		1.1	10-1-11		1.0	Measured	value (mm)		(Averaged	
Components	Material	Designed OD	Region	Area	105	2⇔6	3⇔7	4⇔8	Averaged (mm)	measured value- Designed OD) /Designed OD(%)
Re-Heater Outlet	6.7007.0	12.5		Base metal	558.62	566.60	562.37	560.43	562.00	+0.57
Header(Right)	SA335 P-22	558.8mm	(Header side)	HAZ	557.15	560.16	561.75	559.92	559.75	+0.17
Re-Heater Outlet	1	1.000		Base metal	559.24	559.63	560.57	560.22	559.92	+0.20
Header(Left)	SA335 P-22	558.8mm	(Header side)	HAZ	558.96	559.16	560.19	559.96	559.57	+0.14

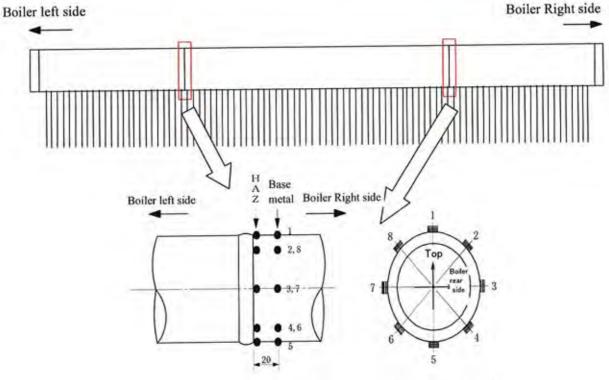
Table II -22 (Unchahar) Re-Heater Outlet Header Outside Diameter Measurement Results





Measurement point of left side of RH outlet header

Measurement point of right side of RH outlet header



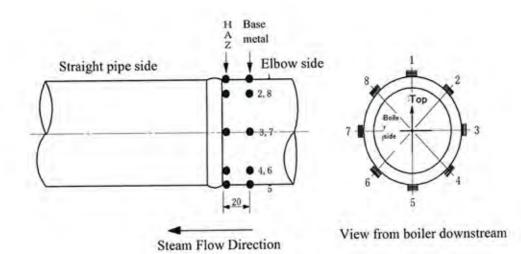
View from boiler right side

Ⅱ-186

Components Material Designed OD Po	1 million 1 million		1	Measured	value (mm)		(Averaged measured			
Components	Material	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	Position	Region	105	2⇔6	3⇔7	4⇔8	(mm)	value-Designed OD) /Designed OD(%)
a sala di ar i			Downstream side	Base metal	510.00	507.57	506.39	508.33	508.07	+0.01
Hot Reheat Pipe	SA335 P-22	508.0mm	(straight pipe side)	HAZ	508.17	506.77	505.17	507.77	506,97	-0.20

Table II -23 (Unchahar) Hot Reheat Pipe Outside Diameter Measurement Results





# Sample tube inspection [Unchahar #2]

Sample tube inspection and creep rupture test were carried out as one of the boiler residual life assessment items for Unchahar Super Thermal Power Station #2 unit. The results are reported as follows.

#### 1. Unit for evaluation

Unchahar Super Thermal Power Station #2 unit

#### 2. Sample tube for inspection

- · Platen-SH tube
- Final-SH tube (#1,#119)

#### 3. Operation condition

(1) Cumulative operation hours:	139,098	hours
(2) Cumulative start and stop times:	96	times

#### 4. Summary of inspection results

- (1) As a result of tube appearance observation after acid cleaning, traces of corrosion at outside surface and slightly rough condition at inside surface were observed for each sample tube.
- (2) As a result of tube dimension measurement, OD of each tube was less than designed value, and the thickness of each tube was larger than the designed value.
- (3) As a result of steam oxide scale examination, steam oxide scale was adhering evenly by cross sectional observation for each tube.

Average thickness of steam oxide scale mainly consisting of Fe and O was larger in the order of Final-SH #1, Final-SH #119 and Platen-SH tube.

- (4) As a result of hardness measurement, the hardness values were stable in circumferential direction, though measured values were out of the normal value of virgin material by Japanese steel manufacturer.
- (5) As a result of creep rupture test, the evaluated residual life of Platen-SH tube was 7,800,000 hours for base metal, 6,800,000 hours for weld joint portion at designed temperature 503°C. As for Final-SH #119 tube, the evaluated residual life was 400,000 hours for base metal, 350,000 hours for weld joint portion at designed temperature 534°C and 41,000 hours for base metal, 35,000 hours for weld joint portion at equivalent temperature 573°C estimated by comparison with the average creep rupture data of NIMS.

It is recommended that the residual life assessment for Final-SH #119 tube be carried out again before reaching the min.evaluated residual life 35,000 hours.

(6) As a result of microstructure comparison method, the min.evaluated residual life was 120,000 hours.

# 5. Sample tube specification

5

Sample tube specification is shown in Table II -30.

Sample	Material	Designed OD×t(mm)	Designed Temperature (°C)	Designed Pressure (MPa)
	SA213T22	\$\$1.0×t9.6	553	17.24
Platen-SH #3-8	SA213T11 <sup>**</sup>	Ø51.0×t7.1	503	17.24
D: 1011 //1	SA213T22	Ф51.0×t9.6	554	17.24
Final-SH #1	SA213T22*	\$\$1.0×t8.8	545	17.24
E: 1 CH (110	SA213T22	Φ51.0×t9.6	545	17.24
Final-SH #119	SA213T22*	\$\$1.0×t8.8	534	17.24

Table II-30	Sample tube	specification
-------------	-------------	---------------

\* : Chemical composition analysis was conducted as shown below.

The material of sample tubes for evaluation with creep rupture test and microstructural comparison method was confirmed same as the drawing by chemical composition analysis.

Chemical composition analysis results by spark discharge optical emission analysis (wt%)

Sample tube	С	Si	Mn	Р	S	Cr	Мо
Platen-SH #3-8	0.09	0.58	0.44	0.032	0.010	1.12	0.49
Final-SH #1	0.10	0.24	0.42	0.030	0.012	2.20	0.95
Final-SH #119	0.10	0.24	0.42	0.030	0.013	2.22	0.96
SA213T11 (JIS-STBA23)	≦0.15	0.50~1.00	0.30~0.60	≦0.030	≦0.030	1.00~1.50	0.45~0.65
SA213T22 (JIS-STBA24)	≦0.15	≦0.50	0.30~0.60	≦0.030	≦0.030	1.90~2.60	0.87~1.13

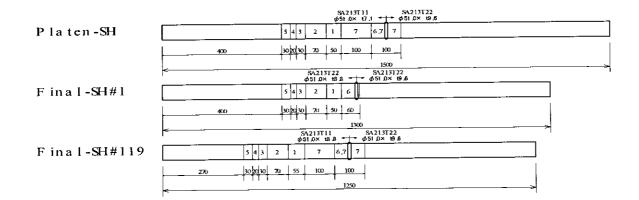
# 6. Inspection item and inspected portion

Inspection item and inspected portion are shown in Table II-31.

