Japanese Boiler RLA Guidline (1)

To extend periodical inspection interval 2 year to 4year after 100,000 hours operation.

(1) Degradation factor to be evaluated

- Creep rupture remaining life
  (Designed temperature beyond 450℃)

(2) Components to be evaluated

- Furnace evaporation header
- Super heater header or Main steam pipe
- Reheater header or High temperature reheat pipe

Representative points among high heat loaded and high stressed portion in these components

Japanese Boiler RLA Guidline (2)

(3) Method to assess the remaining life

➢ More than one method used as shown in table below

Method	Guideline		This study	
	Base metal	Weld (HAZ)	Base metal	Weld (HAZ)
Hardness measuring	—	○		
Electrical resisitance	—	○		
Chemical composition of carbide	○	○		
Creep cavity evaluation	—	○		
Microstructural comparison	○	○	○	○
Urtra sonic scattering noise	—	○		
Interparticle spacing	○	—		
Crystal grain deformation	○	—		
Destructive test	○	○		
Analytical method	○	○		

○ : applicable, −: not applicable

(4) Effective (countable) remaining life

➢ 1/ 2 of remaining life evaluated by above methods

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.

Japanese Boiler Inspection (Example (1))

Components	Inspected portion	degradation factor	Inspection method	Quantity	Note
Drum	Drum and stub	Corrosion loss, pitching	VT、DPT	1set	
	Stub, longitudinal and circumferential weld	Thermal fatigue crack	VT、DPT	1set	
Furnace	Water wall tube	Erosion thinning	VT、UT	2,000points(*1)	Thickness measurement Risidual life asessment
		High temperature corrosion loss	Sampling tube examionation (tube dimention, hardness, microstructure, adhearing scale volume)	4tubes	Tube sampling Risidual life asessment
	Welding portion of tube with attached metal	Thermal fatigue crack	VT、DPT	200points*(1)	
Furnace header	Headr inside	Scale deposition	VT (Fiber scope)	10 headers	
	Circumferntial weld	Thermal fatigue crack	VT, MPI, Replica	3points	Risidual life asessment
	Stub, Stub weld portion	Thermal fatigue crack	VT, DPT	360points(*1)	
SH	Tube	High temperature corrosion loss	VT、UT	300points(*1)	Thickness measurement Risidual life asessment
		Creep	Sampling tube examionation (tube dimention, hardness, microstructure, adhearing scale volume, creep rupture test)	1 tube	Tube sampling Risidual life asessment
		SUS scale deposit	Induction method	1200 points (*1)	
	Disimilar weld	Creep fatigue crack	VT, DPT	40points (*1)	
	Welding portion of tube with attached metal	Thermal fatigue crack	VT、DPT	60points (*1)	
SH header	Headr inside	Scale deposition	VT (Fiber scope)	3 headers	
	Circumferntial weld	Thermal fatigue crack	VT, MPI, Replica	3points	Risidual life asessment
	Stub, Stub weld portion	Thermal fatigue crack	VT, DPT	60points (*1)	

Japanese Boiler Inspection (Example (2))

Components	Inspected portion	degradation factor	Inspection method	Quantity	Note
RH	Tube	High temperature corrosion loss	VT、UT	3000points (*1)	Thickness measurement Risidual life asessment
		Creep	Sampling tube examionation (tube dimention, hardness, microstructure, adhearing scale volume, creep rupture test)	1tube	Tube sampling Risidual life asessment
	Disimilar weld	Creep fatigue crack	VT, DPT	40points (*1)	
	Welding portion of tube with attached metal	Thermal fatigue crack	VT、DPT	80points (*1)	
RH header	Headr inside	Scale deposition	VT (Fiber scope)	1header	
	Circumferntial weld	Thermal fatigue crack	VT, MPI, Replica	3points	Risidual life asessment
	Stub, Stub weld portion	Thermal fatigue crack	VT, DPT	680points (*1)	
Economizer	Tube	Erosion thinning Corrosion loss	VT、UT	100points (*1)	Thickness measurement Risidual life asessment
Economizer header	Headr inside	Scale deposition	VT (Fiber scope)	1header	
	Stub, stub weld	Thermal fatigue crack	VT DPT	40points (*1)	
Main pipe					
Main steam pipe	Longitudinal and circumferential weld	Creep, Creep fatigue	VT, MPI, Replica	3points	Risidual life asessment
Hot reheat pipe	Longitudinal and circumferential weld	Creep, Creep fatigue	VT, MPI, Replica	3points	Risidual life asessment
Boiler circulation pump	Casing, liner	Corrosion/attrition, thermal fatigue crack	VT、PT、MT	1pump	
	Motor coil (pump in water)	Degradation of electrical insulation	Electrical resistivity measurement	1pump	
Air heater	Element	Corrosion/attrition	VT, Weight measurement, Pack pressure measurement	4sector	Risidual life asessment

