

**Japan International Cooperation Agency
Ministry of Power
NTPC LTD**

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

Final Report

Volume II

November 2010

Electric Power Development Co., Ltd.

Tokyo, Japan,

Kyusyu Electric Power Co., Inc.

Fukuoka, Japan

and

The Chugoku Electric Power Co., Inc.

Hiroshima, Japan

IDD

CR(10)

10-129

TABLE OF CONTENTS

CONCLUSION AND RECOMMENDATION

Conclusion	1
Recommendation	5

CHAPTER 1 INTRODUCTION

1.1 Background of the Study	1-1
1.2 Purpose of the Study	1-1
1.3 Schedule of the Study	1-1
1.4 Scope of the Study	1-2
1.5 Outline of the Study	1-3
1.6 Basic Policy of the Study	1-3
1.7 Counterpart Agencies	1-6
1.8 Study Team Member	1-8

CHAPTER 2 POWER SECTOR IN INDIA

2.1 Government Policy	2-1
2.1.1 Law/Regulation	2-1
2.1.2 Power Sector Structure	2-1
2.1.3 Power Demand and Supply	2-7
2.1.4 Policy and Development Plan and MEGA Project	2-12
2.1.5 Tariff	2-15
2.1.6 Assistance Policy and Present Situation of Project Formation Proposed by Other Donors	2-19

CHAPTER 3 PERFORMANCE IMPROVEMENT IN NTPC POWER PLANTS

3.1 NTPC Limited Power Plant	3-1
3.2 Statuses of Operation	3-5
3.3 Former Performance Improvement in NTPC	3-7

CHAPTER 4 WORK IN INDIA

4.1 #1 Kick off Meeting	4-1
4.2 #2 Kick off Meeting	4-1
4.3 #1 Field Work	4-3
4.4 #2 Field Work	4-9
4.5 #3 Field Work	4-9
4.6 #4 Field Work	4-9
4.7 #5 Field Work	4-9

Vol. I

4.8 #6 Field Work	4-9
CHAPTER 5 SELECTION OF CANDIDATE UNITS OF NTPC AND STUDY SCOPE	
5.1 Selected Units and Study Scope	5-1
5.2 Present Operation Condition of the Selected Units	5-9
CHAPTER 6 STUDY RESULT AND RECOMMENDATION	
6.1 Diagnosis of Boiler Problem	6-1
6.2 Combustion Simulation	6-11
6.2.1 Introduction	6-11
6.2.2 Outline of the Combustion Simulation and the Subject in this Project	6-11
6.2.3 The Mesh Pattern and the Simulation Cases	6-12
6.2.4 Results	6-13
6.2.5 Additional Case study for the Effect of the Air and Fuel Bias	6-16
6.3 Boiler Remaining Life Assessment	6-21
6.3.1 Overview	6-21
6.3.2 Procedure	6-23
6.3.3 Report	6-23
6.4 Air Heater (AH) Performance Improvement	6-26
6.4.1 Korba #6	6-26
6.4.2 Singrauli Unit 4	6-29
6.4.3 Efficiency Improvement Proposals	6-33
6.5 Turbine RLA	6-42
6.6 Condenser Leak Buster	6-51
6.7 Pump Assessment	6-52
6.8 Seal Fin Replacement	6-55
6.9 Control System Assessment	6-59
6.9.1 Overview	6-59
6.9.2 Details	6-59
6.9.3 Evaluation	6-59
6.9.4 Improvement Proposals and Effects	6-60
6.10 BFP Turbine Parameter Assessment	6-60
6.11 Generator Assessment	6-62
6.11.1 Target Generator for Assessment and the Procedure	6-62
6.11.2 Korba#6 Generator Assessment	6-63
6.11.3 Rihand#2 Generator Assessment	6-64
6.11.4 Singrauli#4 Generator Assessment	6-65

6.12 Generator Transformer Assessment.....	6-66
6.12.1 Target Transformers for Assessment and the Procedure	6-66
6.12.2 Korba #6 GT Assessment	6-68
6.12.3 Rihand#2 GT Assessment	6-69
6.12.4 Singrauli#6 (R-Phase) GT Assessment	6-71
6.12.5 Korba #6 GT Assessment (3 rd year: 2010)	6-72
6.13 Analysis of Current Performance and Performance Degradation	6-73
6.13.1 General	6-73
6.13.2 Boiler Performance Test	6-77
6.13.3 Turbine Performance Test	6-90
6.14 Review and Improvement of Past and Present O&M Procedure	6-99
6.14.1 Current Conditions of Thermal Power Station Operations	6-99
6.14.2 Current Conditions of Operation	6-99
6.14.3 Outline of a Power Station Management System.....	6-100
6.14.4 Power Generation Equipment Operating States in Each Power Station	6-114
6.14.5 Issues and Countermeasures about Operation of Power Generation Equipment	6-115
6.14.6 Provided Reports and Instructions	6-122
6.15 Economic and Financial Analysis.....	6-124
6.15.1 Concept	6-124
6.15.2 Scope	6-124
6.15.3 Method	6-125
6.15.4 Economic and Financial Analysis - Case Study.....	6-135
6.15.5 Environmental Value Added Analysis.....	6-181
6.16 Application of CDM.....	6-198
6.16.1 Outline of CDM	6-198
6.16.2 Implementation of preparation of PDD Draft	6-202
6.16.3 Summary of PDD Draft	6-203
6.16.4 Planning of schedule of preparatory works for CDM procedure for submission and approval	6-220
6.17 Recommendation.....	6-224