			<b>42</b> .	Inspection item	l		
Comple	1	2	3	4	5	6	7
Sample	Outer surface appearance	Internal surface	Tube dimension •	Metallography	Scale analysis	RLA by microstructure	Creep rupture test
Platen-SH	0	0	0	0	0	0	0
Fainal-SH#1	0	0	0	0	0	0	_
Fainal-SH#119	0	0	0	0	0	0	0

Table II	-31 In	spection	item
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Sample tube appearance and sampling location are shown in Photo II -13. Sampling portion for each inspection item is shown in Fig. II -11.



1: Outer surface appearance 2: Internal surface appearance 3: Tube dimension • Hardness 4: Metallography 5: Scale thickness, EPMA analysis, 6: RLA by microstructural comparison method 7: Creep rupture test

Fig. II -11 Sampling portion for each inspection item

# 7. Inspection results

- (1) Tube appearance
  - a. Tube appearance from outside (Photo II -14)
    - > Hard oxide scale with grayish white color was adhering for each sample tube outer surface.
    - > Traces of corrosion were observed in each sample tube outside surface after acid cleaning.
- b. Tube appearances of sample tubes from inside after removal of steam oxide scale (Photo  $\,\mathrm{II}$  -15 $\sim$

20)

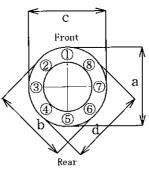
(Platen SH tube)

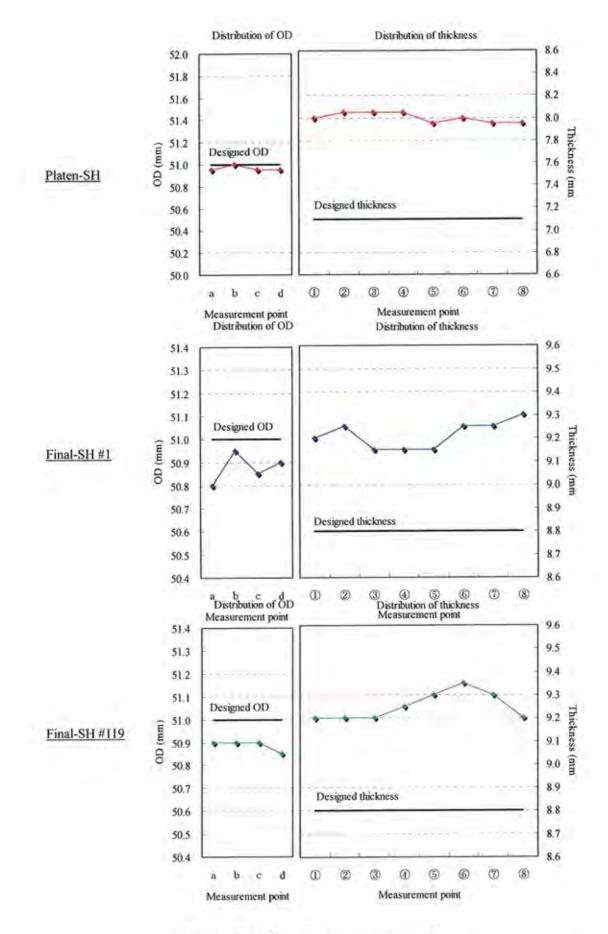
- Internal surface of both front and rear side were covered with gray color steam oxide scale with spotted rust.
- > Slight rough internal surface was observed after acid cleaning.
- (Final SH #1 tube)
  - > Internal surface of both front and rear side were covered with gray color steam oxide scale.
  - > Slight rough internal surface was observed after acid cleaning.
- (Final SH #119 tube)
  - Internal surface of both front and rear side were covered with gray color steam oxide scale with spotted rust.
  - > Slight rough internal surface was observed after acid cleaning.
- (2) Tube dimension measurement (Table II -32, Fig II -12)
  - a. OD measurement
    - OD of each tube was measured to be less than designed values.
  - b. Thickness measurement

Thickness of each tube was measured to be larger than designed value.

			) DD (mm)				Thickness (mm)							
Sample tube	Specification	Direction	OD	ID	1	2	3	4	6	6	$\bigcirc$	8		
		a	50.95	35.05	8.00				7.95					
DI . (11)	A 51 0 17 1	b	51.00	35.00		8.05				8.00				
Platen-SH	Φ51.0×t7.1	с	50.95	34.95			8.05				7.95			
		d	50.95	34.95				8.05				7.95		
		a	50.80	32.45	9.20				9.15					
FINAL-SH	A 51 0.000	b	50.95	32.45		9.25				9.25				
#1	Φ51.0×t8.8	с	50.85	32.45			9.15				9.25			
		d	50.90	32.45				9.15				9.30		
		a	50.90	32.40	9.20				9.30					
FINAL-SH	A51.0.49.0	b	50.90	32.40		9.20				9.35				
#119	Φ51.0×t8.8	с	50.90	32.40			9.20				9.30			
		d	50.85	32.40				9.25				9.20		

Table II-32 Tube dimension measurement results





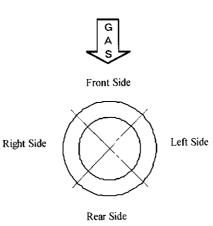


533

- (3) Steam oxide scale adhesion on internal surface
  - a. Cross sectional observation of internal surface (Photo II -21)
    - Steam oxide scale was adhering evenly by cross sectional observation for each location with dual layer consisting of dense inner layer and slightly porous outer layer.
  - b. Thickness measurement of steam oxide scale on internal surface (Table II -33)
    - Average thickness of steam oxide scale mainly consisting of Fe and O was larger in the order of Final-SH #1, Final-SH #119 and Platen-SH tube.

		Scale thicknes	ss (μm)
Sample tube	Position	Average among 90°range	Max. among 90° range
	Front Side	130.3	135.0
	Right Side	130.5	137.0
Platen-SH	Rear Side	125.7	130.0
	Left Side	130.3	138.0
	Front Side	227.4	263.0
	Right Side	198.0	232.0
FINAL-SH#1	Rear Side	202.1	221.0
	Left Side	225.5	257.7
	Front Side	177.4	188.0
	Right Side	182.3	196.0
FINAL-SH#119	Rear Side	179.6	193.0
	Left Side	169.8	186.0

Table II -33 Steam oxide scale thickness measurement results



c. EPMA analysis of steam oxide scale on internal surface (Fig. II -13~24, Table II -34)

Mainly iron oxide scale was formed since Fe and O were remarkably detected.

- In Platen-SH tube, Fe, Cr and Mo were detected as tube material elements, and O, P, Ca as the other detected elements.
- In Final-SH #1 tube, Fe, Cr and Mo were detected as tube material elements, and O, Ca, Si as the other detected elements.
- In Final-SH #119 tube, Fe, Cr and Mo were detected as tube material elements, and O, Mn as the other detected elements.

