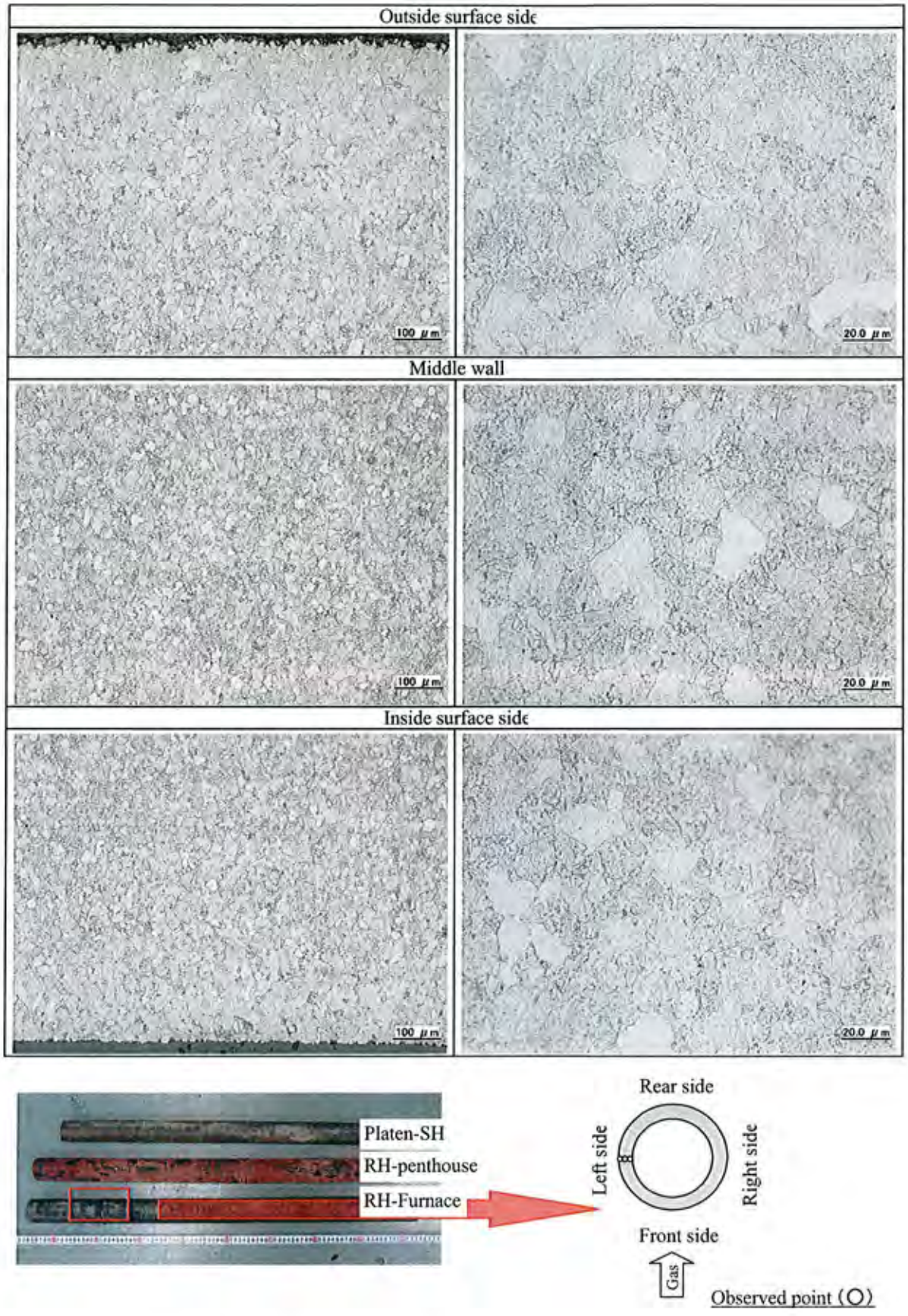
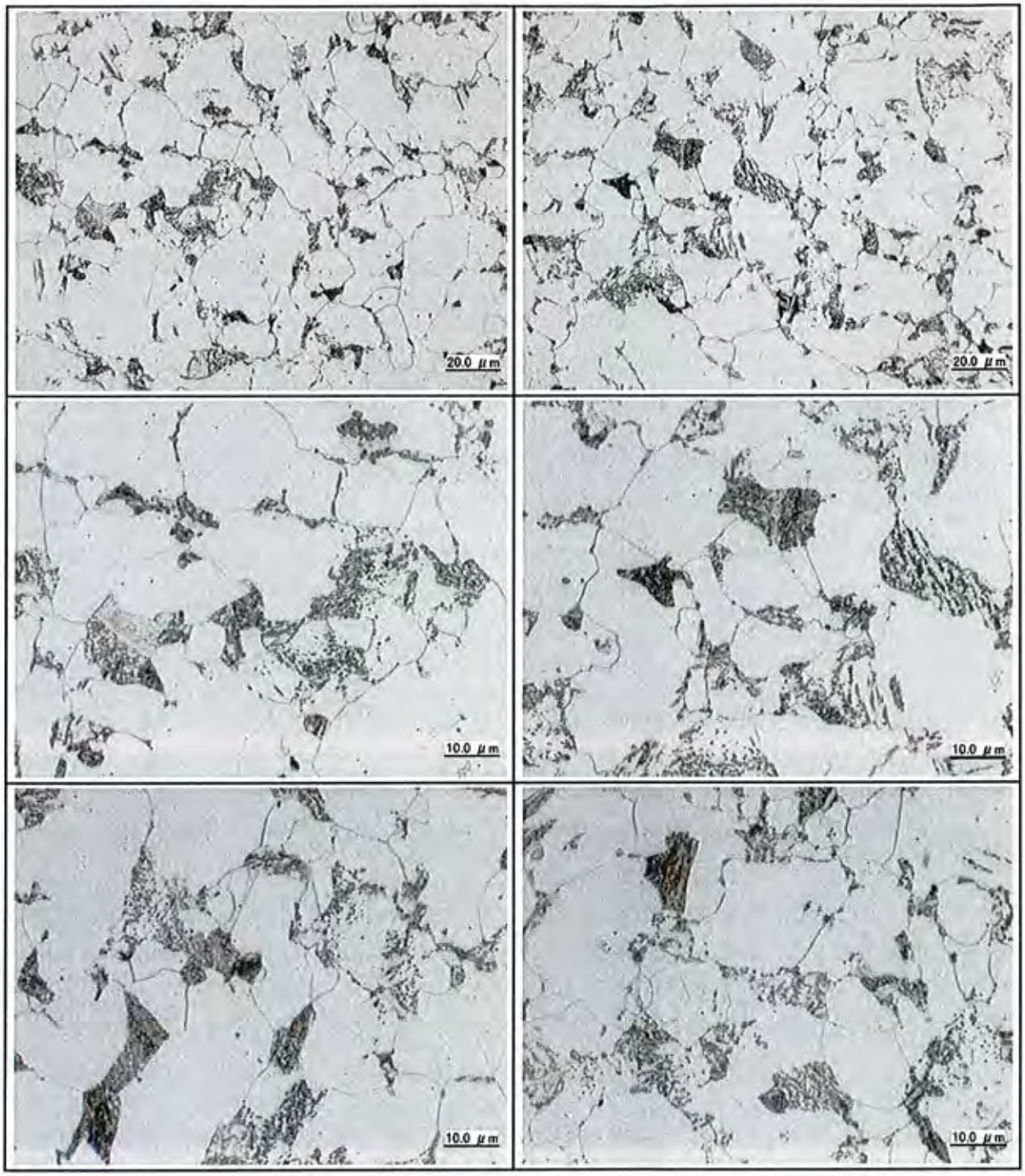


Photo I -25 Microstructure observation