CHAPTER 7 TRAINING PROGRAM

7.1 Periodic Inspection, Efficiency Management, Facility Condition Monitoring and Diagnostic Technology Training.....	7-1
7.1.1 Periodic Inspection Training Course.....	7-2
7.1.2 Efficiency Management Training Course.....	7-4
7.1.3 Facility Condition Monitoring and Diagnostic Technology Training Course	7-5

7.2	Boiler Residual Life Assessment Technique Training.....	7-6	}	Vol. I		
7.2.1	Boiler Residual Life Assessment Technique Training Course	7-7				
7.3	Boiler Combustion Simulation Training.....	7-8				
7.3.1	Boiler Combustion Simulation Training Course	7-9				
7.4	Evaluation of the Trainings	7-10				
7.4.1	Evaluation of Training Programs	7-10				
7.4.2	Evaluation of Training Program and Implementation.....	7-10				
CHAPTER 8 ATTACHMENT						
8.1	Minutes of Meeting (MOM)				}	Vol. I
8.1.1	MoM of First Steering Committee					
8.1.2	MoM of Second Steering Committee					
8.1.3	MoM of Third Steering Committee					
8.1.4	MoM of Fourth Steering Committee		}	Vol. II		
8.2	Presentation Slides					
8.2.1	#1 Work Shop		}	Vol. III		
8.2.2	Other work shop and seminar					
8.3	Survey Sheets for the Selection of the Candidate Units					
8.4	Assessment / Test procedure and report					
8.4.1	Boiler RLA					
8.4.2	Condenser Leak Buster					
8.4.3	Pump Test					
8.4.4	Control System Assessment					
8.4.5	Generator Assessment					
8.4.6	Generator Transformer Assessment					
8.4.7	Performance Test					
8.4.8	Combustion Simulation		}	Vol. IV		
8.4.9	BFPT Parameter Assessment					
8.4.10	Preparation of PDD Draft					
8.4.11	Turbine RLA		}	Vol. V		

8.4.1 Boiler RLA

Scope of work and diagnosis procedure for Boiler RLA

< Objectives of power plants >

- (1) Singrauli Unit 6
- (2) Unchahar Unit 2
- (3) Rihand Unit 2

< Objectives of boiler components >

- (1) Water wall
- (2) Super heater
- (3) Reheater
- (4) Super heater header
- (5) De super heater pipe
- (6) Reheater header
- (7) Main steam pipe

< Procedure >

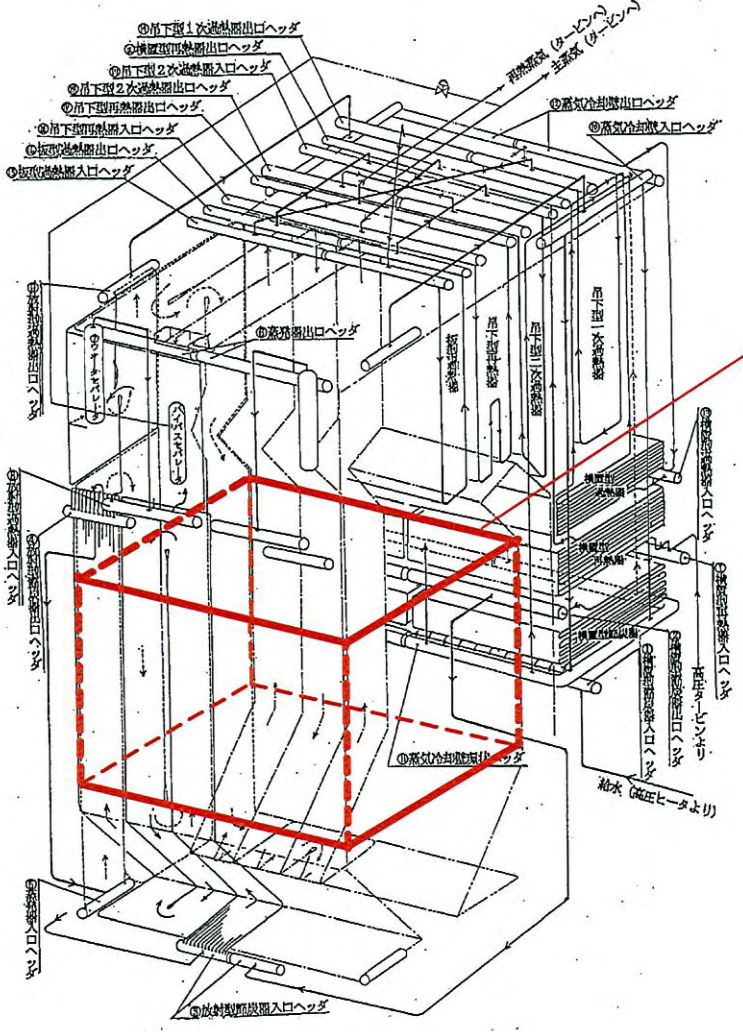
Boiler remaining life assessment will carried out based on the following procedure.

