exist or Nil
	(4) 4th test	Exist or Nil
	(5) 5th test	Exist or Nil
6	Records of insulation oil cleaning(deaeration)/changing	
	(1) 1st insulation oil cleaning(deaeration)/changing	
	(2) 2nd insulation oil cleaning(deaeration)/changing	
	(3) 3rd insulation oil cleaning(deaeration)/changing	
	(4) 4th insulation oil cleaning(deaeration)/changing	
7	Records of implementing furfural testing in transformer insulation oil	
	(1) 1st test	Exist or Nil
	(2) 2nd test	Exist or Nil
	(3) 3rd test	Exist or Nil
	(4) 4th test	Exist or Nil
	(5) 5th test	Exist or Nil
8	Manufacturer (country)	
9	Records of accident	
10	Records of refurbishment	

INVESTIGATION SHEET-1 TOR 4

SHUT DOWN BY TROUBLE

No.	DATE	SHUT DOWN PERIOD (HR)		EQUIPMENT	REASON/COUNTER MEASURE
	D/M/Y	UNIT SHUT DOWN	PARTIAL SHUT DOWN		

INVESTIGATION SHEET-2 TOR 4

EQUIPMENT LIST WITH FREQUENT TROUBLE

No.	DATE D/M/Y	SHUT DOWN PERIOD (HR)		EQUIPMENT	REASON/COUNTER MEASURE
		PLANT SHUT DOWN	PARTIAL SHUT DOWN		

INVESTIGATION SHEET-3 TOR 4

PAST RENOVATION

No.	DATE D/M/Y	SHUT DOWN PERIOD (HR)	SYSTEM/EQUIPMENT CONTENT OF RENOVATION	REASON/RESULT