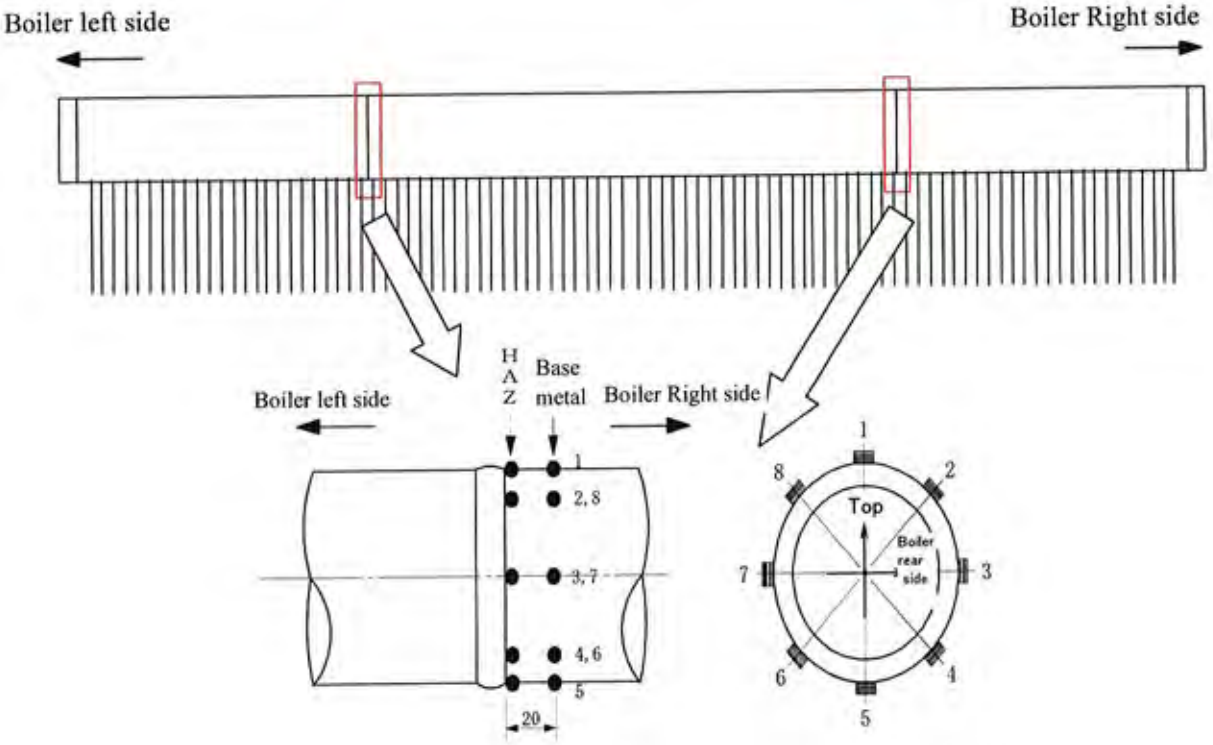
Table Ⅱ-22 (Unchahar) Re-Heater Outlet Header Outside Diameter Measurement Results

Components	Material	Designed OD	Region	Area	Measured value (mm)				Averaged (mm)	(Averaged measured value-Designed OD) /Designed OD(%)
					1⇔5	2⇔6	3⇔7	4⇔8		
Re-Heater Outlet Header(Right)	SA335 P-22	558.8mm	(Header side)	Base metal	558.62	566.60	562.37	560.43	562.00	+0.57
				HAZ	557.15	560.16	561.75	559.92	559.75	+0.17
Re-Heater Outlet Header(Left)	SA335 P-22	558.8mm	(Header side)	Base metal	559.24	559.63	560.57	560.22	559.92	+0.20
				HAZ	558.96	559.16	560.19	559.96	559.57	+0.14

Measurement point of left side of RH outlet header

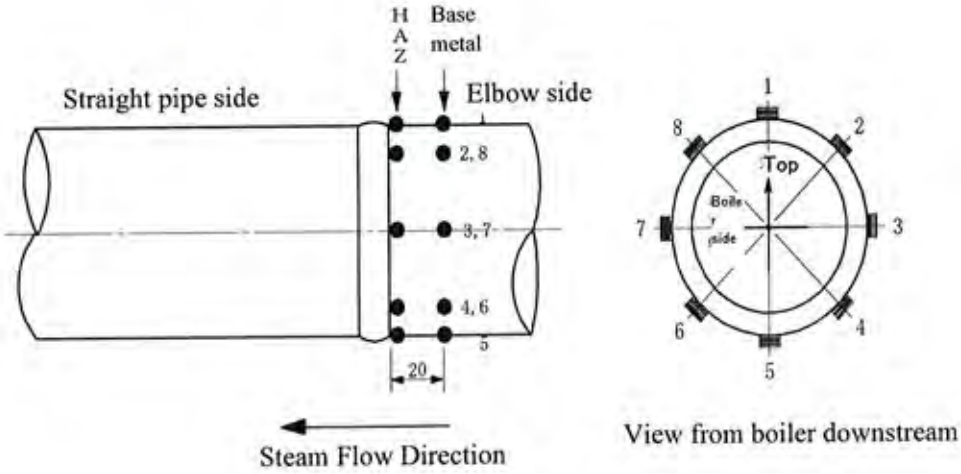
Measurement point of right side of RH outlet header



View from boiler right side

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

Components	Material	Designed OD	Position	Region	Measured value (mm)				Averaged (mm)	(Averaged measured value-Designed OD) /Designed OD(%)
					1⇔5	2⇔6	3⇔7	4⇔8		
Hot Reheat Pipe	SA335 P-22	508.0mm	Downstream side (straight pipe side)	Base metal	510.00	507.57	506.39	508.33	508.07	+0.01
				HAZ	508.17	506.77	505.17	507.77	506.97	-0.20



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℃.

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℃and 41,000 hours for base metal, 35,000 hours for weld joint portion at equivalent temperature 573℃ 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

Sample tube specification is shown in Table Ⅱ-30.

Table Ⅱ-30 Sample tube specification

Sample	Material	Designed OD×t(mm)	Designed Temperature (℃)	Designed Pressure (MPa)
Platen-SH #3-8	SA213T22	Φ51.0×t9.6	553	17.24
	SA213T11※	Φ51.0×t7.1	503	
Final-SH #1	SA213T22	Φ51.0×t9.6	554	17.24
	SA213T22※	Φ51.0×t8.8	545	
Final-SH #119	SA213T22	Φ51.0×t9.6	545	17.24
	SA213T22※	Φ51.0×t8.8	534	

※ : 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	C	Si	Mn	P	S	Cr	Mo
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

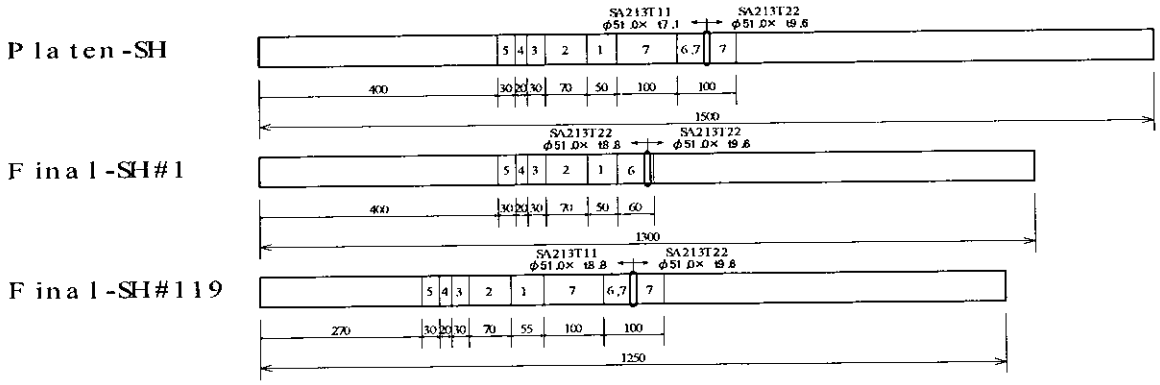
Inspection item and inspected portion are shown in Table Ⅱ-31.

Table Ⅱ-31 Inspection item

Sample	Inspection item						
	1	2	3	4	5	6	7
	Outer surface appearance	Internal surface	Tube dimension・	Metallography	Scale analysis	RLA by microstructure	Creep rupture test
Platen-SH	○	○	○	○	○	○	○
Fainal-SH#1	○	○	○	○	○	○	—
Fainal-SH#119	○	○	○	○	○	○	○

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 II-15～20)

(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

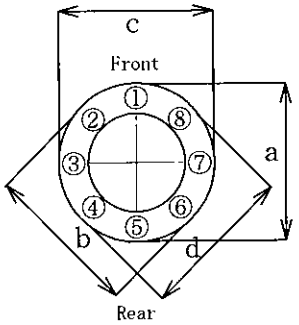
OD of each tube was measured to be less than designed values.

b. Thickness measurement

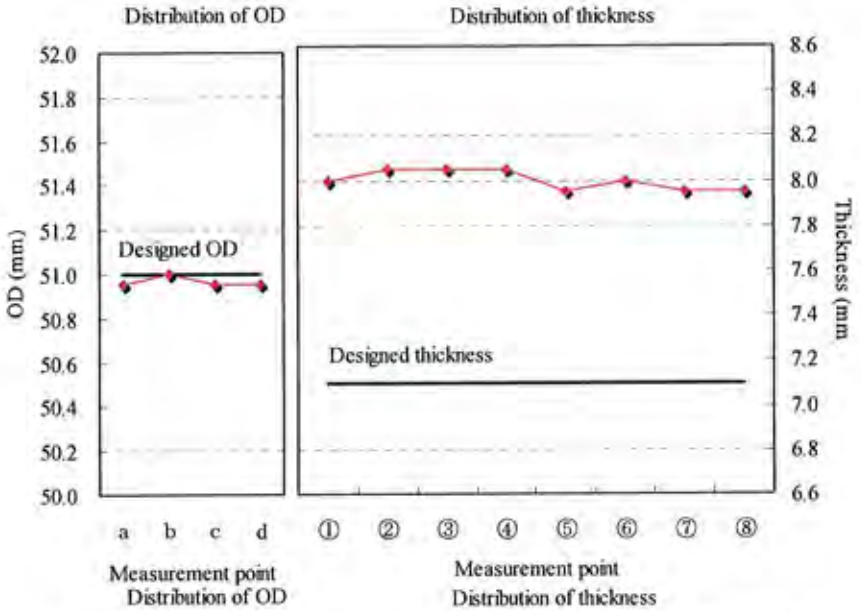
Thickness of each tube was measured to be larger than designed value.