NO.	Parts	INSPECTION	Singrauli 6	Rihand 2	Unchahar 2	Reference
1	WATER WALL	VT	• Mainly at burner level • Erosion part		*	
2		THICKNESS	• 20 points (5 points each from 4 corners)		*	8-4-1-1
3	SUPER HEATER	VT	• Mainly Platen super heater		*	
4		THICKNESS MEASUREMENT	• 50 points around soot blower		*	8-4-1-2
5		SAMPLE TUBE INSPECTION	• 1 tube with 1m length for Platen SH including weld joint portion		*	8-4-1-3
6		CREEP RUPTURE TEST (inspected in Japan)	• 3 specimens from base metal, 3 specimens from weld joint from the tube identical to above.		*	8-4-1-4
7		SUS SCALE DEPOSITION INSPECTION	• 50 points of bottom bend portion of austenitic steel tubes		*	8-4-1-5
8	REHEATER	VT	• Mainly around soot blower		*	
9		THICKNESS MEASUREMENT	—		*	
10		SAMPLE TUBE INSPECTION (inspected in Japan).	• 2 tubes with 1m length for Final RH (one each from furnace inside and penthouse) including weld joint portion		*	8-4-1-3
11		CREEP RUPTURE TEST (inspected in Japan) for 1 tube with 1m length.	• 3 specimens from base metal, 3 specimens from weld joint from the tube identical to the one of the above sample tubes		*	8-4-1-4
12		SUS SCALE DEPOSITION INSPECTION	• 50 points of bottom bend portion of austenitic steel tubes		*	8-4-1-5
13	SUPER HEATER HEADER	VT	• Visual inspection in penthouse • If the fiber scope is shipped in time, fiber scope inspection is carried out for outlet header		*	
14		PT(DPT)	• 4 portions at stub weld of Inlet header		*	8-4-1-6
15		UT	• 1 ring of circumferential weld of outlet header with UT and TOFD identical to the replica portion		*	8-4-1-7
16		REPLICA INSPECTION	• 1 point on 1 ring of circumferential weld of left outlet header • 1 point on base metal of left outlet header	• 2 point on 1 ring of circumferential weld of outlet header	*	8-4-1-8 8-4-1-9 8-4-1-10
17	DE SUPER HEATER PIPE	REPLICA INSPECTION	• 2 points (one each from 2 rings of circumferential weld)		*	8-4-1-8 8-4-1-9 8-4-1-10
18	REHEATER HEADER	VT	• Visual inspection in penthouse		*	
19		REPLICA INSPECTION	• 2 points (one each from circumferential weld of left and right of out let header)	• 2 point on 1 ring of circumferential weld for outlet header	*	8-4-1-8 8-4-1-9 8-4-1-10
20	MAIN STEAM PIPE (near the stop valve weld joint)	REPLICA INSPECTION	• 2 points on circumferential weld of left main steam pipe	• 2 points (one each from left and right side)	*	8-4-1-8 8-4-1-9 8-4-1-10

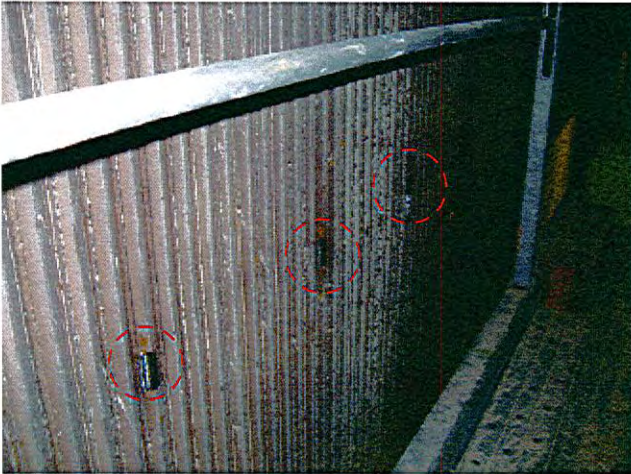
*:Decided after site meeting, basically followed by items of the other two units.

• BUILDING OF SCAFFOLDS, REMOVAL OF THERMAL INSULATION ,
AND REMOVAL OF DUST IN BOILER FURNACE SHALL BE COMPLETED IN ADVANCE.

Thickness Measurement (Water wall tube)



Bird's eye view of boiler



Example of measurement points

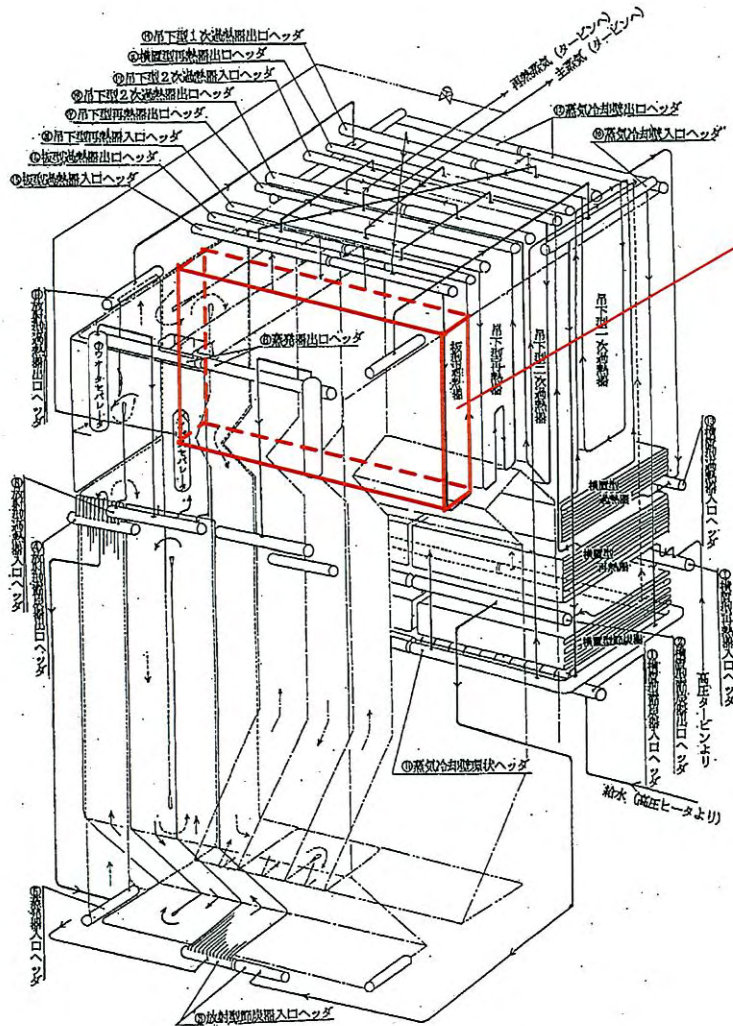
Selection criteria

- The most severe heat load portion like the upper part of the burner level .
(Available metal temperature data would help the selection)