※1: Quantity is 60% of capacity 700MW (Suoer crytical boiler)

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

Boiler Remaining Life Assessment
Inspection Report

JICA Study Team (Kyusyu Electric Power Co.,Inc.)
Kyudensangyo Co.,Inc

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Table of content Ⅰ-2 〔Singrauli #6〕

Table of content II -1 〔Unchahar #2〕

Table of content Ⅱ-2 〔Unchahar #2〕

Inspection at Singrauli #6

Boiler residual life assessment was carried out as one of the activities to improve the efficiency of coal-fired thermal power plants in NTPC-India and transfer to counterpart the technology.
Boiler residual life assessment results are reported as follows.

1. Unit for evaluation

Singrauli Super Thermal Power Station #6 unit

2. Operation condition

(1) Cumulative operation hours: 172,000 hours

(2) Cumulative start and stop times: 309 times

3. Summary of residual life assessment results

The highest creep life consumption ratio among evaluated pipes and headers were 80% at Main Steam Pipe-Left (Circumferential weld, intrados) with the evaluated residual life 21,000 hours and 70% at Main Steam Pipe-Left (Circumferential weld, extrados) with the evaluated residual life 37,000 hours accompanied by microstructural degradation, though no direct creep damage was observed such as creep void and creep strain. The evaluated residual life for the other components was 105,000 hours or more.

It is recommended that the residual life assessment for Main Steam Pipe be carried out again before reaching the evaluated residual life.

Residual life assessment results by microstructural comparison method

Components	Location	Max. creep life consumption ratio (%)	Min. Evaluated residual life (h)	Evaluated region
Platen SH Outlet Header-Left	Circumferential weld at left side	38	140,000	Fine grain HAZ
De-Super heater-Left	Circumferential weld	45	100,000	Coarse grain HAZ
De-Super heater-Right	Circumferential weld	45	100,000	Coarse grain HAZ
RH Outlet Header-Left	Circumferential weld at left side	20	340,000	Coarse grain HAZ
RH Outlet Header-Right	Circumferential weld at right side	6	1,300,000	Base Metal
Main Steam Pipe-Left	Circumferential weld,extrados	70	37,000	Base Metal
Main Steam Pipe-Left	Circumferential weld,intrados	80	21,000	Fine grain HAZ

4. Summary of the other inspection results

(1) Visual inspection

- As results of visual inspection of boiler inside and penthouse, the decrease in thickness by erosion for Water wall tubes around short soot blower and the decrease in thickness by attrition of Platen SH binding tubes and cooling spacer tube in Platen SH were observed.
- Disorder of panel arrangement with distortion was observed at lower part of in Platen SH and RH.
- No appearance abnormality was observed in stubs and the other weld portions for headers in penthouse.

(2) Thickness measurement

- As a result of thickness measurement for Water wall tubes at erosion area around short soot blowers near each 4 corner (71points in total), the measured thickness for a number of tubes (min. 3.7mm) was less than tsr (thickness required) 5.5mm calculated with designed OD, pressure and allowable stress at the designed temperature.
- As a result of thickness measurement for mainly for outer tubes of rear side portion at soot blower level and outer bottom tubes of Platen SH tube (50points in total), no measured thickness value was found to be below the designed value.

(3) OD measurement

- As a result of OD measurement of Platen-SH outlet header-left, De-Super heater (left&right), RH outlet header (left&right) and Main Steam Pipe-left, the increase in measured OD to designed value was less than 1% for each component, indicating no remarkable creep strain

(4) SUS scale deposition inspection

- As a result of SUS scale deposition inspection for mainly outermost tubes of Platen-SH and RH 50 points for each, 5 portions were 15% fullness, 3 portions were 10% fullness and the others were less than 10% fullness of SUS scale deposition, indicating no remarkable SUS scale deposition.

(5) Dye penetrant inspection

- As a result of Dye penetrant inspection 4 stub weld portions of #5 panel from left of Platen SH inlet, a linear indication was found in tube side, which had disappeared after grinding off 1mm depth from surface.