Table Ⅱ-32 Tube dimension measurement results

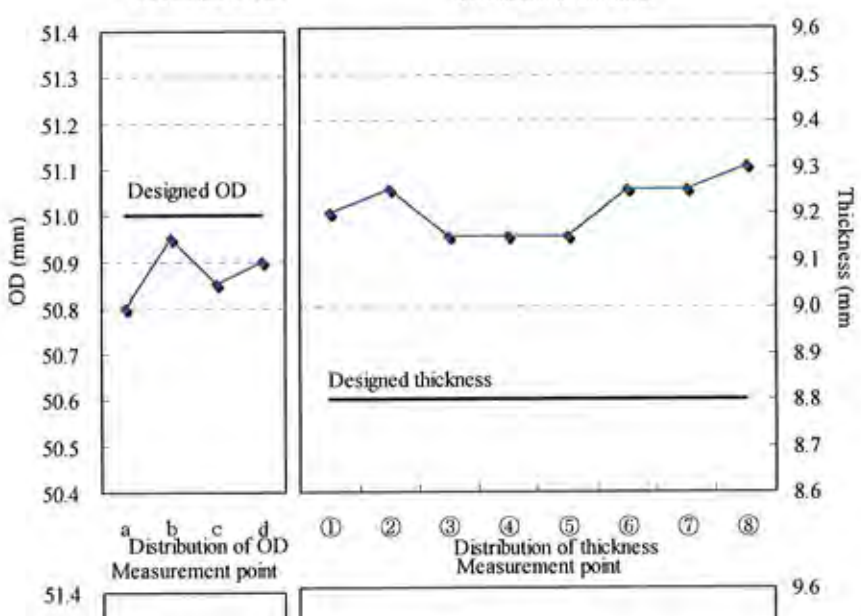
Sample tube	Specification	OD (mm)			Thickness (mm)							
		Direction	OD	ID	①	②	③	④	⑤	⑥	⑦	⑧
Platen-SH	Φ51.0×t7.1	a	50.95	35.05	8.00				7.95			
		b	51.00	35.00		8.05				8.00		
		c	50.95	34.95			8.05				7.95	
		d	50.95	34.95				8.05				7.95
FINAL-SH #1	Φ51.0×t8.8	a	50.80	32.45	9.20				9.15			
		b	50.95	32.45		9.25				9.25		
		c	50.85	32.45			9.15				9.25	
		d	50.90	32.45				9.15				9.30
FINAL-SH #119	Φ51.0×t8.8	a	50.90	32.40	9.20				9.30			
		b	50.90	32.40		9.20				9.35		
		c	50.90	32.40			9.20				9.30	
		d	50.85	32.40				9.25				9.20



Platen-SH



Final-SH #1



Final-SH #119

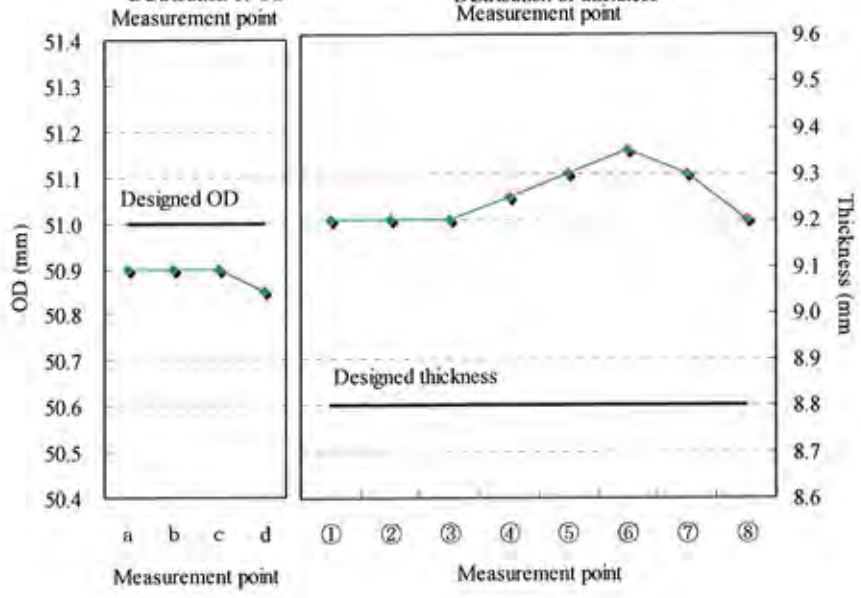


Fig II-12 Tube dimension measurement results

(3) Steam oxide scale adhesion on internal surface

a. Cross sectional observation of internal surface (Photo II -21)

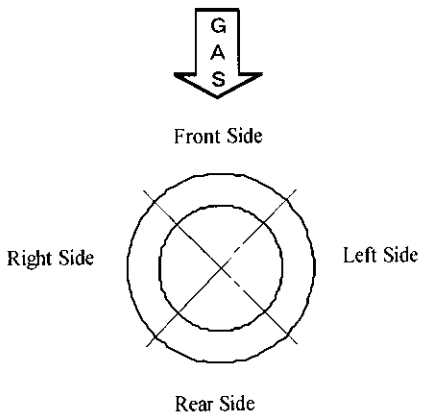
- Steam oxide scale was adhering evenly by cross sectional observation for each location with dual layer consisting of dense inner layer and slightly porous outer layer..

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.

Table II -33 Steam oxide scale thickness measurement results

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



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.

Table Ⅱ-34 Elements detected by EPMA analysis

Sample tube	Position	Element												
		O	S	P	N	Na	Si	Ca	Mn	Fe	Ti	Cr	Ni	Zn	Mo
Platen-SH	Front Side	■		■			■	■	■	■		■			■
	Right Side	■		■			■	■		■		■			■
	Rear Side	■		■			■	■	■	■		■			■
	Left Side	■		■			■	■	■	■		■			■
Final-SH#1	Front Side	■					■	■	■	■		■			■
	Right Side	■					■	■	■	■		■			■
	Rear Side	■					■	■	■	■		■			■
	Left Side	■					■	■	■	■		■			■
Final-SH#119	Front Side	■							■	■		■			■
	Right Side	■							■	■		■			■
	Rear Side	■							■	■		■			■
	Left Side	■							■	■		■			■

■ : Elements detected clearly

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

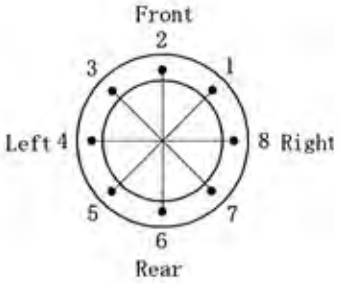
- The hardness of Platen-SH tube (SA213T11) was higher than the normal value of virgin material by Japanese steal manufacturer.
- The hardness of Final-SH#1,#119 tube (SA213T22) were lower than the normal value of virgin material by Japanese steal manufacturer.

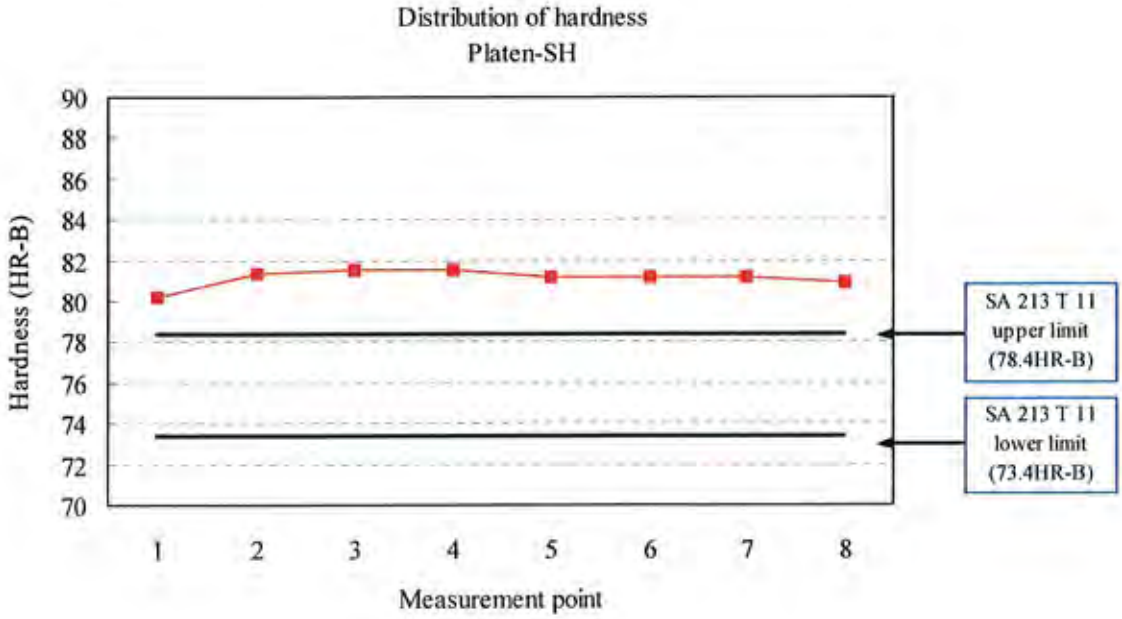
Table Ⅱ-35 Hardness measurement results

(unit:HR-B)