C FOUND	- 00 T	Element													
Sample tube	Position	0	S	Р	N	Na	Si	Ca	Mn	Fe	Ti	Cr	Ni	Zn	Mo
	Front Side	-		11							- 21		1	$\geq$	M
Platen-SH	<b>Right Side</b>	12	-		1				1	0			i = 1		
Platen-Sri	Rear Side					10.1							1-1		
	Left Side	1	-			5	1	1				-			
	Front Side	-	-	. 1		11.5		100		1		1		i –	1
Tinal Plan	Right Side								3					1	2
Final-SH#1	Rear Side	1.	10.1		10	111				0			10		
	Left Side	1	1		1		1 Y		-			4	1.1	1	
	Front Side	1							1		6	1	10	1	
Final CUALLO	Right Side					UC.			1			)	1.5		1
Final-SH#119	Rear Side	-	-					11				8	( pri		
	Left Side	100	1			in f	1								

Table II -34 Elements detected by EPMA analysis

:Elements detected clearly

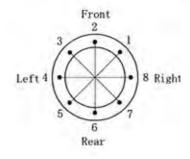
(4) Hardness measurement (Fig. II -35, Table II -25)

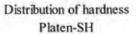
- The hardness of Platen-SH tube (SA213T11) was higher than the normal value of virgin material by Japanese steal manufacturer.
- The hardness of Final-SH#1,#119 tube (SA213T22) were lower than the normal value of virgin material by Japanese steal manufacturer.

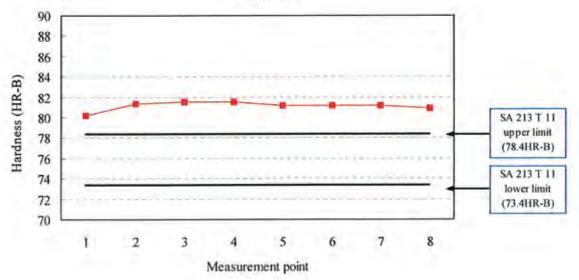
Sample tube	Marterial	1	2	3	4	5	6	7	8
Platen-SH	SA 213 T 11	80	81	82	82	81	81	81	81
FINAL-SH#1	SA 213 T 22	74	74	75	75	75	75	76	75
FINAL-SH#119	SA 213 T 22	74	74	74	74	74	75	74	75

Table II-35 Hardness measurement results

Hardness value of vigin material by fabricator : SA 213 T 22;76.4~81.6(HR-B) SA 213 T 11;73.4~78.4(HR-B)







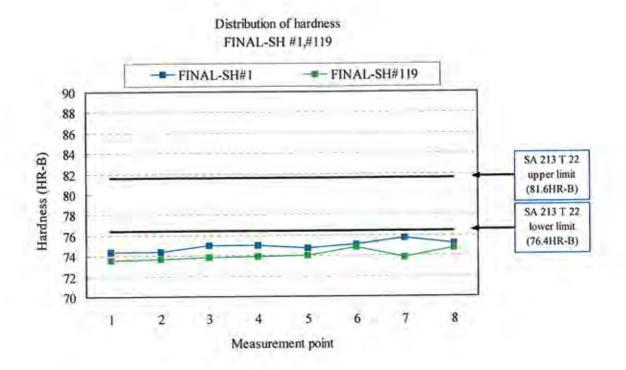


Fig II -25 Hardness measurement results

(5) Metallographic observation

Microstructure observation results at cross section in circumferential direction of sample tube were shown in Photo II -22 $\sim$ 27.

(Platen-SH tube (SA 213 T11))

Microstructural degradation with disintegration of pearlite structure and precipitation in ferrite grain was not observed, though precipitation at gain boundary were observed.

(Final-SH#1,#119 tube (SA 213 T22))

Microstructural degradation with disintegration of pearlite structure and precipitation in ferrite grain was not observed.

(6) Creep rupture test

a. Test condition

The creep test condition is shown in Table II -36. The shape of test specimens is shown in Fig. II -26

3 specimens were cut out from each of base metal portion and weld portion in Platen-SH tube and Final-SH #119 tube with a set of three test conditions for each portion.

As the shape of test specimens,  $\phi$  6mm round bar specimen was applied.

			Test c	ondition	Shape		
Sample tube	Portion	Material	Tem. (°C)	Stress (MPa)	of specimer		
		1	635	68.6			
	Base Metal	SA213T11	635	83.4			
Distan CII	100000000000000000000000000000000000000		665	45.9	φ6		
Platen-SH	1.4.1.1.1.1.1		665	68.6			
	Weld Metal	SA213T11	665	83.4			
			700	45.9			
	10 1977		665	63.7			
	Base Metal	SA213T22	665	78.5			
Final-SH			700	38.3	φ6		
#119	No. of Contract		665	63.7	] \$0		
	Weld Metal	SA213T22	665	78.5			
	in the second se	1.000	700	38.3			

Table II-36 Creep test condition



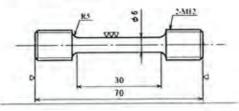
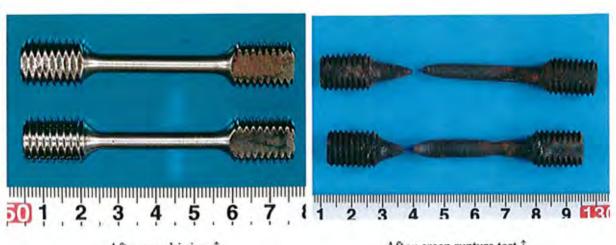


Fig II -26 Shape of test specimens

Test specimens before and after creep rupture test

Before machining  $\Rightarrow$ 





After machining ↑

After creep rupture test 1



Creep rupture testing machine  $\Rightarrow$ 

#### b. Test results

х У Test result is shown in Table II -37. All specimens had ruptured for each test condition.

			Test co	ondition	Rupture	LMP	Fracture	Reduction
Compo	Component		Temp. T(℃)	Stress (MPa)	time t (h)	C=19.95	elongation (%)	of area (%)
	Base Metal		635	68.6	278.7	20,341	62	94
		<b>SA 213 T</b> 11	635	83.4	90.8	19,899	57	91
			665	45.9	322.4	21,072	86	94
Platen-SH		SA 213 T11	635	68.6	264.3	20,320	16	81
	Weld Metal		635	83.4	127.5	20,033	18	82
			665	45.9	287.5	21,026	13	80

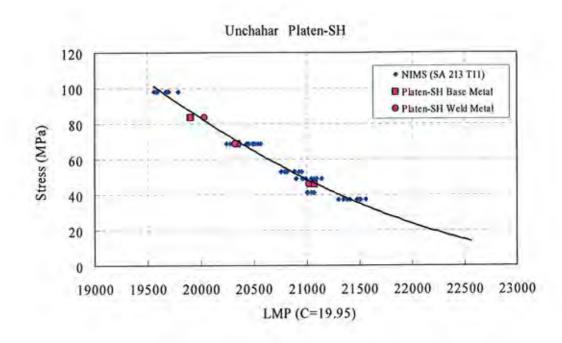
 Table II - 37-1
 Creep rupture test results (Platen-SH)

Table	II -37-2	Creep rupture test results	(Final-SH #119)
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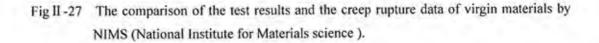
			Test co	ondition	Rupture	LMP	Fracture	Reduction
Compo	Component		Temp. T(℃)	Stress (MPa)	time t (h)	C=15.77	elongation (%)	of area (%)
			665	63.7	113.1	16,725	69	91
	Base Metal	SA 213 T22	665	78.5	32.1	16,212	55	92
E' 1000//110			700	38.3	162.6	17,503	67	94
Final-SH#119			665	63.7	86.0	16,614	30	84
	Weld Metal	l SA 213 T22	665	78.5	27.3	16,146	31	83
			700	38.3	143.7	17,451	22	81

The comparison of the test results and the creep rupture data of virgin materials by NIMS (National Institute for Materials Science ) is shown in Fig. II -27 .