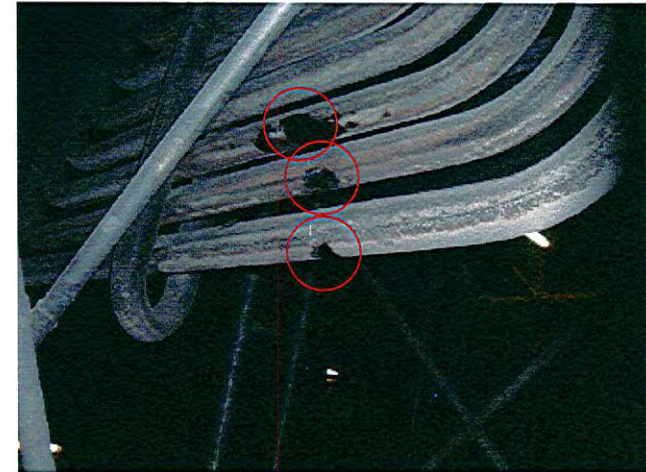
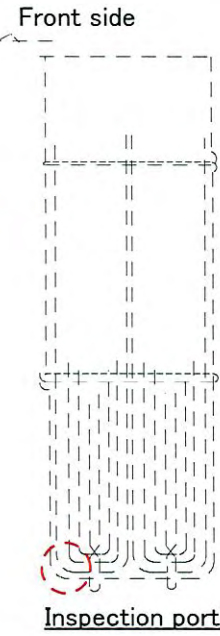
Measurement points and quantity

- 5 points of each corner.

Thickness Measurement (Super heater tube)



Bird's eye view of boiler



Example of measurement points

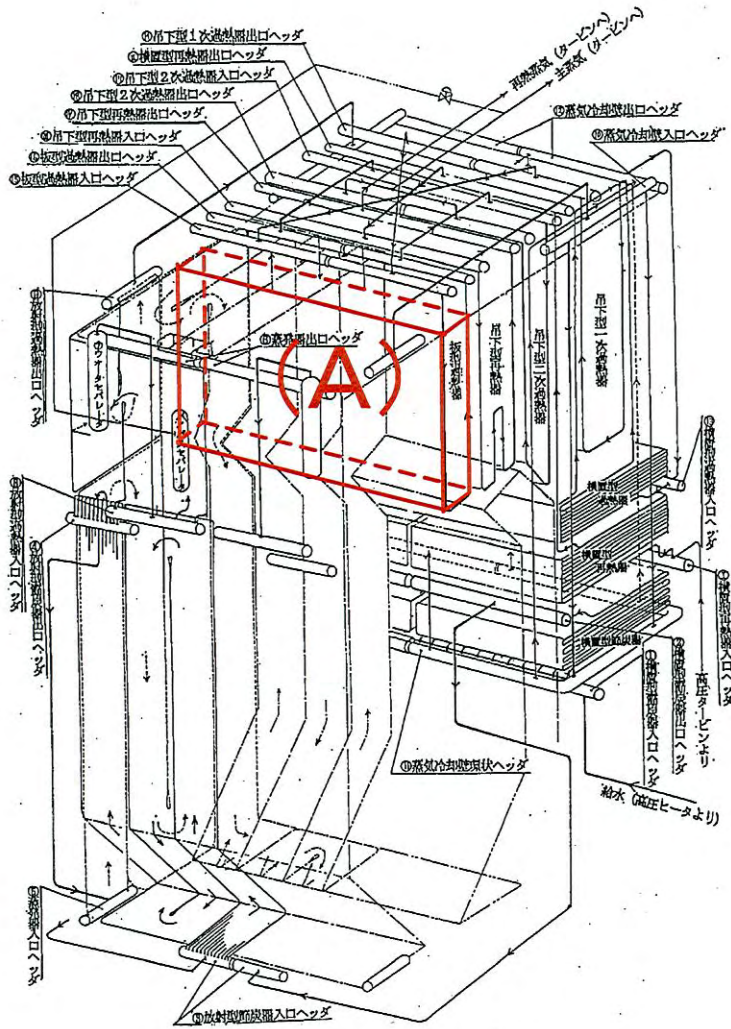
Selection criteria

- The highest temperature portion of super heater tubes (or reheater tubes) .
- The portion directly exposed to combustion gases from the furnace with the risk of thickness loss by oxidation from outside.

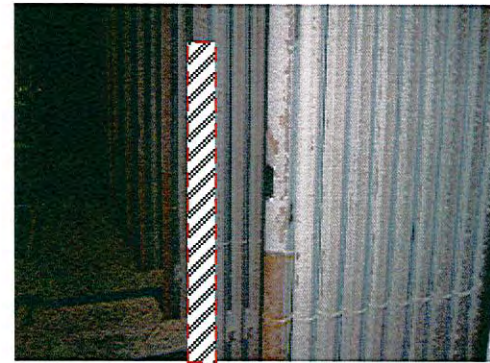
Measurement points and quantity

- Total 50 points of the straight portion of outer tube (1-3rd) around soot blower for selected final superheater panel.

Sample Tube Inspection (Super heater tube, Reheater tube)



Bird's eye view of boiler



Example of sampling point for SH

Examination item

1. Appearance inspection
2. Inner and outer surface inspection
3. Inner scale examination (adhesion thickness, composition(water wall tube))
4. Hardness test
5. Tube dimensions measurement
6. Microstructure examination

Selection criteria

[Super heater tube]

- The highest temperature portion of super heater tubes (or reheater tubes).