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

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)





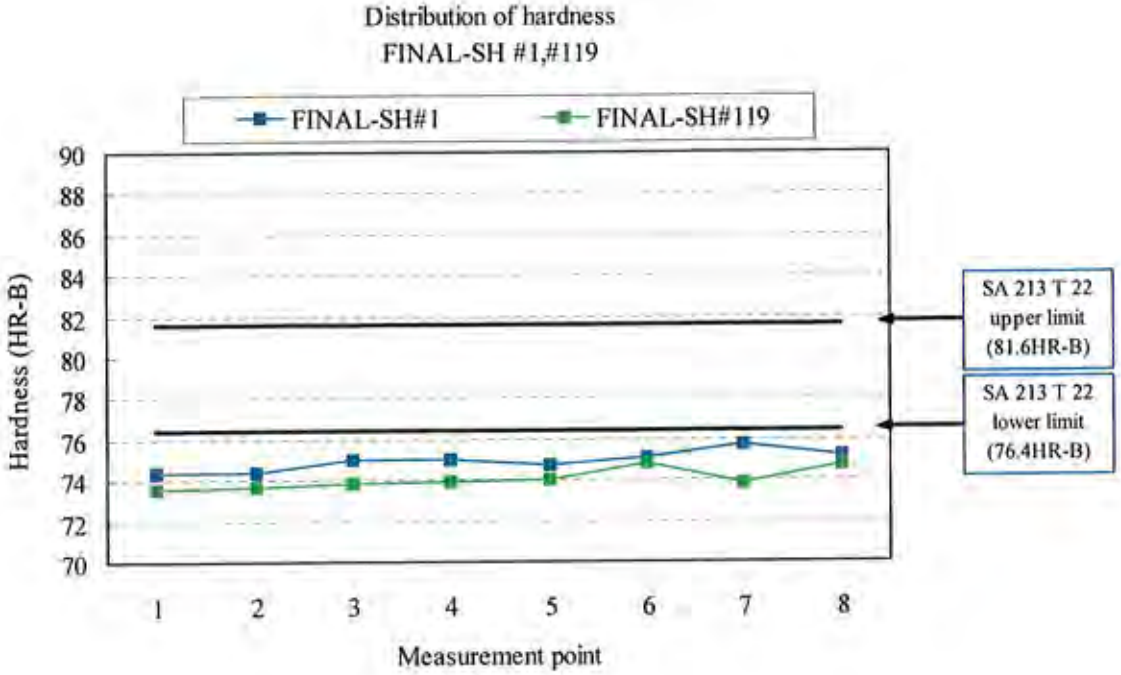


Fig II -25 Hardness measurement results

(5) Metallographic observation

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

(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, ϕ 6mm round bar specimen was applied.

Table Ⅱ-36 Creep test condition

Sample tube	Portion	Material	Test condition		Shape of specimen
			Tem. (℃)	Stress (MPa)	
Platen-SH	Base Metal	SA213T11	635	68.6	φ6
			635	83.4	
			665	45.9	
	Weld Metal	SA213T11	665	68.6	
			665	83.4	
			700	45.9	
Final-SH #119	Base Metal	SA213T22	665	63.7	φ6
			665	78.5	
			700	38.3	
	Weld Metal	SA213T22	665	63.7	
			665	78.5	
			700	38.3	

φ 6round bar

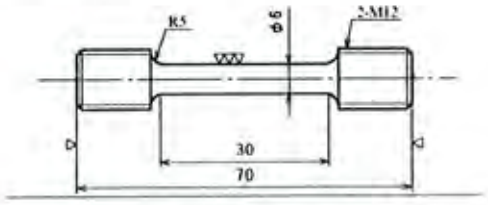
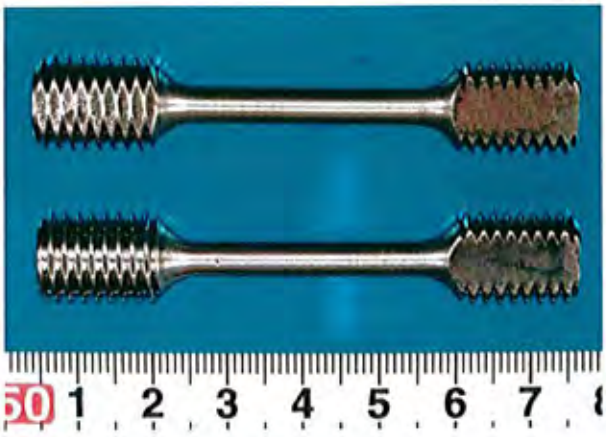


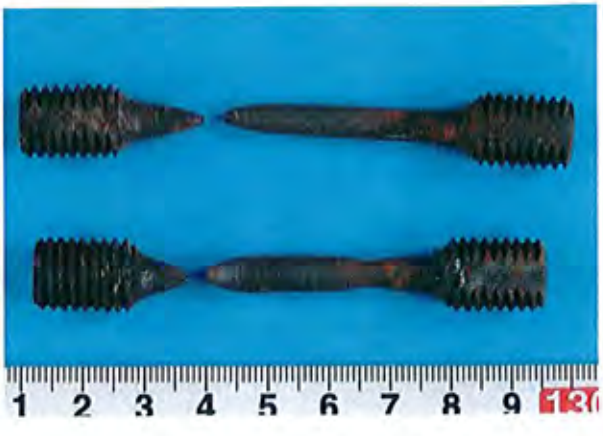
Fig Ⅱ-26 Shape of test specimens

Test specimens before and after creep rupture test

Before machining ⇒



After machining ↑



After creep rupture test ↑

Creep rupture testing machine ⇒

b. Test results

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

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

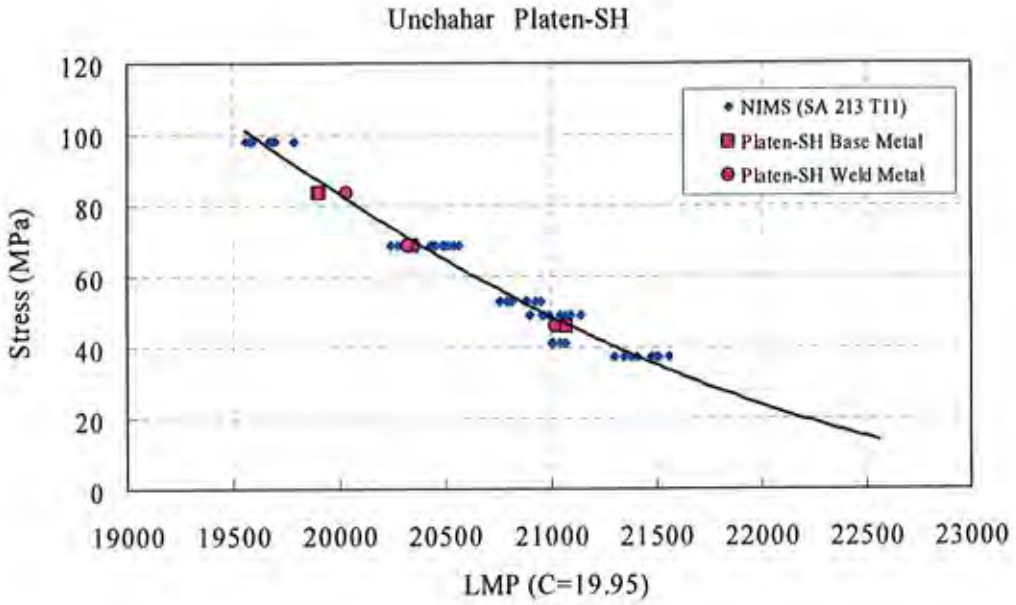
Component		Material	Test condition		Rupture time t (h)	LMP C=19.95	Fracture elongation (%)	Reduction of area (%)
			Temp. T(℃)	Stress (MPa)				
Platen-SH	Base Metal	SA 213 T11	635	68.6	278.7	20,341	62	94
			635	83.4	90.8	19,899	57	91
			665	45.9	322.4	21,072	86	94
	Weld Metal	SA 213 T11	635	68.6	264.3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

Table Ⅱ-37-2 Creep rupture test results (Final-SH #119)

Component		Material	Test condition		Rupture time t (h)	LMP C=15.77	Fracture elongation (%)	Reduction of area (%)
			Temp. T(℃)	Stress (MPa)				
Final-SH#119	Base Metal	SA 213 T22	665	63.7	113.1	16,725	69	91
			665	78.5	32.1	16,212	55	92
			700	38.3	162.6	17,503	67	94
	Weld Metal	SA 213 T22	665	63.7	86.0	16,614	30	84
			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.



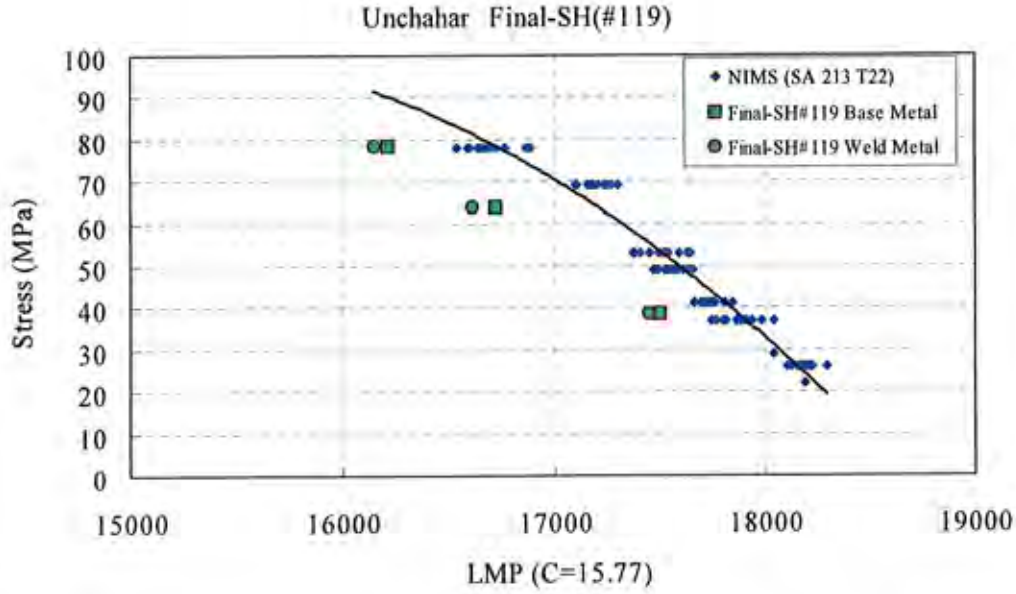


Fig II -27 The comparison of the test results and the creep rupture data of virgin materials by NIMS (National Institute for Materials science).