- > The test results for base metal and weld joint in Platen-SH tube indicate almost same creep rupture strength as NIMS data.
- > The test results for base metal and weld joint in Final-SH#119 tube indicate the lower creep rupture strength than NIMS data.



Unchahar Final-SH(#119) 100 + NIMS (SA 213 T22) 90 Final-SH#119 Base Metal 80 O Final-SH#119 Weld Metal 70 0 0 Stress (MPa) 60 50 40 30 20 10 0 17000 19000 18000 16000 15000 LMP (C=15.77)



### c. Residual life evaluation results

Residual life evaluation results by creep rupture test are shown in Table II -38.

The stress condition for the evaluation was calculated as the hoop stress with the measured OD, thickness of the test sample tube and the designed pressure. As for the temperature condition for the evaluation, two conditions were used for evaluation, those are the case of evaluation at the designed temperature and the other one at equivalent temperature estimated by comparison with the average creep rupture data of NIMS.

(Platen-SH tube)

The evaluated residual life (half of residual life evaluated by creep rupture test) of Platen-SH tube was 7,800,000 hours for base metal, 6,800,000 hours for weld joint portion at designed temperature  $503^{\circ}$ C.

Equivalent temperature could not be evaluated since the test results for base metal in Platen-SH tube indicate higher creep rupture strength than NIMS data.

(Final-SH #119 tube)

The evaluated residual life (half of residual life evaluated by creep rupture test) of Final-SH #119 tube was 400,000 hours for base metal, 350,000 hours for weld joint portion at designed temperature  $534^{\circ}$ C.

In case of evaluation at equivalent temperature  $573^{\circ}$ C estimated by comparison with the average creep rupture data of NIMS, the evaluated residual life of Final-SH #119 tube was 41,000 hours for base metal, 35,000 hours for weld joint portion.

It is recommended that the residual life assessment for Final-SH #119 tube be carried out again before reaching the min.evaluated residual life 35,000 hours.

Table II -38	Residual life	evaluation	results of	creep	rupture	test	by parametermethod	d
--------------	---------------	------------	------------	-------	---------	------	--------------------	---

		Рага	meter metho	d (evaluated at	designed tem	p.)		
Component		Material	Operation hours (h)	Hoop Stress	Designed temp. (°C)	Residual life (h)	Creep life consumption ratio	Evaluated residual life (h)
	Base Metal	SA 213 T11	139,098	45.9	503	15,726,180	0.01	7,800,000
Platen-SH	Weld Metal	SA 213 T11	139,098	45.9	503	13,692,433	0.01	6,800,000
5. 1011/110	Base Metal	SA 213 T22	139,098	38.3	534	812,994	0.15	400,000
Final-SH#119	Weld Metal	SA 213 T22	139,098	38.3	534	700.466	0.17	350,000

		Parar	neter method	l (evaluated at o	equivalent tem	.p.)			
Component		Material	Operation hours (h)	Hoop Stress (MPa)	Equivalent temperature (°C)	Residual life (h)	Creep life consumption <u>ratio</u>	Evaluated residual life (h)	
	Base Metal	SA 213 T11	139,098	45.9	Non evaluation( $\%1$ )				
Platen-SH	Weld Metal	SA 213 T11	139,098	45.9					
E' 1011#110	Base Metal	SA 213 T22	139,098	38.3	573	82,798	0.63	41,000	
Final-SH#119	Weld Metal	SA 213 T22	139,098	38.3	573(※2)	71,826	0.66	35,000	

X I; Equivalent temperature could not be evaluated since the test results for base metal in Platen-SH tube indicate higher creep rupture strength than NIMS data.

2; Equivalent temperature evaluated at base metal

# (7) Residual life assessment by microstructural comparison method

#### a. Platen-SH tube

(Microstructure observation)

The results of microstructure observation are shown in Photo II -28 $\sim$ 32.

The summary of observation results is shown in Table  $\ II$  -39.

Precipitates at gain boundary were observed in base metal, intercritical zone, coarse grain HAZ and weld metal. Granular precipitates in grain were observed in base metal, intercritical zone, fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates by SEM observation are shown in Photo  $II-33\sim$  34.

> Precipitates at gain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation of extracted replica)

The results of precipitates distribution observation by TEM observation are shown in Photo II  $-35 \sim 38$ .

The summary of observation results is shown in Table II-40.

- > Precipitates free zone along grain boundary was observed in base metal.
- Rod-shaped precipitates were observed in base metal and coarse grain HAZ Fine needlelike precipitates had disappeared in base metal, fine grain HAZ, coarse grain HAZ.
- Disintegration of pearlite like structure was observed in base metal and fine grain HAZ.

b. Final-SH #1 tube

(Microstructure observation)

The results of microstructure observation are shown in Photo II -39 $\sim$ 43.

The summary of observation results is shown in Table II-39.

- > Precipitates at gain boundary were observed in base metal, fine grain HAZ and weld metal.
- Granular precipitates in grain were observed in base metal, fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates by SEM observation are shown in Photo II -44 $\sim$  45.

> Precipitates at gain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation of extracted replica)

The results of precipitates distribution observation by TEM observation are shown in Photo II -46 $\sim$ 49.

The summary of observation results is shown in Table  $\Pi$ -40.

- Precipitates free zone along grain boundary and rod-shaped precipitates was observed in base metal.
- > Fine needlelike precipitates had disappeared in coarse grain HAZ.

c. Final-SH #119 tube

(Microstructure observation)

The results of microstructure observation are shown in Photo  $II - 50 \sim 54$ .

The summary of observation results is shown in Table  $\ \mbox{II}$  -39.

- Precipitates at gain boundary were observed in base metal, intercritical zone and fine grain HAZ.
- > Granular precipitates in grain were observed in each region.

(Grain boundary precipitates observation)

The results of grain boundary precipitates by SEM observation are shown in Photo II -55 $\sim$  56.

> Precipitation at gain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation of extracted replica)

The results of precipitates distribution observation by TEM observation are shown in Photo II -57~60.

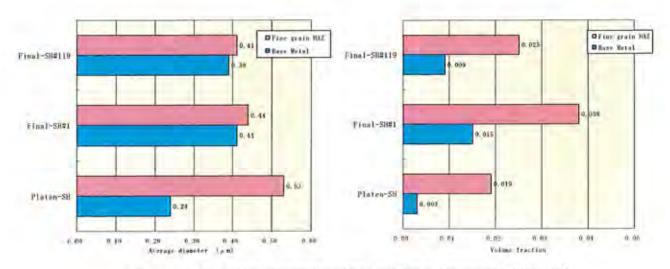
The summary of observation results is shown in Table II -40.