at cross section of sample tube
〔RH-Furnace (left side, Base Metal)〕



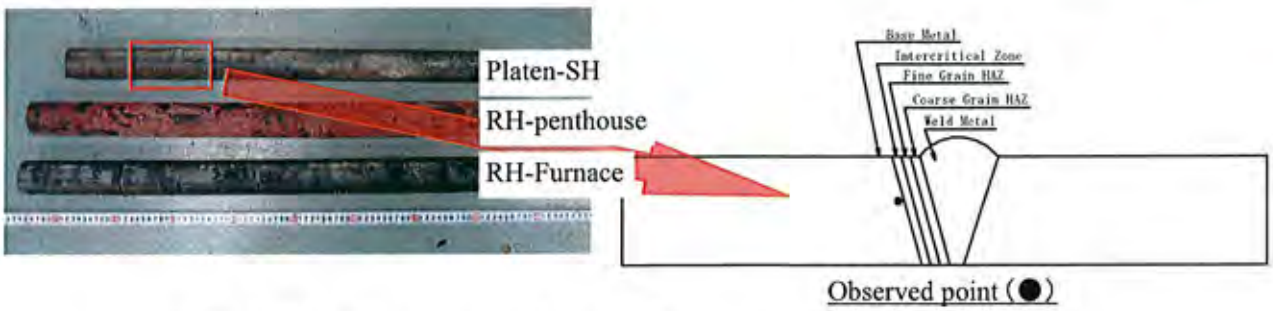