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℃.

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℃.

In case of evaluation at equivalent temperature 573℃ 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 parameter –method

Parameter method (evaluated at designed temp.)								
Component		Material	Operation hours (h)	Hoop Stress	Designed temp. (℃)	Residual life (h)	Creep life consumption ratio	Evaluated residual life (h)
Platen-SH	Base Metal	SA 213 T11	139,098	45.9	503	15,726,180	0.01	7,800,000
	Weld Metal	SA 213 T11	139,098	45.9	503	13,692,433	0.01	6,800,000
Final-SH#119	Base Metal	SA 213 T22	139,098	38.3	534	812,994	0.15	400,000
	Weld Metal	SA 213 T22	139,098	38.3	534	700,466	0.17	350,000

Parameter method (evaluated at equivalent temp.)								
Component		Material	Operation hours (h)	Hoop Stress (MPa)	Equivalent temperature (℃)	Residual life (h)	Creep life consumption ratio	Evaluated residual life (h)
Platen-SH	Base Metal	SA 213 T11	139,098	45.9	Non evaluation(※1)			
	Weld Metal	SA 213 T11	139,098	45.9				
Final-SH#119	Base Metal	SA 213 T22	139,098	38.3	573	82,798	0.63	41,000
	Weld Metal	SA 213 T22	139,098	38.3	573(※2)	71,826	0.66	35,000

※1; 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-28～32.

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-33～34.

- 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-35～38.

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-39～43.

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-44～45.

- 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-46～49.

The summary of observation results is shown in Table Ⅱ-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-50～54.

The summary of observation results is shown in Table 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-55～56.

- 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.

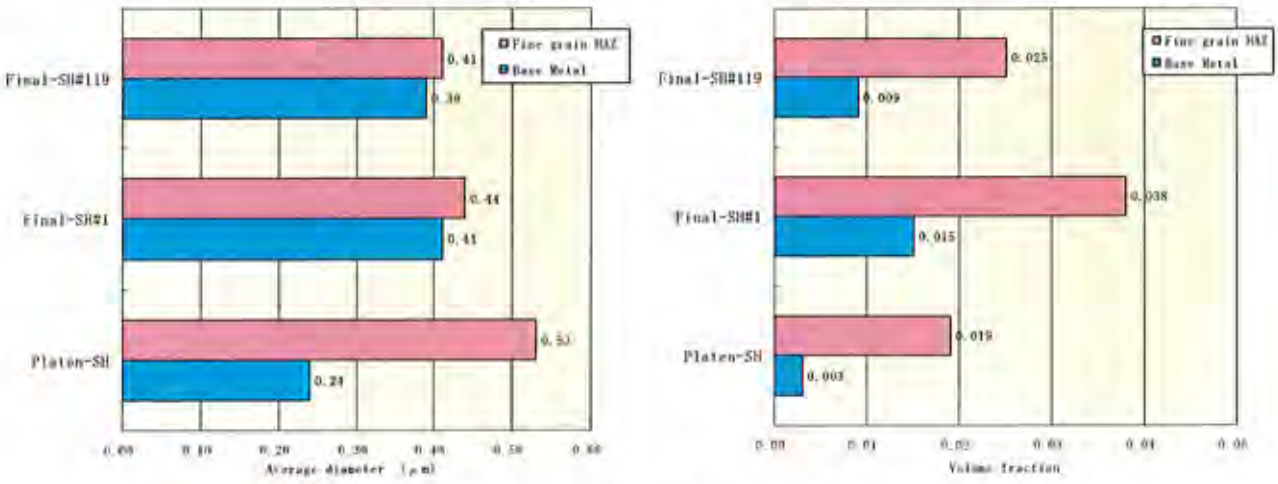
The summary of observation results is shown in Table II-40.

- 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 σ 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.

Table Ⅱ -43 Operational condition of evaluated components

Component	Material	Operational condition				
		OD※1 mm	t※1 mm	Designed Temperature ℃	Designed Pressure MPa	Hoop 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

※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-28～30 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.

Table Ⅱ-44 Residual life evaluation results

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

Table Ⅱ-39 Microstructure observation resuluts

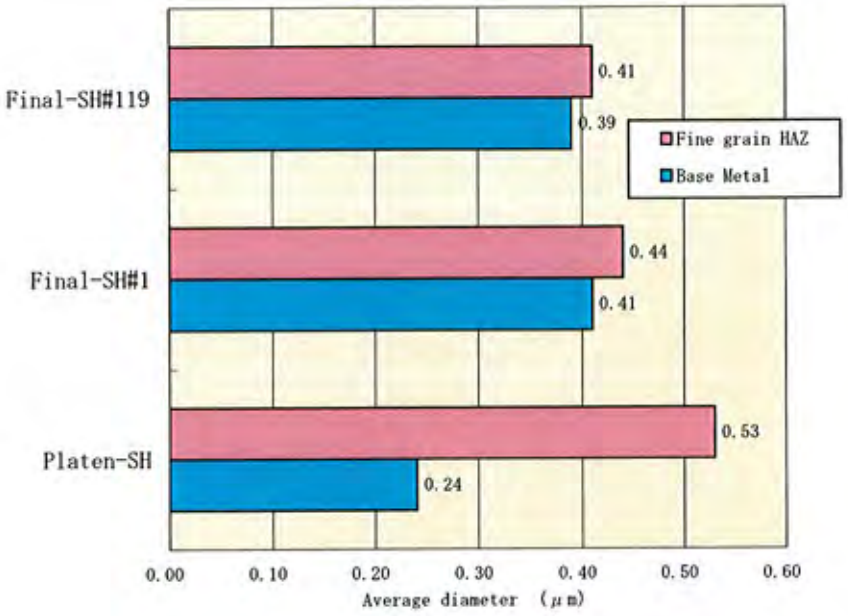
Components	Location		Observed region	OM						
				Microstructural features						
				Precipitation at gain boundary	Precipitates free zone along grain boundary	Precipitation in ferite grain		Pearlite structure	Subgrain boundary	Ferrite grain
						Granular precipitates	Rod-shaped precipitates			
Platen SH tube (SA 213 T11)	#3-8th tube from rear	Circumferential weld	Base metal	Appeared	Not appeared	Appeared	Not appeared	Disintegrated		
			Intercritical zone	Appeared		Appeared	Appeared	Disintegrated	Normal	
			Fine grain HAZ	Appeared		Not appeared	Not appeared			
			Coarse grain HAZ	Appeared		Appeared				
			Weld metal	Not appeared		Appeared				Appeared
Final SH tube (SA 213 T22)	#1-3rd tube from rear	Circumferential weld	Base metal	Appeared	Not appeared	Appeared	Not appeared	Normal		
			Intercritical zone	Not appeared		Not appeared	Not appeared			
			Fine grain HAZ	Appeared		Appeared	Not appeared			
			Coarse grain HAZ	Not appeared		Appeared				
			Weld metal	Appeared		Appeared				
	#19-3rd tube from rear	Circumferential weld	Base metal	Appeared	Not appeared	Appeared	Not appeared	Normal		
			Intercritical zone	Appeared		Appeared	Not appeared			
			Fine grain HAZ	Appeared		Appeared	Not appeared			
			Coarse grain HAZ	Not appeared		Appeared				
			Weld metal	Not appeared		Appeared				
View nos. for each area				×500 (2 views) ×1000 (4 views)						

Table Ⅱ-40 Precipitates distribution observation results

Components	Location		Observed region	TEM (Transmission Electron Microscope observation)					
				Precipitates features					
				Precipitates free zone along grain boundary	Precipitation in ferite grain			Pearlite structure	Aggromerated precipitates structure
					Fine needlelike and granular	Rod-shaped precipitates	Atenuated platedlike precipitates		
Platen SH tube (SA 213 T11)	#3-8th tube from rear	Circumferential weld	Base metal	Appeared	Remaining	Appeared	Not appeared	Disintegrating	
			Fine grain HAZ		Remaining	Not appeared	Not appeared	Disintegrated	
			Coarse grain HAZ		Remaining	Appeared	Not appeared		Disintegrated
			Weld metal		Remaining				
Final SH tube (SA 213 T22)	#1-3rd tube from rear	Circumferential weld	Base metal	Appeared	Remaining	Appeared	Not appeared	Normal	
			Fine grain HAZ		Remaining		Not appeared		
			Coarse grain HAZ		Disappeared		Not appeared		
			Weld metal		Remaining				
	#19-3rd tube from rear	Circumferential weld	Base metal	Appeared	Remaining	Not appeared	Not appeared	Remarkably disintegrated	
			Fine grain HAZ		Disappeared		Not appeared		
			Coarse grain HAZ		Disappeared		Not appeared		
			Weld metal		Remaining				
View nos. for each area				×2000 (2 views) ×1000 (4 views)					

Table II-41 Quantitative evaluation of grain boundary precipitates

Component	Material	Average diameter (μm)		Volume fraction	
		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