Measurement points and quantity

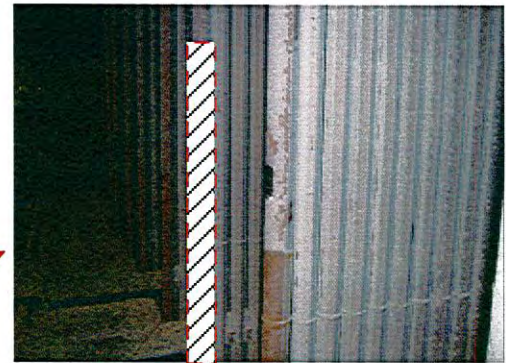
[Super heater tube]

1 tube with 1m length including weld joint portion.

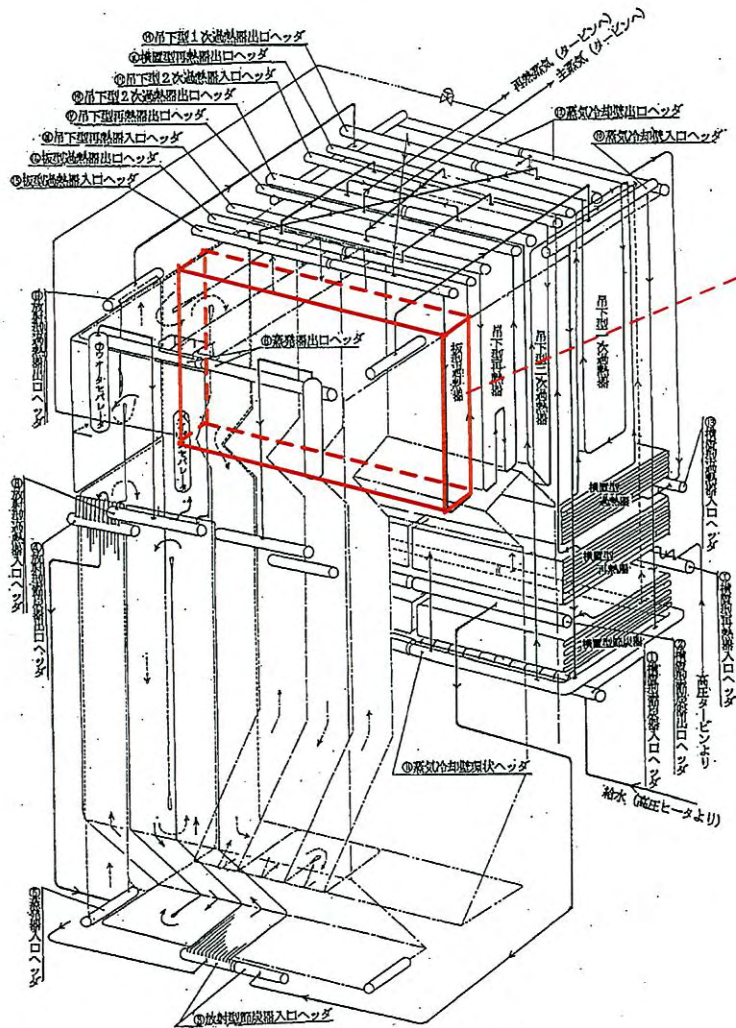
[Reheater tube]

2 tubes with 1m length for Final RH
(one each from furnace inside and penthouse)
including weld joint portion.

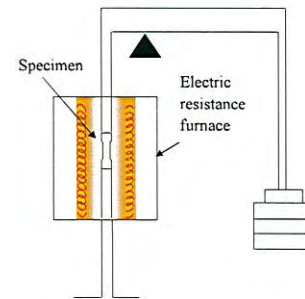
Creep Rupture Test (Super heater tube, Reheater tube)



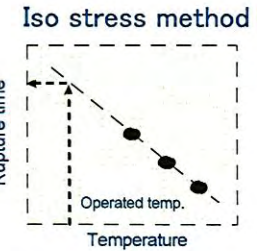
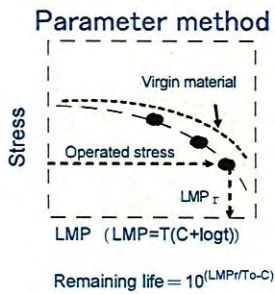
Example of sampling point for SH