(6) UT inspection

- As a result of UT inspection for RH outlet header-Right, no flaw echo judged as a crack was detected.

(7) TOFD inspection

- As a result of TOFD inspection at the location identical to UT inspection in RH outlet header-Right, no flaw echo judged as a crack was detected, although a number of flaw echoes from subtle blow holes and slag inclusions by welding were detected.

5. Components for residual life assessment and inspection

Components for residual life assessment and the other inspections are shown in Table I -1 and Table I -2 respectively.

Location and pictures for each inspection are shown in Fig. I -1 and Photo I -1～3 respectively.

Table I -1 Components for residual life assessment

Component	Location	Material		Designed				
				O.D.	t	Temperature	Pressure	
		ASME	JIS	(mm)	(mm)	(°C)	(MPa)	(kg/cm²)
Platen SH Outlet Header-Left	circumferential weld at left side	SA335P12	STPA22	508.0	80.0	540	17.46	178.0
De-Suerheater-Left	Circumferential weld	SA335P12	STPA22	508.0	70.0	406	18.51	188.7
De-Suerheater-Right	Circumferential weld	SA335P12	STPA22					
RH Outlet Header-Left	Circumferential weld at left side	SA335P22	STPA24	558.8	50.0	540	4.26	43.5
RH Outlet Header-Right	Circumferential weld at right side	SA335P22	STPA24					
Main Steam Pipe-Left	Circumferential weld, extrados sid	SA335P22	STPA24	520.0	85.0	540	17.46	178.0
Main Steam Pipe-Left	Circumferential weld, intrados side	SA335P22	STPA24					

Table I -2 Components for the other inspections

Components	Inspection method
Water wall tube	Visual inspection
	Thickness measurement of tubes
Platten SH tube	Visual inspection
	Thickness measurement of tubes
	SUS scale deposition inspection
	Tube sampling for sample tube inspection
	Creep rupture test
Reheater tube	Visual inspection
	SUS scale deposition inspection
	Tube sampling for sample tube inspection (inspected in Japan).
	Creep rupture test for 1 tube with 1m length.
Super heater header	Visual inspection
	DPT
	Replica inspection
De-Superheater pipe	Replica inspection
Reheater header	Visual inspection
	Replica inspection
	UT
	TOFD
Main steam pipe (near the stop valve weld joint)	Replica inspection