- Precipitates free zone along grain boundary and disintegration of pearlite structure were observed in base metal.
- Fine needlelike and granular precipitates had disappeared in fine grain HAZ and coarse grain HAZ.

d. Quantitative evaluation of grain boundary precipitates

The results of quantitative evaluation of grain boundary precipitates are shown in Table II -41.

- The max. value of average diameter of grain boundary precipitates was 0.41µm in base metal at Final-SH #1 tube, 0.53µm in fine grain HAZ at Platen-SH tube.
- The max. value of volume fraction of grain boundary precipitates was 0.015 in base metal at Final-SH #1 tube, 0.038 in fine grain HAZ at Final-SH #1 tube.



Quantitative evaluation of grain boundary precipitates [extracted Table II-41]

e. Quantitative evaluation of precipitates free band width along grain boundary

The results of quantitative evaluation of precipitates free band width along grain boundary are shown in Table II -42.

- The quantitative evaluation was focused on base metal of SA 213 T22 for Final-SH #1 tube and Final-SH #119 tube.
- The precipitates free band width along grain boundary was 0.55µm. for Final-SH #1 tube and 0.60µm for Final-SH #119 tube.

f. Operational condition of residual life evaluation portion

Operational condition of evaluated components are shown in Table II -43.

The evaluation stress  $\sigma$  was the hoop stress calculated with designed pressure, designed diameter D and thickness t of each component.

 $\sigma = P(D-t) / 2t$ 

where P: Designed pressure.

		Operational condition							
Component	Material	OD <sup>×1</sup>	<u>ا</u> **۱	Desig	Ноор				
	Materia	mm		Temperature °C	Pressure MPa	Stress MPa			
Platen-SH	SA213T11	51.0	8.0	503	17.2	46.3			
Final-SH#1	SA213T22	50.9	9.2	545	17.2	39.1			
Final-SH#119	SA213T22	50.9	9.3	545	17.2	38.6			

Table II -43	Operational condition of evaluated components
--------------	---

※1 : Measured value

g. Residual life evaluation results by microstructure comparison method

Evaluation figures of residual life assessment for each components by microstructural comparison method are shown in Fig. II -28 $\sim$ 30 and evaluation results are shown in Table II -44.

> The highest creep life consumption ratio was evaluated at Final-SH #1 tube with 36% and evaluated residual creep life (half of residual life evaluated microstructure comparison method) was 120,000 hours.

						Residual life evaluation results	
Component	Component Material		con	Creep life consumption ratio (%)		Residual life (h)	Evaluated residual life (h)
		Base Metal		9		1,406,000	
Platen-SH	SA213T11	Fine grain HAZ	0	$\sim$	2	6,816,000 <	290,000
		Coarse grain HAZ	2	$\sim$	19	593,000 ~ 6,816,000	
		Base Metal	28	~	36	247,000 ~ 358,000	
Final-SH#1	SA213T22	Fine grain HAZ		3		4,498,000	120,000
		Coarse grain HAZ	6	~	11	1,125,000 ~ 2,179,000	
		Base Metal	27	~	33	282,000 ~ 376,000	
Final-SH#119	SA213T22	Fine grain HAZ		23		466,000	140,000
		Coarse grain HAZ	5	$\sim$	11	1,125,000 ~ 2,643,000	

Table II -44 Residual life evaluation results

ß							ОМ																
Components		LOID				Mic	rostructural feat	ures	•														
Dodu		Locauon	Observed region	Precipitation at	Precipitates	Precipitation		Pearlite	Subgrain														
Ŝ	-			gain boundary	free zone along grain boundary	Granular _ precipitates	Rod-shaped precipitates	structure	boundary	Ferrite grain													
	ear	- 	Base metal	Appeared	Not appeared	Appeared	Not appeared	Disintegrated															
H tube	rater 5r1 tuoe (SA 213 T11) #3-8th tube from rear Circumferential weld	erential d	Intercritical zone	Appeared		Appeared	Appeared	Disintegrated	Normal														
aten S SA 21:		Circumfe wel	Fine grain HAZ	Appeared		Not appeared	Not appeared																
E O		O O	Coarse grain HAZ	Appeared		Appeared	$\square$																
			Weld metal	Not appeared		Appeared	$\langle$			Appeared													
	La la		Base metal	Appeared	Not appeared	Appeared	Not appeared	Normal															
	rom re	rcumferent weld	Intercritical zone	Not appeared		Not appeared	Not appeared																
	#1-3rd tube from rear		Circumfere weld	Circumfer weld	Circumfer weld	Circumfere weld	Circumfere	Circumfere weld	Circumfer weld	Circumfer weld	Circumfere	Circumfere weld	Circumfere	Circumfer weld	Circumfer weld	Fine grain HAZ	Appeared		Appeared	Not appeared			
e (1	#]-3rd															Cire	Circ	Circle	Circe	Cire	Circ	Circ	Coarse grain HAZ
Final SH tube (SA 213 T22)			Weld metal	Appeared		Appeared																	
Final : (SA 2	car		Base metal	Appeared	Not appeared	Appeared	Not appeared	Normal															
	from r	ential	Intercritical zone	Appeared		Appeared	Not appeared																
	d tube	Circumferential weld	Fine grain HAZ	Appeared		Appeared	Not appeared																
	#19-3r	#19-3rd tube from rear Circumferential weld	Coarse grain HAZ	Not appeared		Appeared																	
			Weld metal	Not appeared		Appeared																	
	Viev	v nos. :	for each area	×500 (2 views) ×1000 (4 views)	)																		