Bird's eye view of boiler



Schematic view of creep rupture test



RLA by creep rupture test

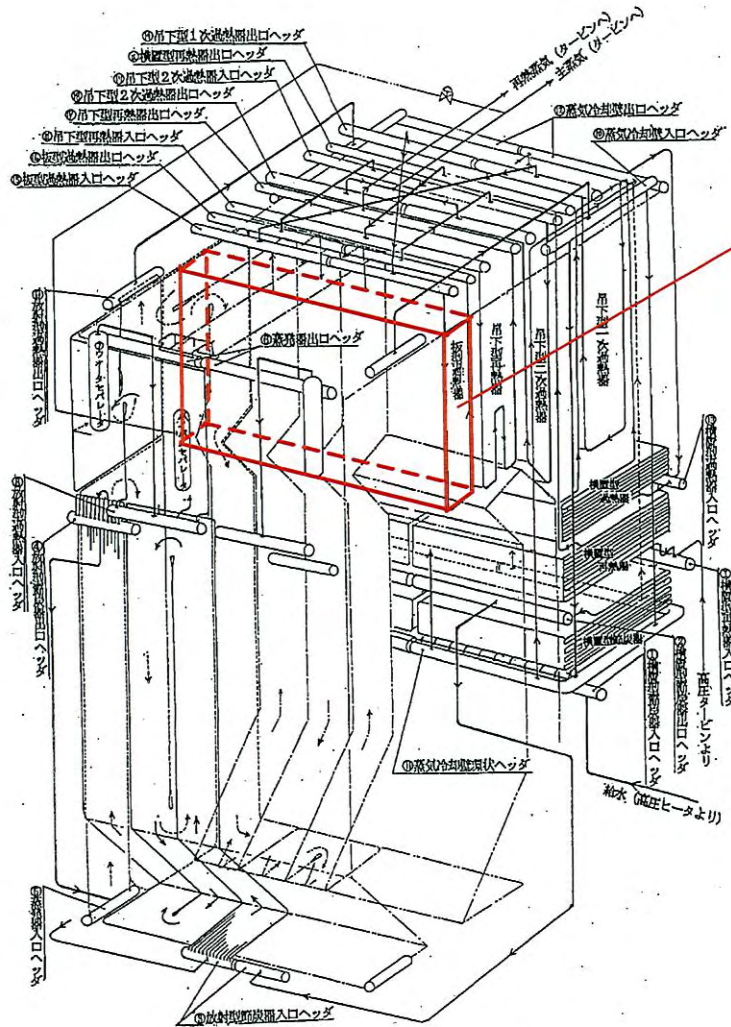
Selection criteria

- The highest temperature portion of super heater tubes and reheater tubes (Including circumferential weld portion)

Measurement points and quantity

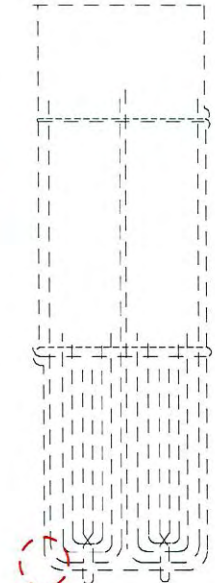
- 1 tube with 1m length including circumferential weld portion of super heater (Base metal and weld portion evaluated separately (test pieces total 6))
- 1 tube with 1m length including circumferential weld portion of reheater (Base metal and weld portion evaluated separately (test pieces total 6))

SUS Scale Deposition Inspection (Super heater tube, Reheater tube)

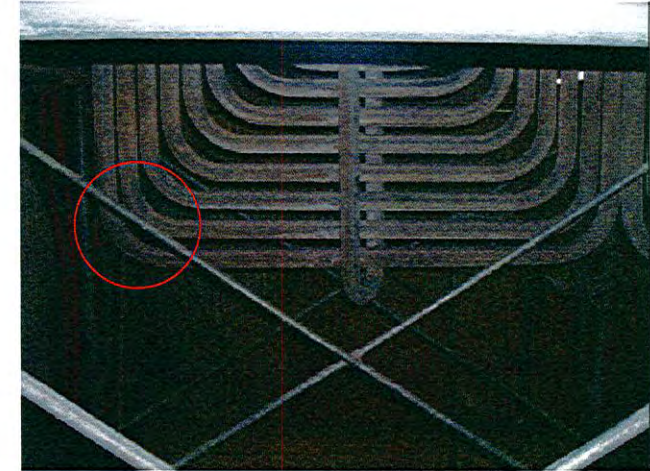


Bird's eye view of boiler

Front side



Inspection portion



Example of inspection points

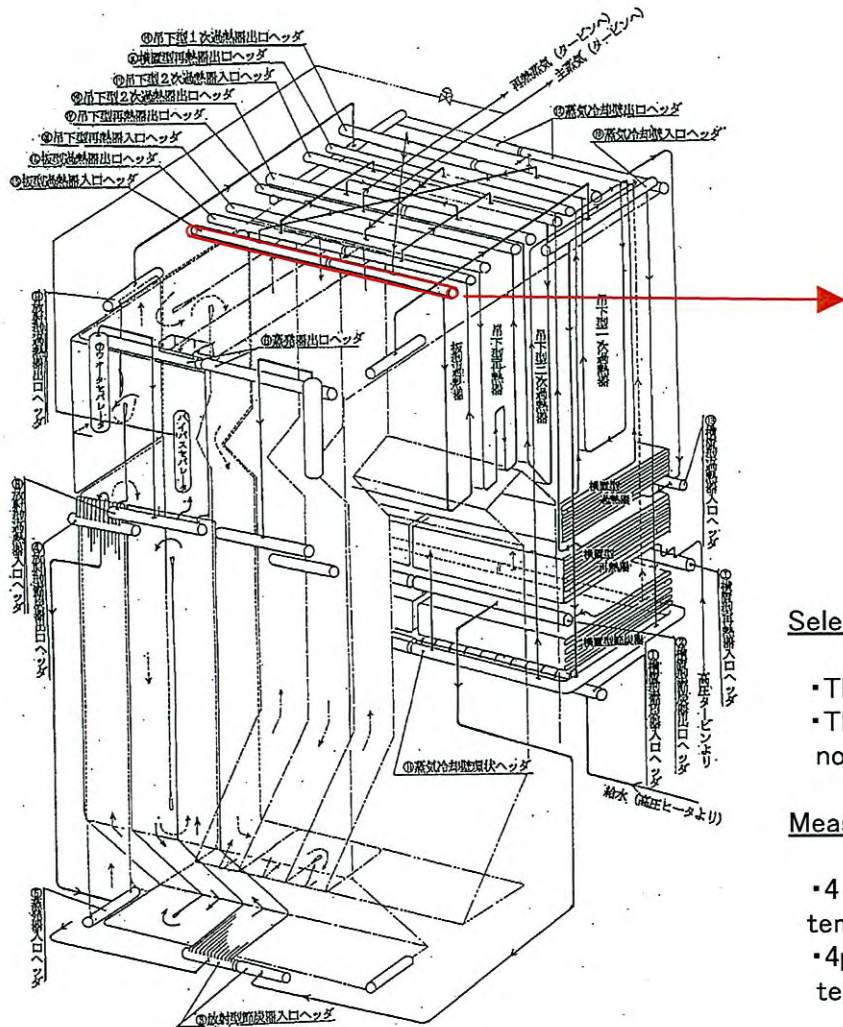
Selection criteria

- Portion of super heater tubes and reheater tubes where austenitic stainless steel is used.
- Bottom bend portion where exfoliated steam oxidation scale from inner surface of tube by thermal expansion and contraction during start-stop is expected to fall and pile up.