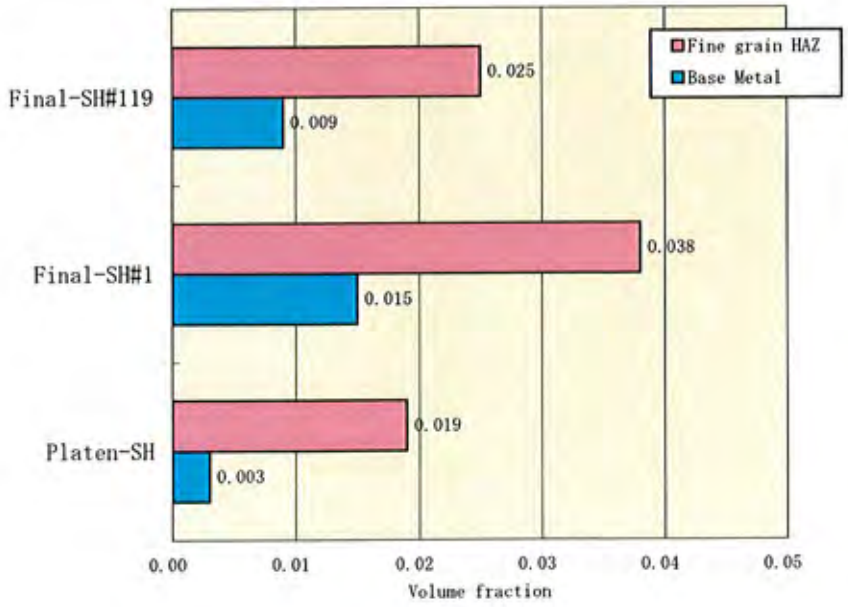
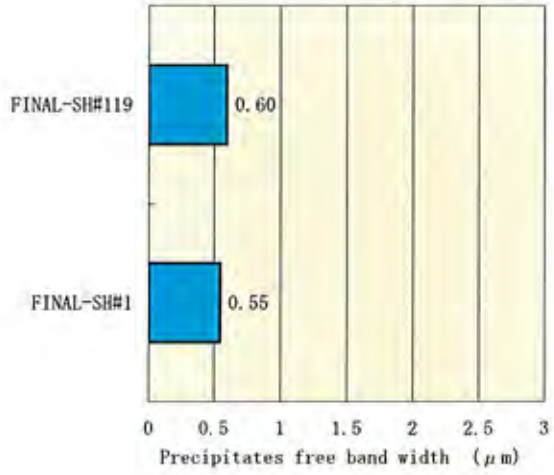
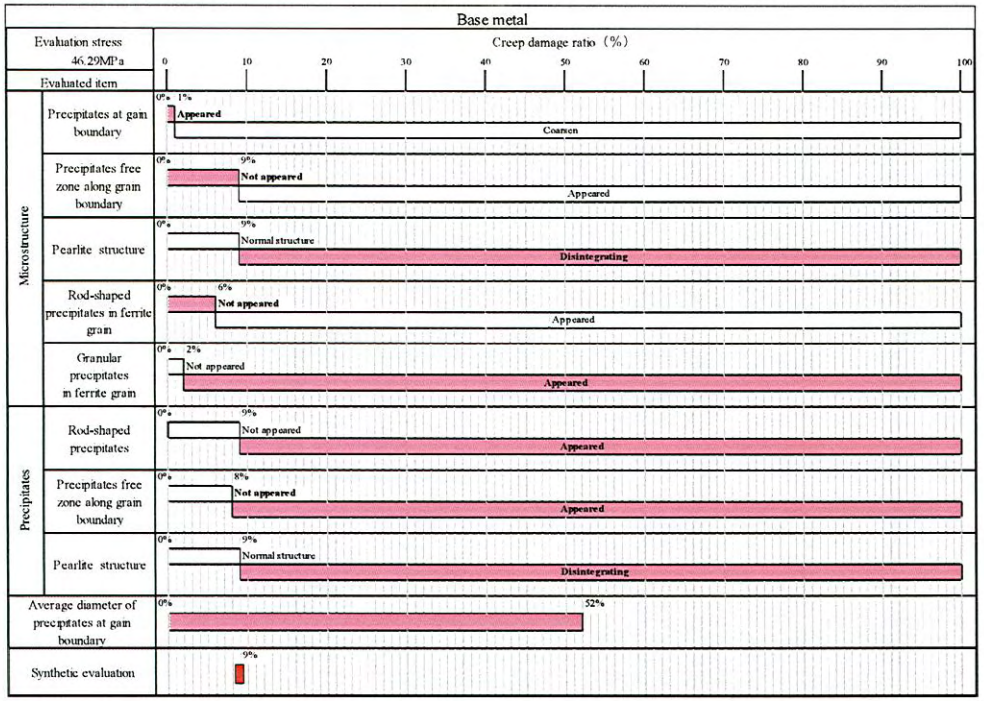


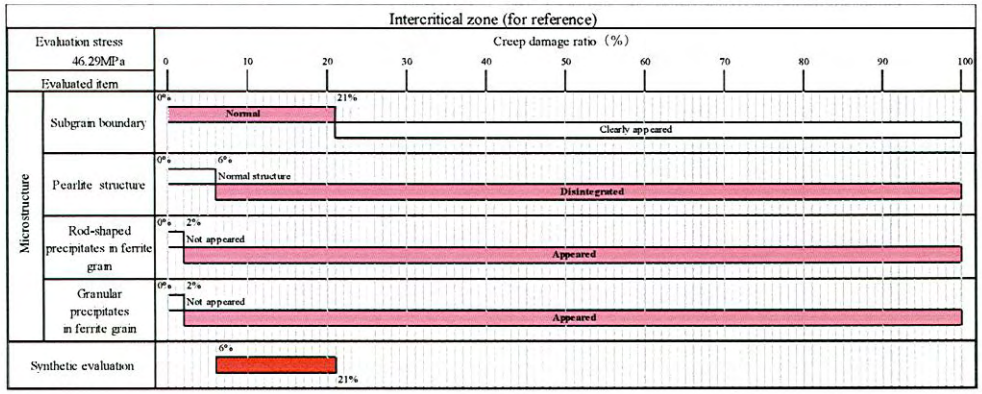
Table Ⅱ-42 Precipitates free band width along grain boundary

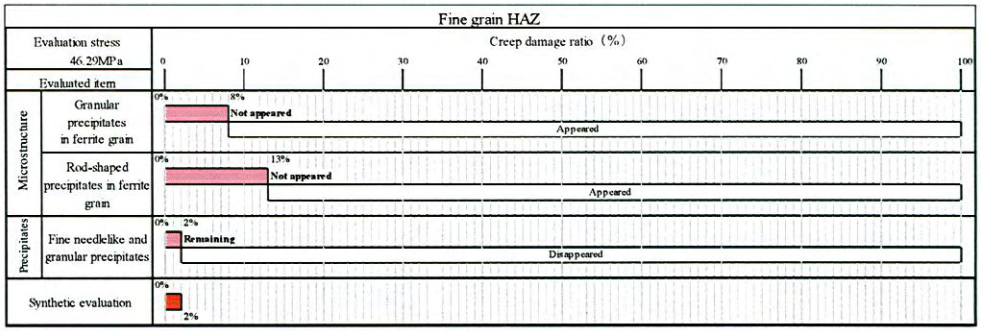
Sample tube	Material	Precipitates free band width (μm) ※1
		Base Metal
FINAL-SH#1	SA213T22	0.55
FINAL-SH#119	SA213T22	0.60

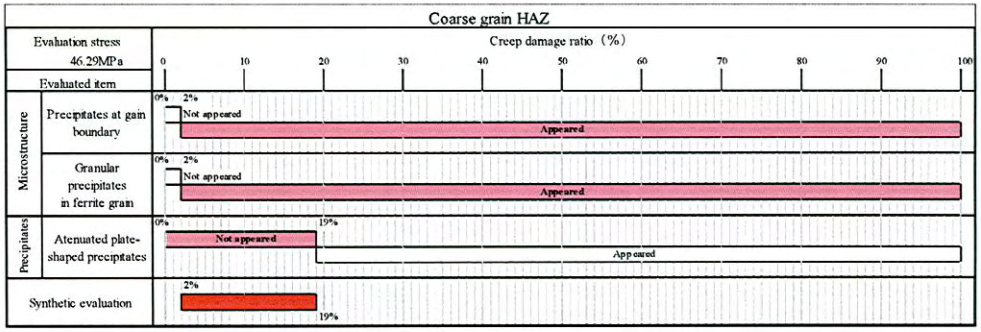
※1 : Average value of 10 measured points