# Table II-39 Microstructure observation resuluts

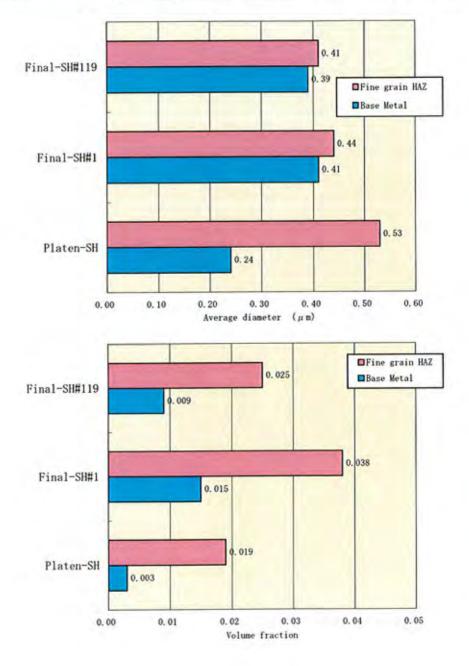
				TEM (	Transmission	Electron M	icroscope ob	servation)																
ents	ş	II.			_	Precipitates f	eatures	•																
Uod	ter.	Call(	Observed region	Precipitates free	Precip	itation in ferite	e grain		Aggromerate															
Components	Observed regio			zone along grain boundary	Fine needlelike and granular	Rod-shaped precipitates	Atenuated platedlike precipitates	Pearlite structure	d precipitates structure															
a _	rear	-	Base metal	Appeared	Remaining	Appeared	Not appeared	Disintegrating																
Platen SH tube (SA 213 T11)	#3-8th tube from rear	Circumferential weld	Fine grain HAZ		Remaining	Not appeared	Not appeared	Disintegrated																
laten 3 SA 21	8th tub	Circum	Coarse grain HAZ		Remaining	Appeared	Not appeared		Disintegrated															
щ	#3-		Weld metal		Remaining																			
	rear	l	Base metal	Appeared	Remaining	Appeared	Not appeared	Normal																
	#1-3rd tube from rear	mferentia weld	Fine grain HAZ		Remaining		Not appeared																	
	3rd tub	Circumf	Circumf	Circumf	Circum	Circum	Circum	Circum	Circum	Circum	Circum	Circum	Circum	Circum	Circum		Circumf	Coarse grain HAZ		Disappeared		Not appeared		
l SH tube 213 T22)	#1-	Ŭ	Weld metal		Remaining																			
Final SH tube (SA 213 T22)	і геаг	RI I	Base metal	Appeared	Remaining	Not appeared	Not appeared	Remarkably disintegrated																
	#19-3rd tube from rear	Circumferential weld	Fine grain HAZ		Disappeared		Not appeared																	
	-3rd tul	Circam	Coarse grain HAZ		Disappeared		Not appeared																	
	61#		Weld metal		Remaining																			
	1/2			×2000 ( 2 views)																				
	view	nos. I	or each area	×1000 (4 views)																				

Je.

# Table II -40 Precipitates distribution observation results

		Average diam	neter (µm)	Volume fraction		
Component	Material	Base Metal	Fine grain HAZ	Base Metal	Fine grain HAZ	
Platen-SH	SA213T11	0.24	0.53	0.003	0.019	
Final-SH#1	SA213T22	0.41	0.44	0.015	0.038	
Final-SH#119	SA213T22	0.39	0.41	0.009	0.025	

Table II-41 Quantitative evaluation of grain boundary precipitates

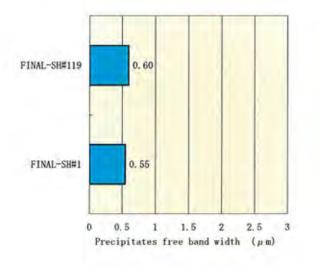


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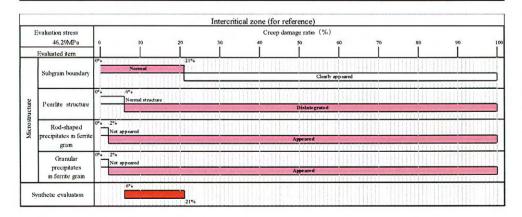
Sample tube	Material	Precipitates free band width (µm) *							
Sample tube	Wateria	Base Metal							
FINAL-SH#1	SA213T22	0.55							
FINAL-SH#119	SA213T22	0.60							

Table II -42 Precipitates free band width along grain boundary

※1 : Average value of 10 measured points



_			_		Base meta	1					
1	Evaluation stress				Creep	damage ratio	(%)				
	46.29MPa	10	20	30	40	50	60 I	70	80	90	100
-	Evaluated item	• 1%	_	_							
	Precipitates at gain boundary	Appeared			HI KUI	Coarsen			ilidid Dichici		
	Precipitates free zone along grain	9% Not appeared	911411			Appeare	d				
ructure	boundary	• 9%	*								
Microstructure	Pearlite structure					Disintegr	sting				the second
-	Rod-shaped precipitates in ferrite grain	Not appeared				Appeared					
	Granular precipitates	Not appeared			HILLI	Appeared					
	in ferrite grain Rod-shaped precipitates	• 9% Not appeared				Appeared					
Precipitates	Precipitates free zone along grain boundary	• 8*5 Not appeared				Appeared					
8	Pearlite structure	9% Normal structur	re			Disintegr	ating				a filmeters
	verage diameter of recipitates at gain boundary					52%					
s	ynthetic evaluation	9%									

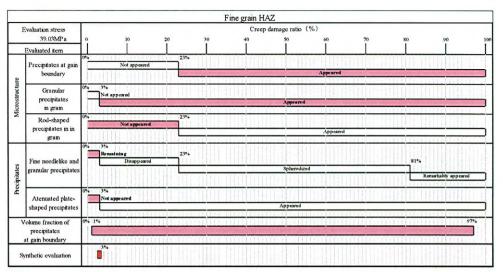


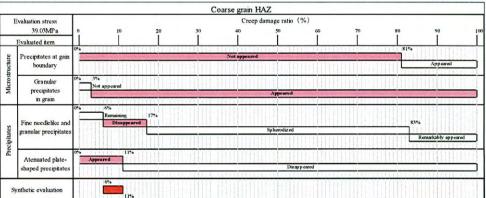
								Fi	ne grain	HAZ						
I	Evaluation stress								Cr	eep dama	ige ratio (	%)				
_	46.29MPa	0		10		20	30		40		50	60	70	80	90	1
	Evaluated item								_							
e	Granular	0%	511D	8% Not ap	speared	111.1	1911	1111	HHI			111111	IIII.			11H
nuctur			11111			10111	0110711	TECTI	11111	11116	Appeared		THEFT	DETROT		
Microstructure	Rod-shaped precipitates in ferrite grain	0%6	13111) Mar 19,500	-	13%	arrd			1111	Mah		11110	1111103			
2		1	11111	1.11		-					Ap	eared				
			124 14		11111	1111	COLUMN 1		11111	11111		11111111	TUTLICE	111111111	11111111111	11.1
Precipitates	Fine needlelike and	0%	2% Remainin	ng				1141	0110		11111		1011111			
ecip	granular precipitates									1	Disappeared					
2											1 1 1 1 1 1					