Measurement points and quantity

- 50 points of bend portion of austenitic stainless steel for selected final superheater panel.
- 50 points of bend portion of austenitic stainless steel for selected reheater panel.

Penetrant Testing (Stub portion of final super heater header)



Bird's eye view of boiler



Example of inspection points

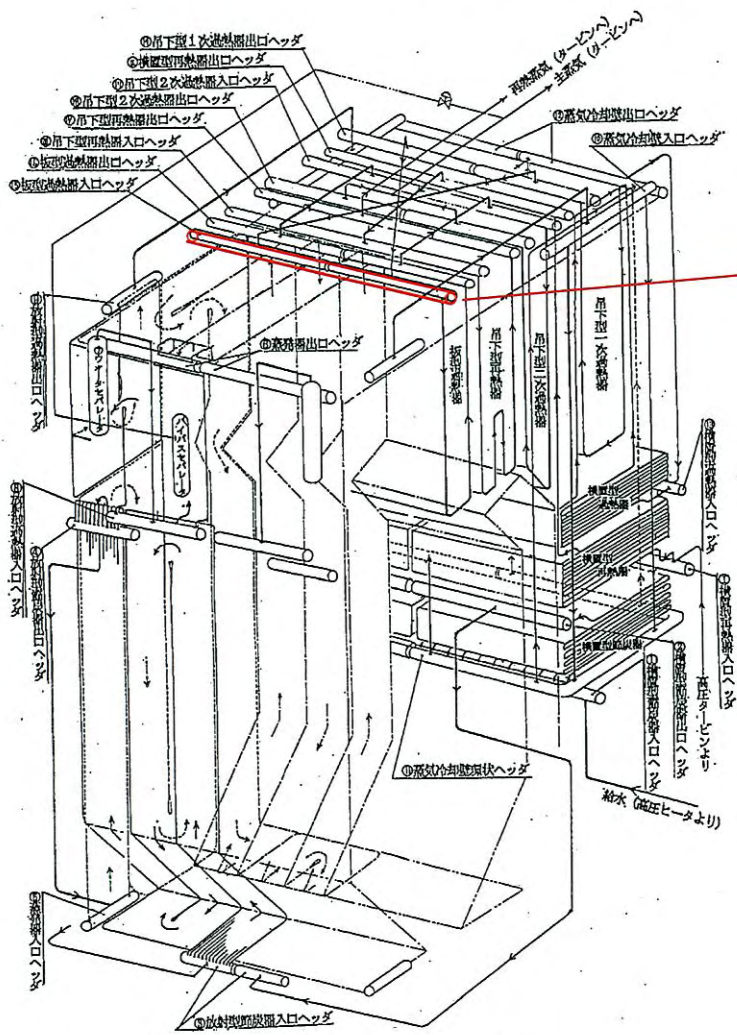
Selection criteria

- The highest temperature stub, if metal temperature data is available.
- The high stressed stub by structural constraint, if metal temperature data is not available.

Measurement points and quantity

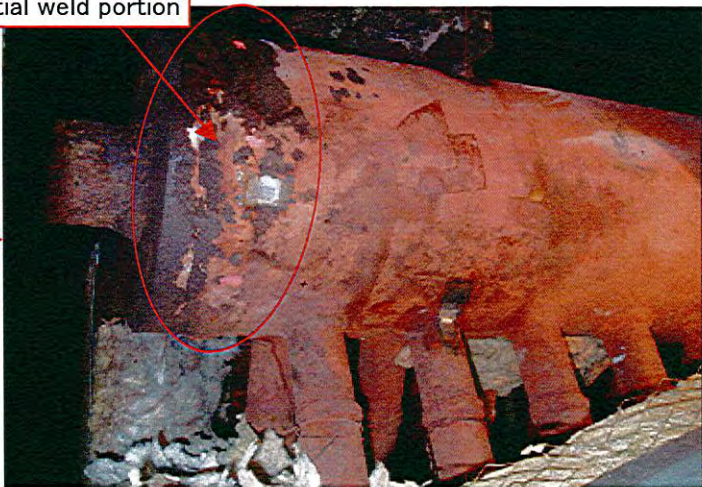
- 4 points with high temperature portion among axial direction, if metal temperature data is available.
- 4 points of stubs with high stressed portion by structural constraint, if metal temperature data is not available.