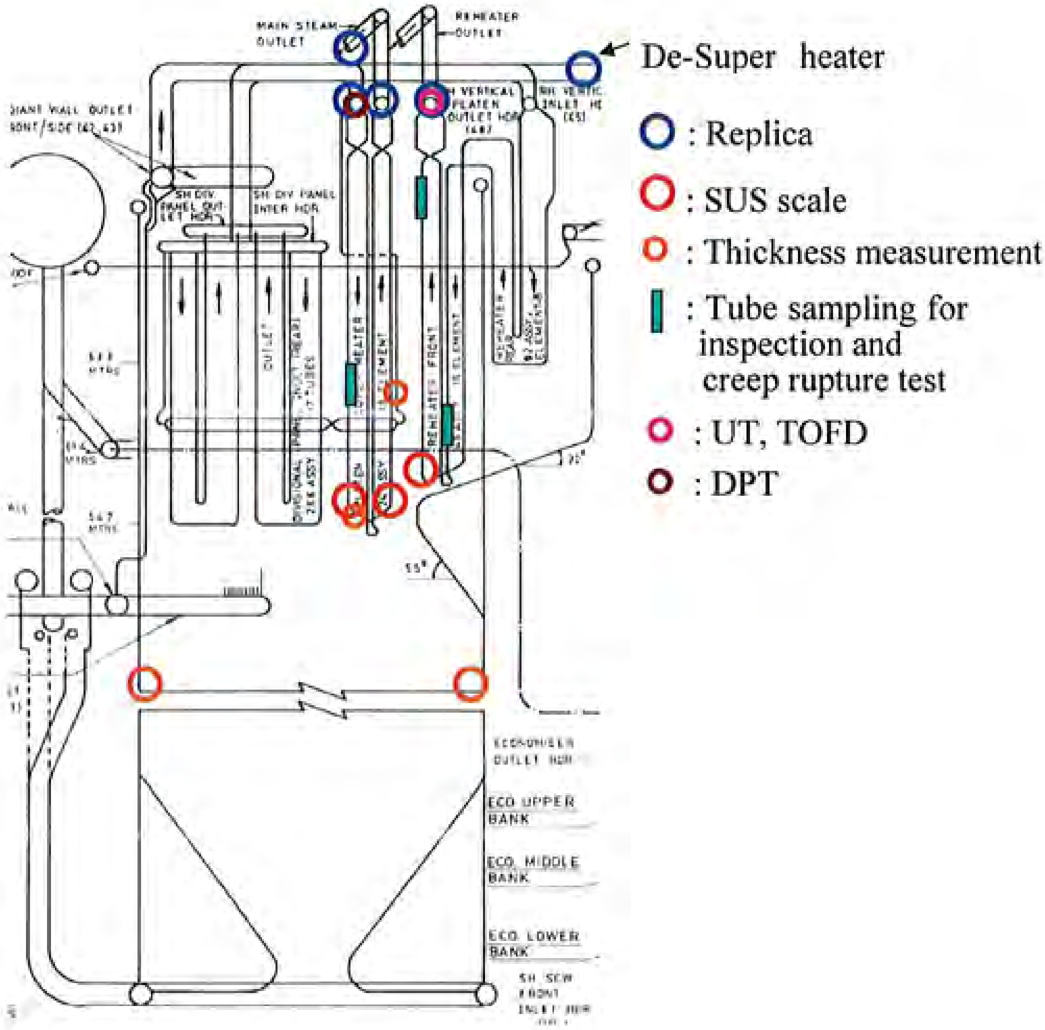

Fig. Ⅰ-1 Location for each inspection

6. Items for residual life assessment

Items for residual life assessment by microstructural comparison method are shown in Table I -3.

Table I -3 Items for residual life assessment

Components	Location	Material	Area	Microstructure	Carbide precipitation	Creep void grade	Average diameter of grainboundary precipitates	Average volume fraction of grainboundary precipitates	Precipitates free band width along grainboundary
Platen SH Outlet Header-Left	circumferential weld at left side	SA335P12	Base metal	O	O			O	
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				
De-Suerheater-Left	Circumferential weld	SA335P12	Base metal	O	O			O	
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				
De-Suerheater-Right	Circumferential weld	SA335P12	Base metal	O	O			O	
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				
RH Outlet Header-Left	Circumferential weld at left side	SA335P22	Base metal	O	O		O	O	O
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				
RH Outlet Header-Right	Circumferential weld at right side	SA335P22	Base metal	O	O		O	O	O
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				
Main Steam Pipe-Left	Circumferential weld,extrados	SA335P22	Base metal	O	O		O	O	O
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				
Main Steam Pipe-Left	Circumferential weld,intrados	SA335P22	Base metal	O	O		O	O	O
			Intercritical zone	O					
			Fine grain HAZ	O	O		O	O	
			Coarse grain HAZ	O	O	O			
			Weld metal	O	O				

(1) Microstructure evaluation

The existence of crack and microstructural degradation was inspected by optical microscope observation.

(Observed region)

Base metal, Intercritical zone, Fine grain HAZ, Coarse grain HAZ, Weld metal

(Observed magnification)

×500(2 views), ×1000(4 views) for each region

(2) Carbide precipitation evaluation

Morphology and distribution of precipitates were inspected by TEM (Transmission Electron Microscope) observation.

(Observed region)

Base metal, Intercritical zone, Fine grain HAZ, Coarse grain HAZ, Weld metal

(Observed magnification)

Main steam pipe ; ×1000 (2 views), ×5000(3 views), ×10000(2 views)

Other components ; ×2000 (2 views), ×10000(4 views)

(3) Creep void grade evaluation

The existence of micro crack and creep void was inspected by SEM (Scanning Electron Microscope) observation.

(Observed region)

Fine grain HAZ, Coarse grain HAZ, Weld metal (Evaluation was focused on Coarse grain HAZ).

(Observed magnification)

×500, ×2000 for each region (3 views for each)

(4) Quantitative evaluation of average diameter and volume fraction of grain boundary precipitates

Average diameter and volume fraction of grain boundary precipitates were evaluated quantitatively by SEM observation.

(Observed region)

Base metal, Fine grain HAZ

(Observed magnification)

Base metal ; ×3000, Fine grain HAZ ; ×4000 (6 views for each)

(5) Quantitative evaluation of precipitates free band width along grain boundary

Precipitates free band width along grain boundary were evaluated quantitatively by TEM observation.

(Observed region)

Base metal

(Observed magnification)

Base metal ; ×2000 (10 points evaluated in 6views)