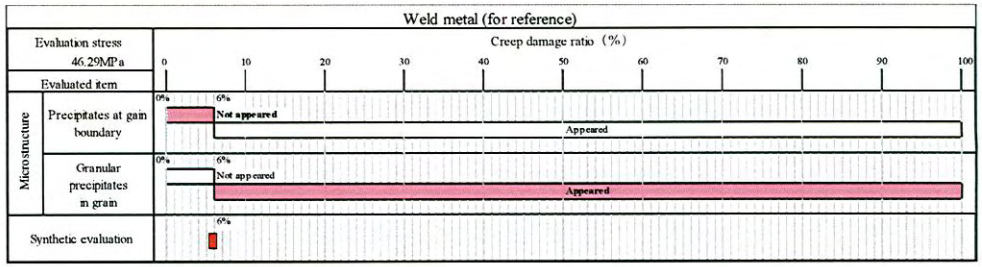
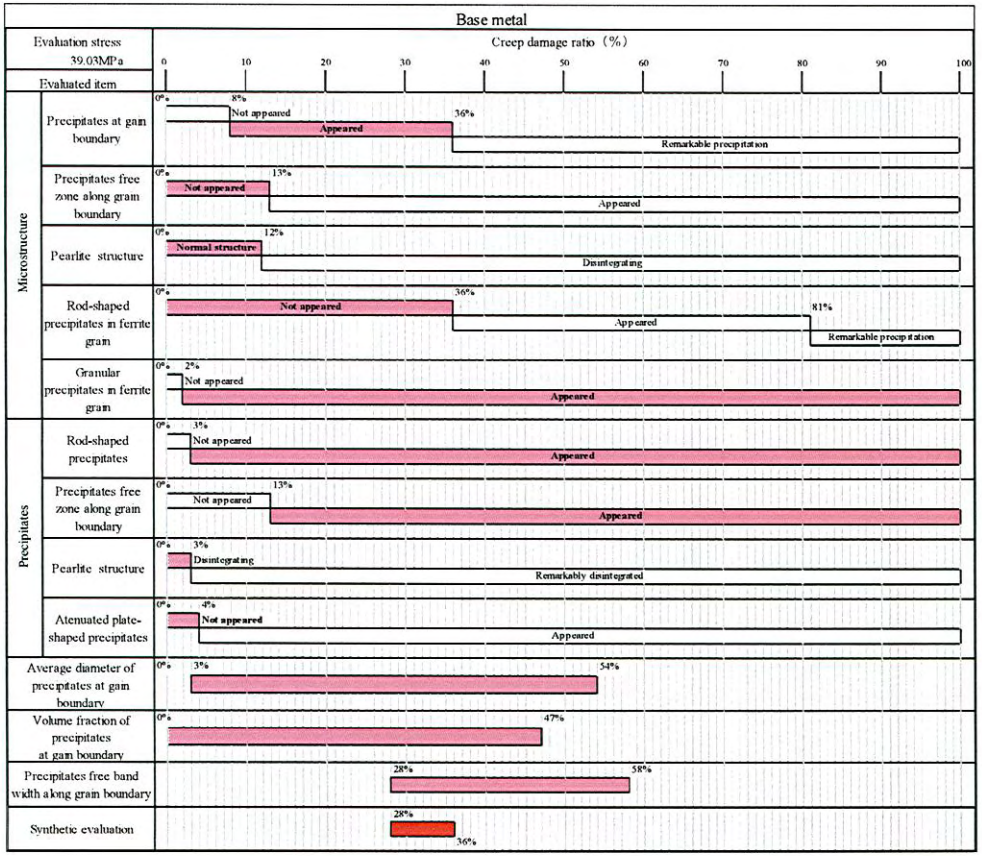
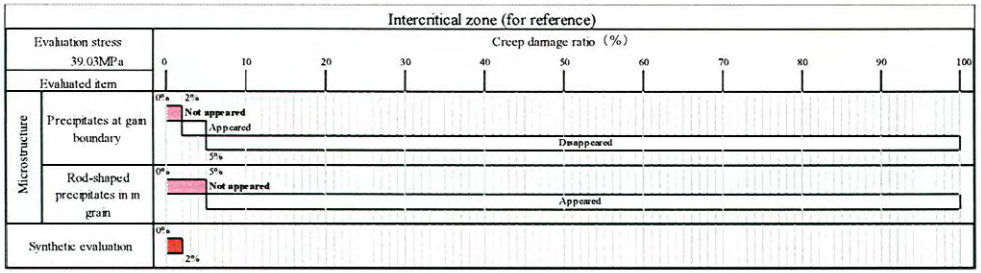
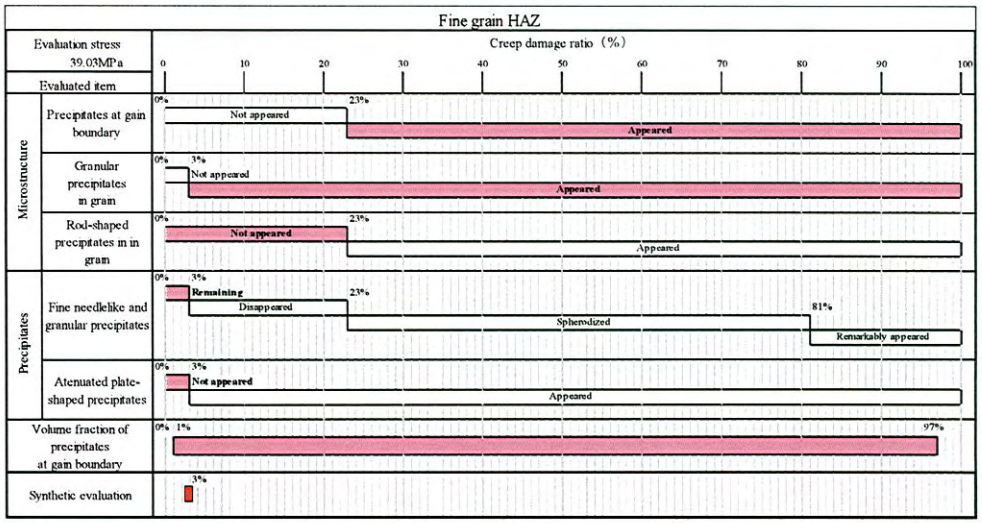
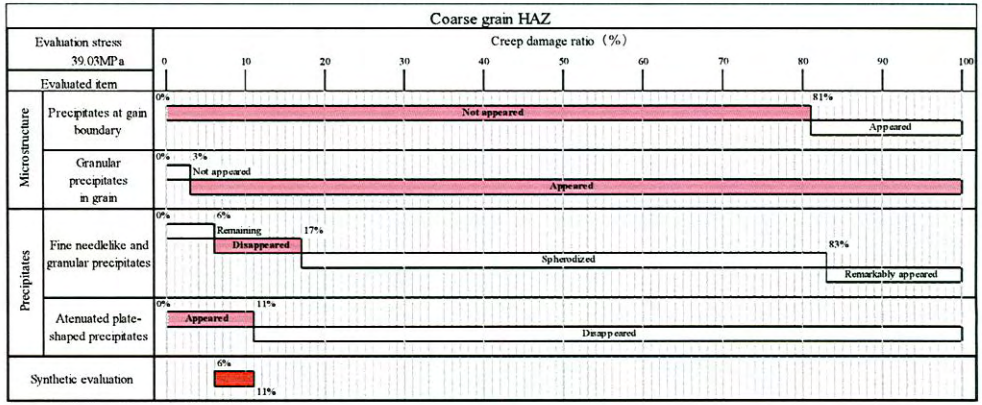