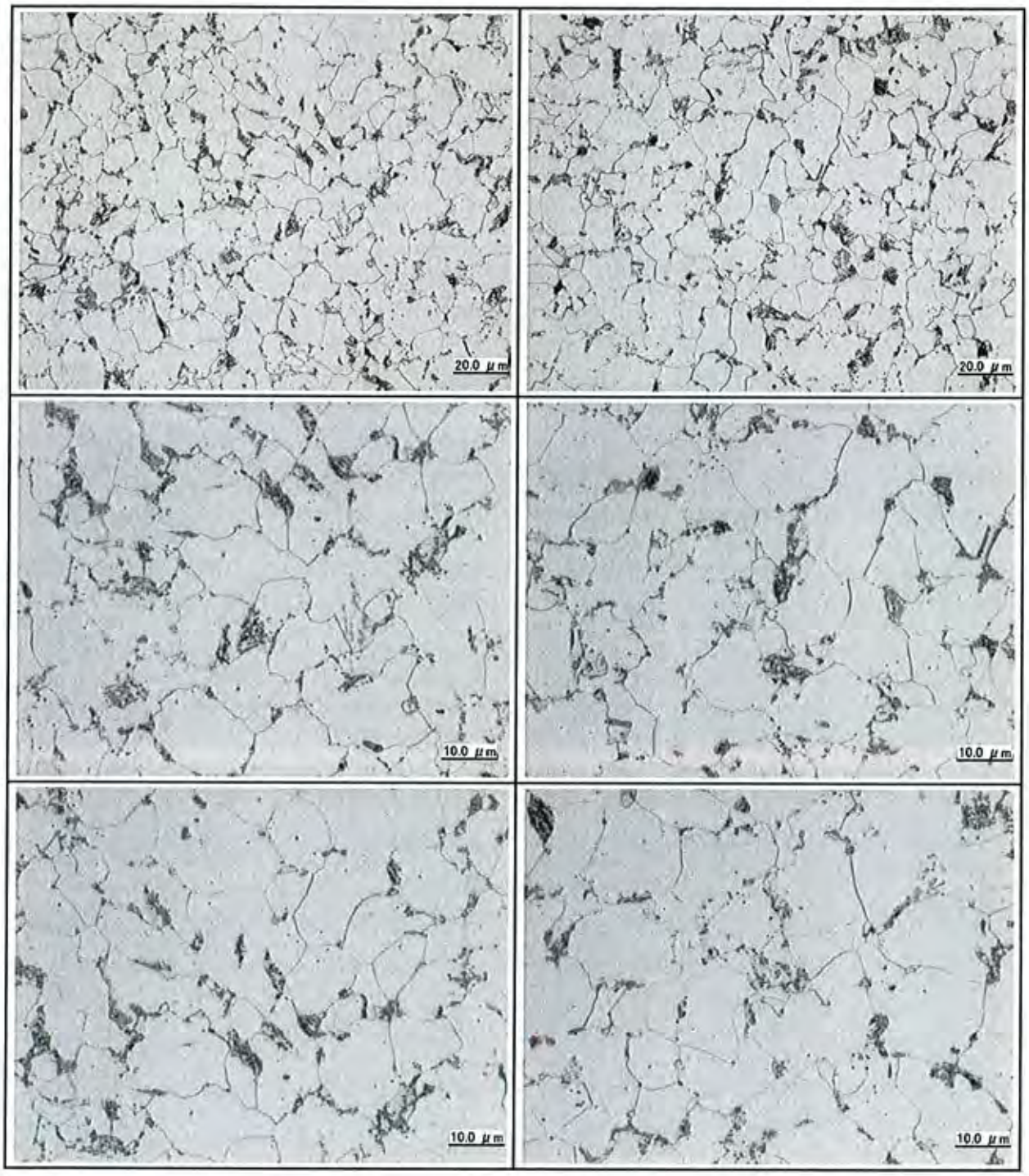


Photo I -26 Microstructure observation at cross section of sample tube
〔Platen-SH (Base Metal)〕