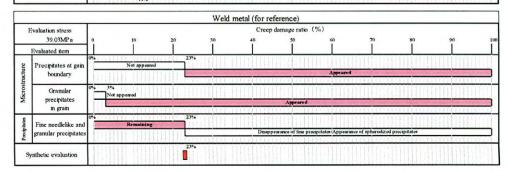
aluation stress 46.29MPa											
46.29MPa					Creep d	amage ratio	(%)				
	0	10	20	30	40	50	60	70	80	90	100
valuated item											
Precipitates at gain boundary Granular mecipitates	0%6	2% Not appeared			HHHH	1.11111		11HIIII			nıl:
		addies the state of the state of	ing the second second	See Manutan	Maria Managana na	Appeared				2 1 M 1 M	and the second
						11111111	11111111	HIMILIN			
Granular	5										
precipitates in ferrite grain		William Chronic Street Arrows	South Street and	the set of the set	Network With Start	Appeared	and the state of the second	Carlos and the state of the	Norman States	a second a second second second	
	11		11111111	11111111	TUTTUET	1 1 2 1 4 1 1 1	CELO PED	TUTIER	THE PERIOD	THE PROPERTY OF	131
Atenuated plate-	0%	Not appeared	19%					MANDER			
shaped precipitates			11				Appeared				
			dining	J. Chilled	CHAIL FILL	1111111		HUDLES	LING	INTERNA DE LA COMPANSIÓN D	111
thetic evaluation		2%									
s	Precipitates at gain boundary Granular precipitates in ferrite gran Atenuated plate- haped precipitates	recipitates at gain     boundary     Granular     precipitates     in ferrite grain     Atenuated plate- haped precipitates	Trecipitales at gain boundary  Granular precipitales in ferrite grain  Atenuated plate- haped precipitales  2%	Precipitales at gain boundary  Granular precipitales in ferrite grain  Atemated plate- haped precipitates  2%	receptates at gain receptates receptates receptates receptates receptates	recipitates at gain precipitates in ferrite grain Atemated plate- haped precipitates  7% Not appeared  7% Not appeared 7% Not appeared 7% Not appeared 7% Not appeared 7% Not a	receptates at gain receptates a	Precipitates at gain	Precipitales at gain	Precipitales at gain	Precipitates at gain Appeared Precipitates at gain Appeared Precipitates at gain Appeared Precipitates at gain Appeared Precipitates Appeared Precipitates Appeared Precipitates Appeared Precipitates Appeared Precipitates Appeared Precipitates Precipita

I	Evaluation stress					Creep	damage ratio (	(%)				
	46.29MPa	0	10	20	30	40	50	60	70	80	90	10
	Evaluated item											
an	Precipitates at gain boundary Granular	0%	6% Not appeared									
2		1111					Appeared	4				
ELS		1115				1010101	11-12 11-11-11	11111111	1111111111			ULL LT
Micros		0%	6% Not app cared									
~	precipitates	1111	College and a state	Calle Called	and the second second second	and the state of the state of the	Appeare	destation	and the state of the second second	Chargest Hilfson and Parket Com	and the second second second	and the should be
	m gram	11111		1.1.1.1.1.1.1.1.1								

		Base metal
E	valuation stress	Creep damage ratio (%)
	39.03MPa	0 10 20 30 40 50 60 70 80 90 100 1 1 1 1 1 1 1 1 1 1
	Evaluated item	0% 8% Not appared
	Precipitates at gain boundary	Not appeared 36% Appeared Remarkable proceptition
e	Precipitates free zone along gram boundary	OP = 13%     Not appeared     Appeared
Microstructure	Pearlite structure	0% 12% Normal structure Dustograng
	Rod-shaped precipitates in ferrite grain	0°+ 38% 81% 81% 81% Remarkable proop if dion
	Granular precipitates in ferrite grain	0° = 2° 5 Not appeared Appeared Appeared
	Rod-shaped precipitates	Offe 37e Not appeared Appeared
Precipitates	Precipitates free zone along grain boundary	Off. 13%. Not appeared Appeared
Precip	Pearlite structure	0° = 3% Deintograting Remarkably desintograted
	Atenuated plate- shaped precipitates	CP. 47:
	recapt diameter of recapitates at gain boundary	0*6  3*6
2	olume fraction of precipitates at gain boundary	47% 47% 38%
	cipitates free band along grain boundary	28%
Sy	nthetic evaluation	36%
		Intercritical zone (for reference)
	Evaluation stress 39.03MPa	Creep damage ratio (%)           0         10         20         30         40         50         60         70         80         90         100           1 </td
Microstructure	Evaluated item Precipitates at gain boundary	Not appeared Job provided Description of the second description of th
Micros	Rod-shaped precipitates in m grain	(P* 5%) Not appeared Appeared
Sy	inthetic evaluation	



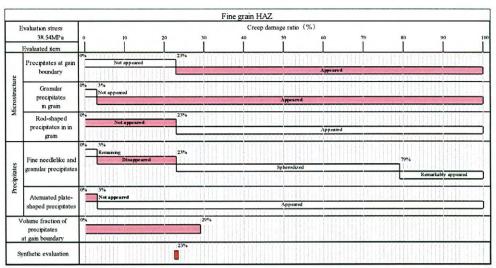


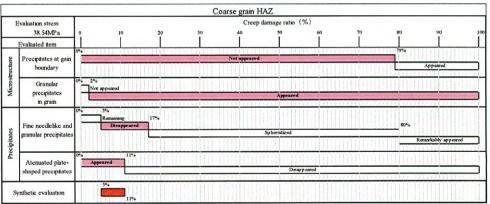


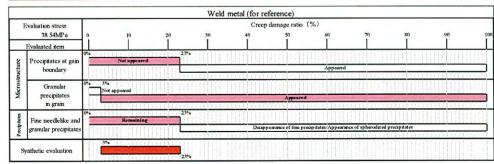
FigII-29 Evaluation Results Final SH #1

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						Base m	etal							
E	valuation stress						eep dama	ge ratio (%						
	38.54MPa Evaluated item	0	10 	20	30 	40		50 1	60 	70	80	)	90 	100
	Precipitates at gain boundary	0°• 8	ines Not appeared A	Appeared		35%			Remar	kable precipr	ation			
ure	Precipitates free zone along grain boundary	0%. Not appear	13%					Арро	sared					
Microstructure	Pearlite structure	0%. Normal structu					np.	Disinte	gaing					
M	Rod-shaped precipitates in ferrite gram	0%•	Not app	eared		35*•		Арре	cared			Remark	able precipitatio	n
	Granular precipitates in ferrite grain	0% 2% Not appears	5d					ppeared						
	Rod-shaped precipitates	Not apper	ared					Appeared			211111	11111		
Precipitates	Precipitates free zone along grain boundary	0°o Not appears	nd 13%					Аррея	red					
Precip	Pearlite structure	0*s Disintegrati	ng				Remarkabl	y disinte gratee	4					
	Atenuated plate- shaped precipitates	(Po 4%) Not app	wared				1110	Appeared				11.11		
	rerage diameter of precipitates at gain boundary	3%			u Qurb Coriada			53%						
	olume fraction of precipitates at gain boundary	0*•				3%								
	cipitates free band along grain boundary				27%			5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	6%					
Sy	mthetic evaluation				and the second se	3%								
					Intercrit	tical zone								
F	Evaluation stress 38.54MPa	0	10	20	30	40	reep dam:	ige ratio (%	60 	70	8	0	90	100
Microstructure	Evaluated item Precipitates at gain boundary	0% 2% Not appear Appear						Duappeared						
Micros	Rod-shaped precipitates in m grain	0% 5% Not a	ppeared					Appeared						
Sy	withetic evaluation	2% 5%												