Fig Ⅱ-28 Evaluation Results Platen SH









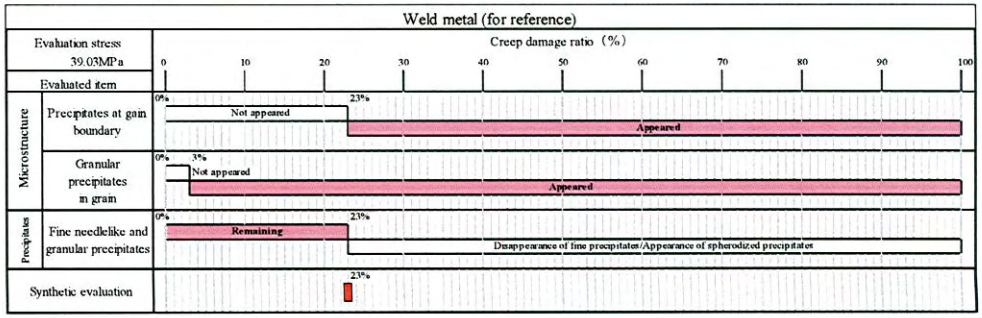
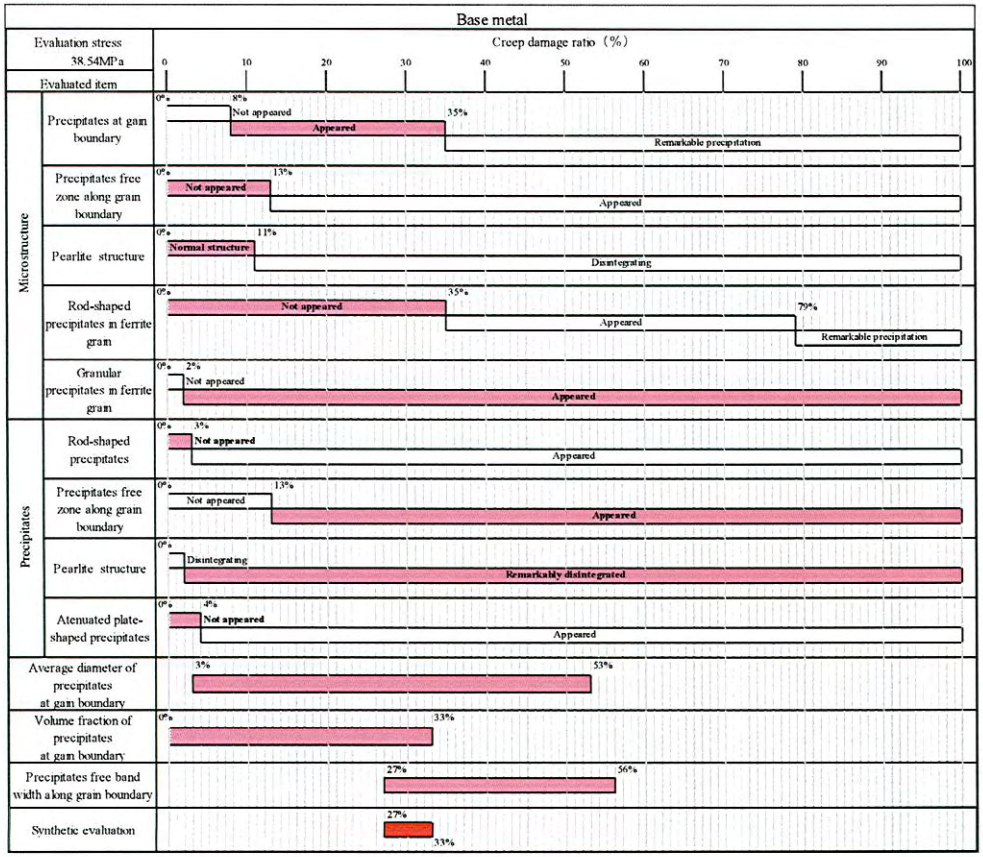
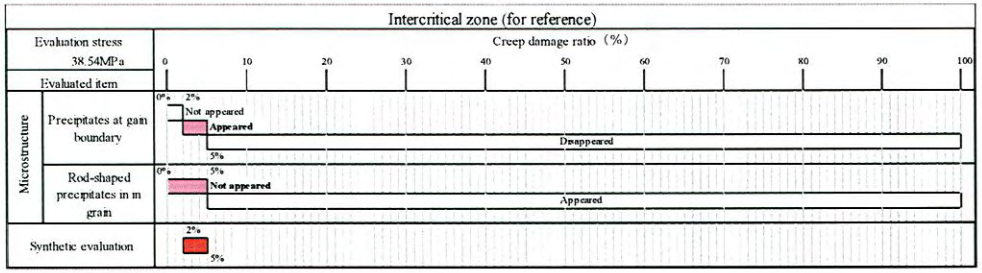
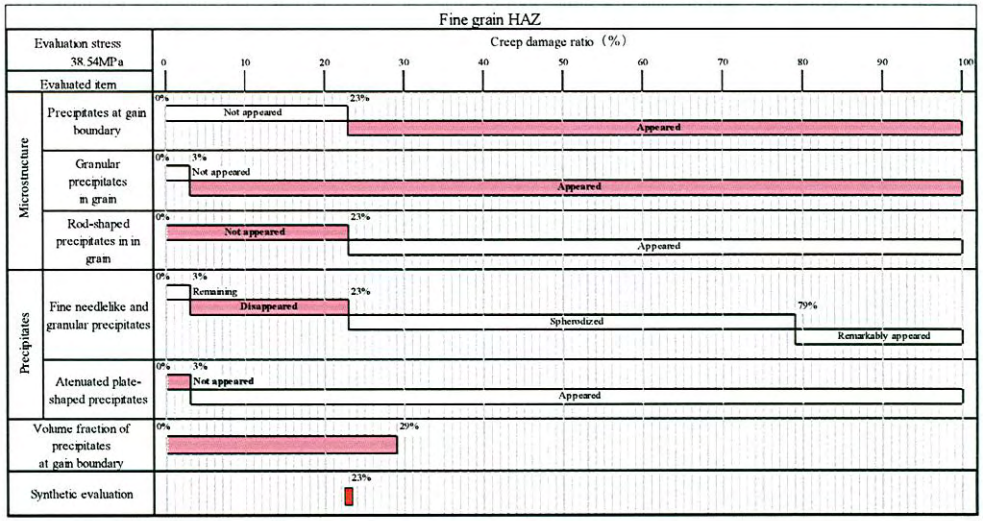
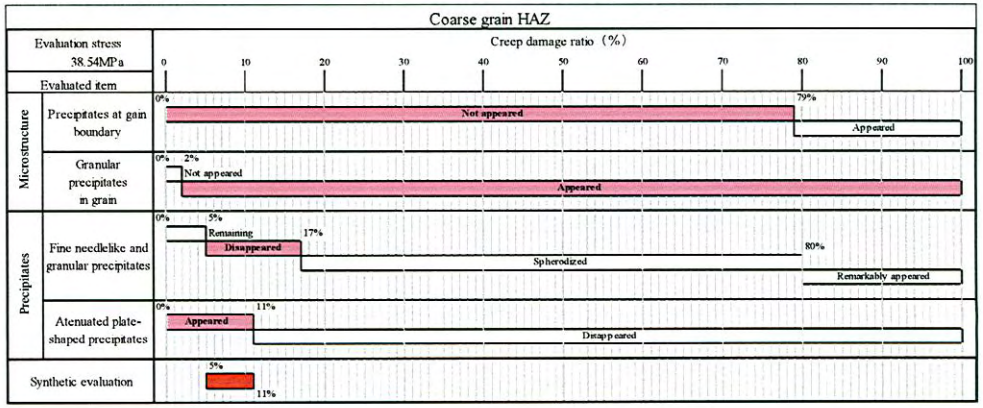