UT Inspection, TOFD Inspection (Final super heater header circumferential weld portion)



Bird's eye view of boiler

Circumferential weld portion



Example of inspection points

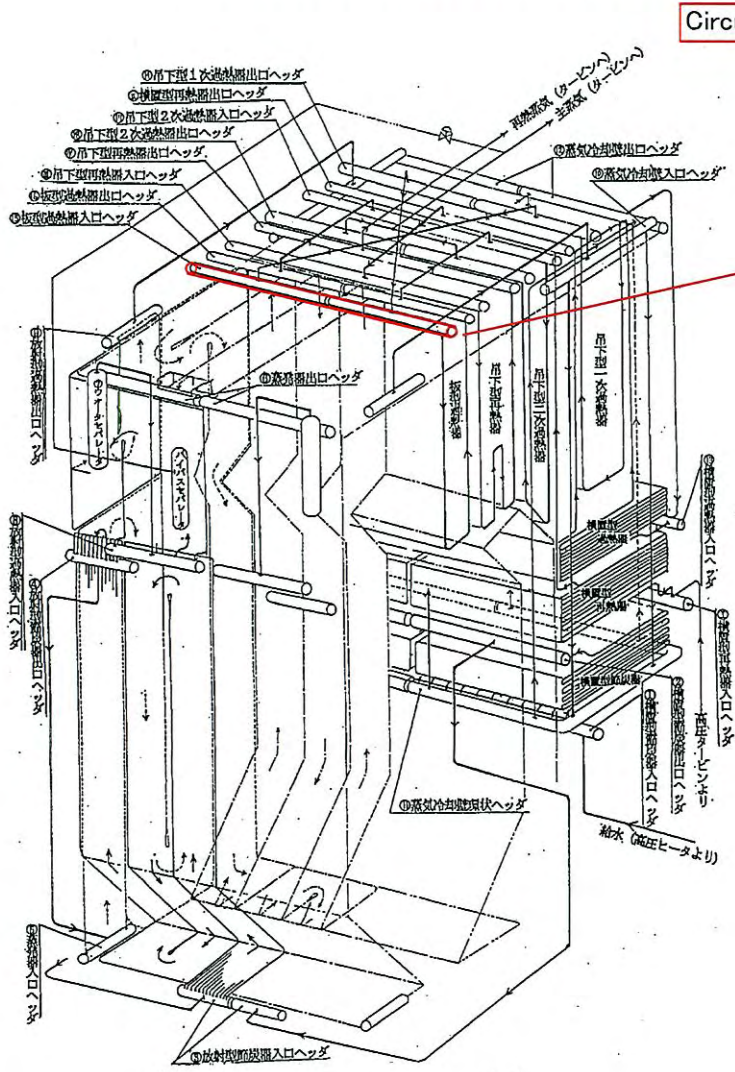
Selection criteria

- Circumferential weld portion with the highest temperature , if metal temperature data is available.
- The high stressed circumferential weld portion by structural constraint, if metal temperature data is not available.

Measurement points and quantity

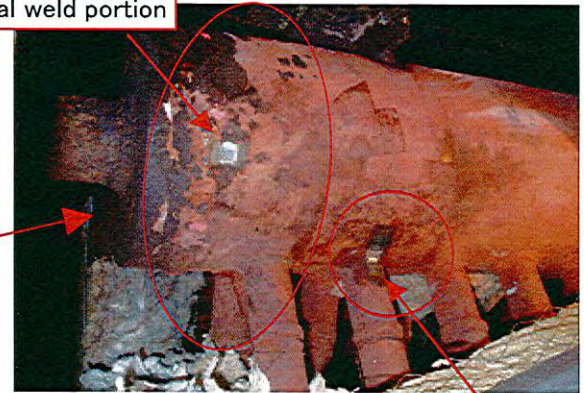
- All around one circumferential weld (1Ring), except interference portion with stubs.

Replica Inspection (Final super heater header, Desuper header, Reheater header and Main steam pipe)



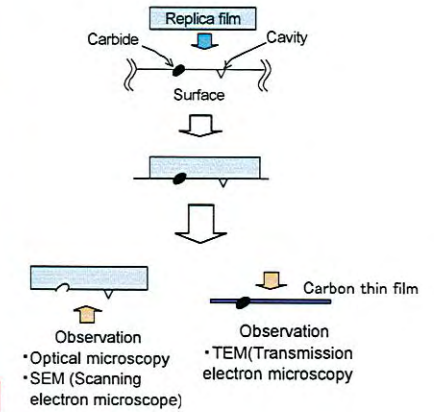
Bird's eye view of boiler

Circumferential weld portion



Stub weld portion

Example of inspection points



Selection criteria

[Circumferential weld and stub weld portion]

- The highest temperature portion, if metal temperature data is available.
- The high stressed weld portion by structural constraint, if metal temperature data is not available.

Measurement points and quantity

[Circumferential weld portion]

- 2 points on 1 ring of circumferential weld in final super heater header
- 2 points (one each from 2 rings of circumferential weld) in desuper heater pipe.
- 2 points on circumferential weld in reheater header.
- 2 points on circumferential weld in main steam pipe.

Japanese RLA guideline

- (1) Degradation factor to be evaluated
 - Creep rupture remaining life (Designed temperature beyond 450°C)
- (2) Components to be evaluated and the method to assess the remaining life
 - [Components]**
 - 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
 - [Method to assess the remaining life]**
 - More than one method shown in table
- (3) Effective (countable) remaining life
 - 1/ 2 of remaining life evaluated by above methodes

Method	Guideline		This study	
	Base metal	Weld (HAZ)	Base metal	Weld (HAZ)
Hardness measuring	—	○		
Electrical resistance	—	○		
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

(Microstructural comparison method outline)
 Remaining life synthetically evaluated by three types of damage as shown below.

- [Base metal]**
 - Evaluation of average diameter
 - Comparison with the referrence picture of microstructure related to creep the damage ratio
 - Comparison with the referrence picture of carbide precipitation related to the creep damage ratio
- [Weld metal]**
 - Comparison with the referrence picture of creep void and micro crack related to creep the damage ratio
 - Comparison with the referrence picture of microstructure related to creep the damage ratio
 - Comparison with the referrence picture of carbide precipitation related to the creep damage ratio

Microstructural comparison method in this study