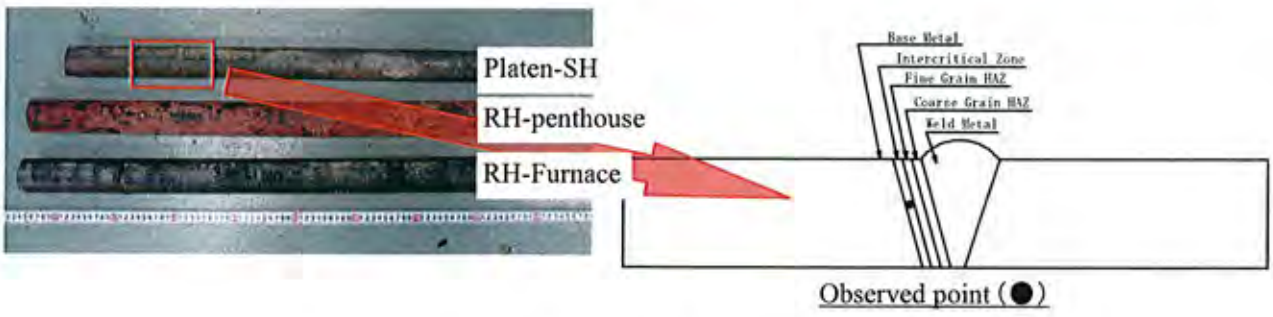
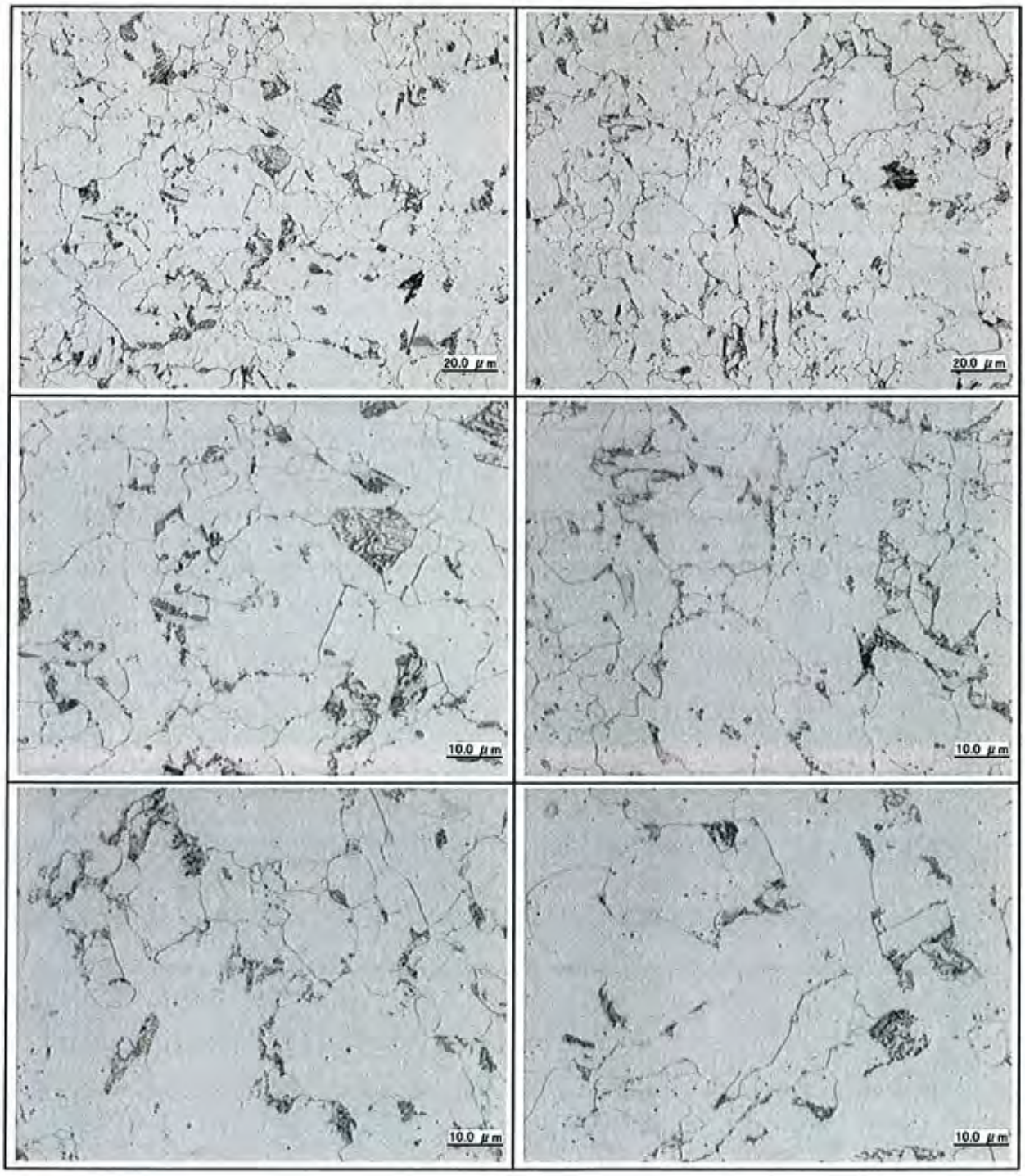


Photo I -27 Microstructure