Fig Ⅱ-29 Evaluation Results Final SH #1









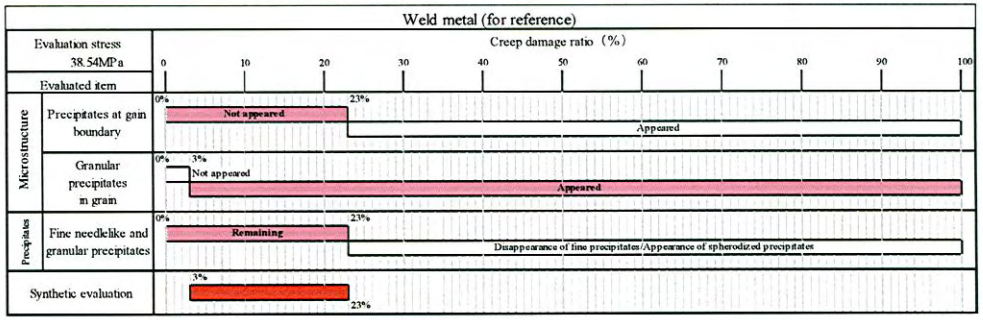


Fig Ⅱ-30 Evaluation Results Final SH #119

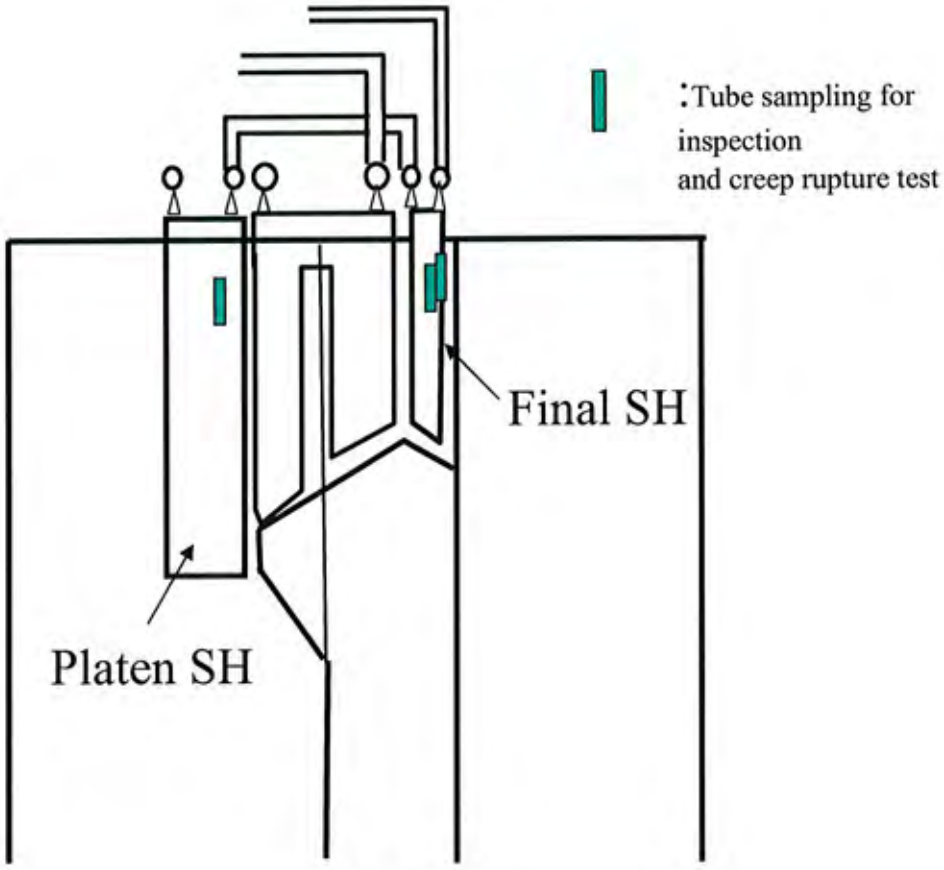


Photo II -13 Tube sampling location

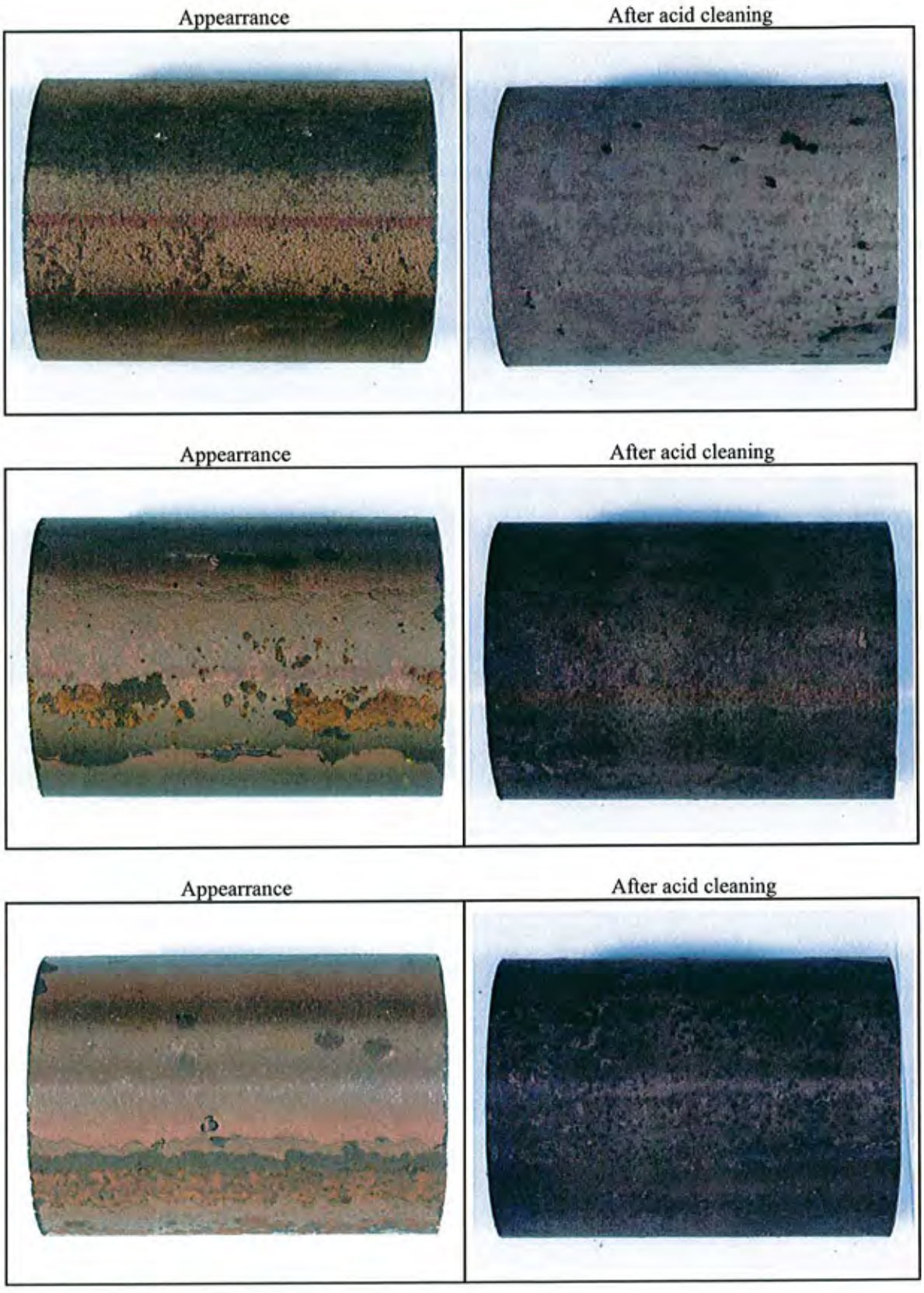


Photo II -14 Tube appearance from outside (boiler front side)

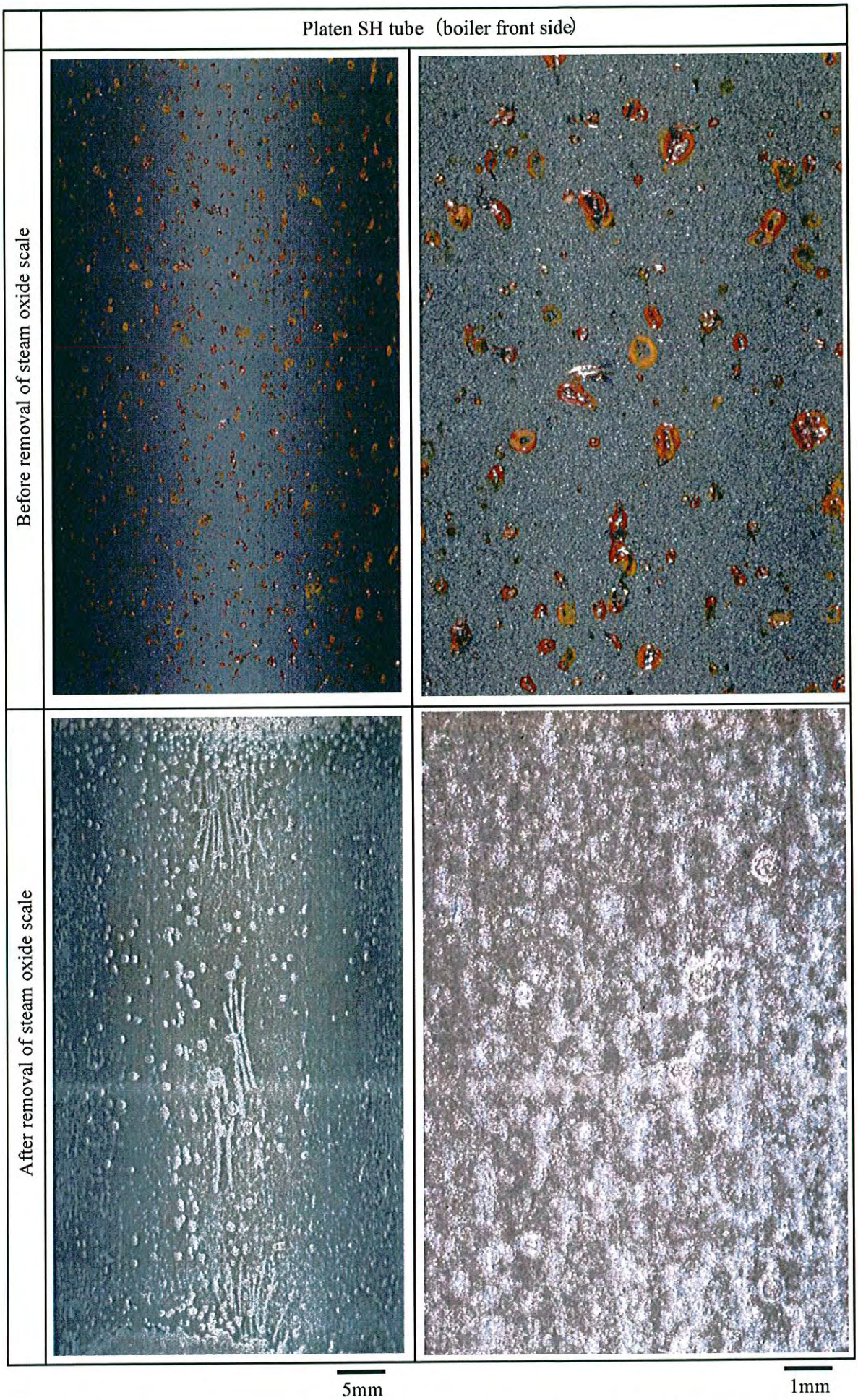


Photo II-15 Tube appearance from inside before and after removal of steam oxide scal
(Platen SH tube-boiler front side)

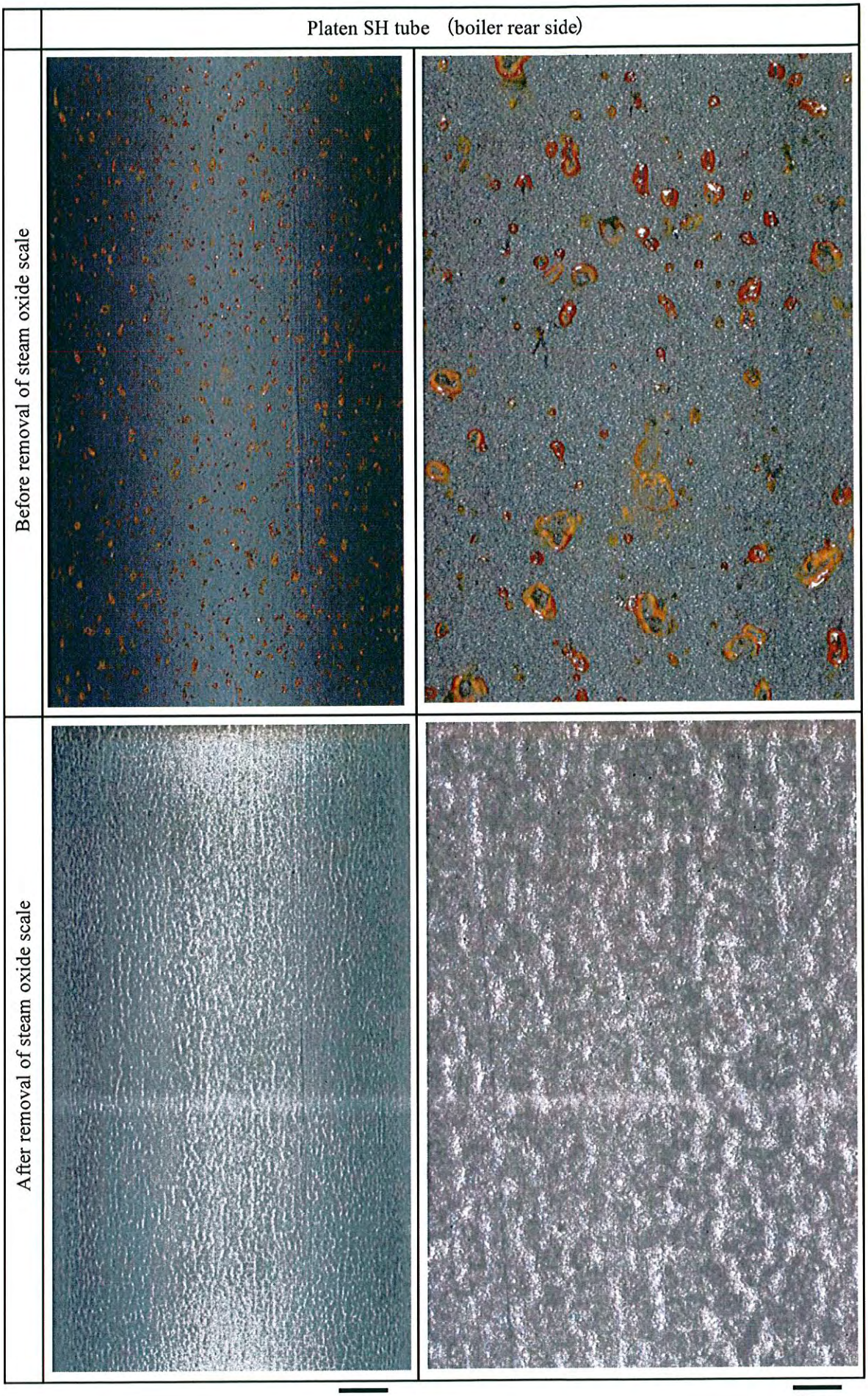


Photo II -16 Tube appearance from inside before and after removal of steam oxide scale
(Platen SH tube- boiler rear side)