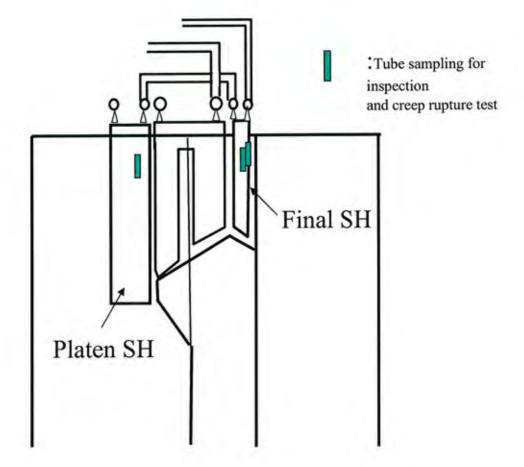
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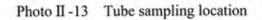
FigII-30 Evaluation Results

Final SH #119

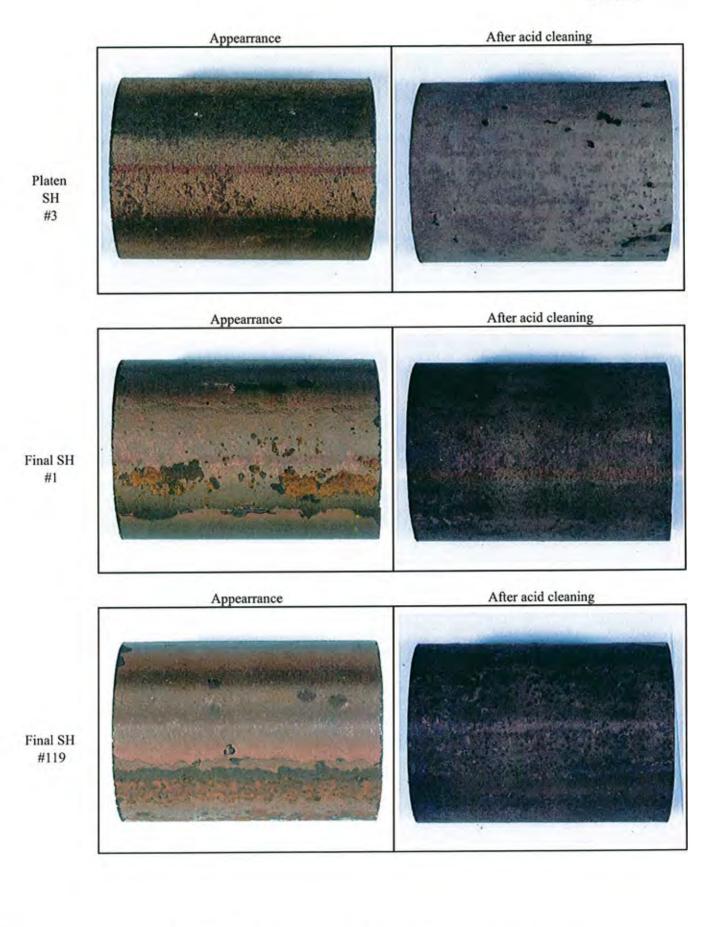
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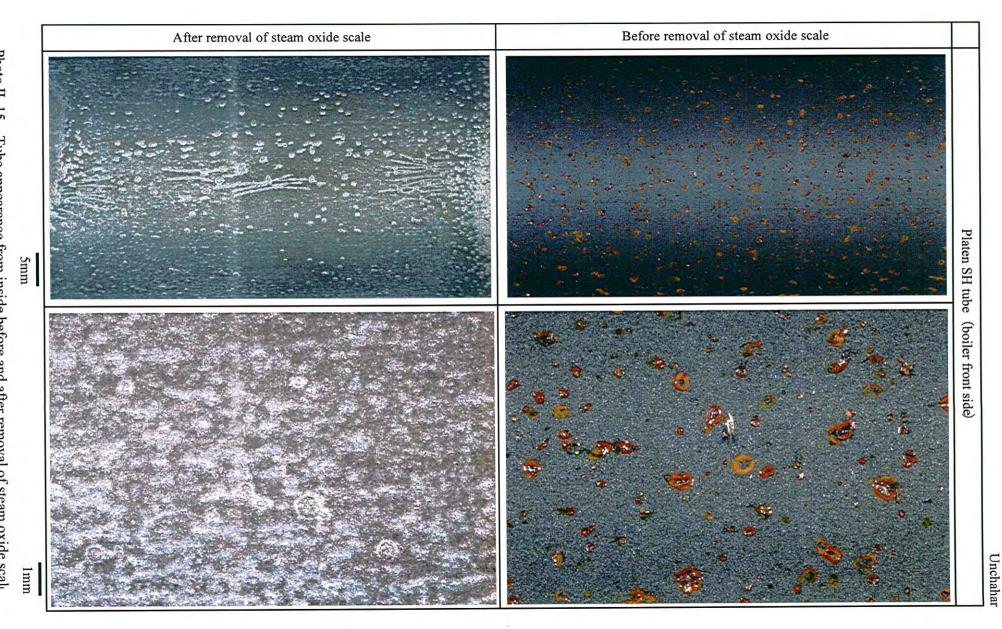




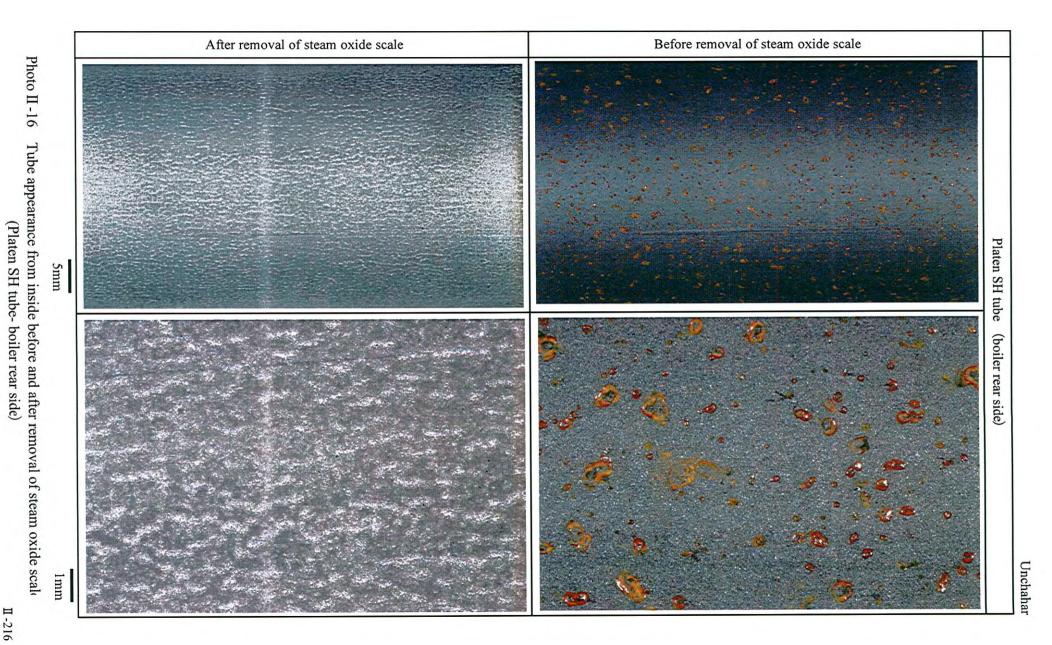


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