observation at cross section of sample tube
〔Platen-SH (Intercritical Zone)〕



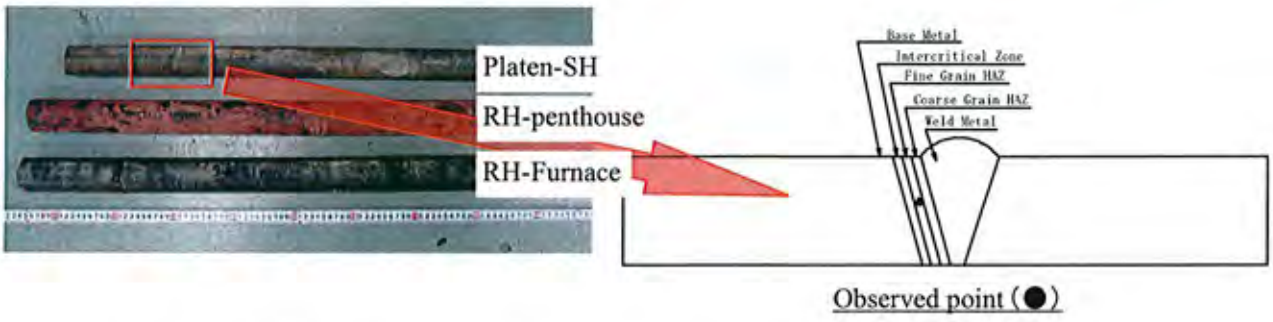
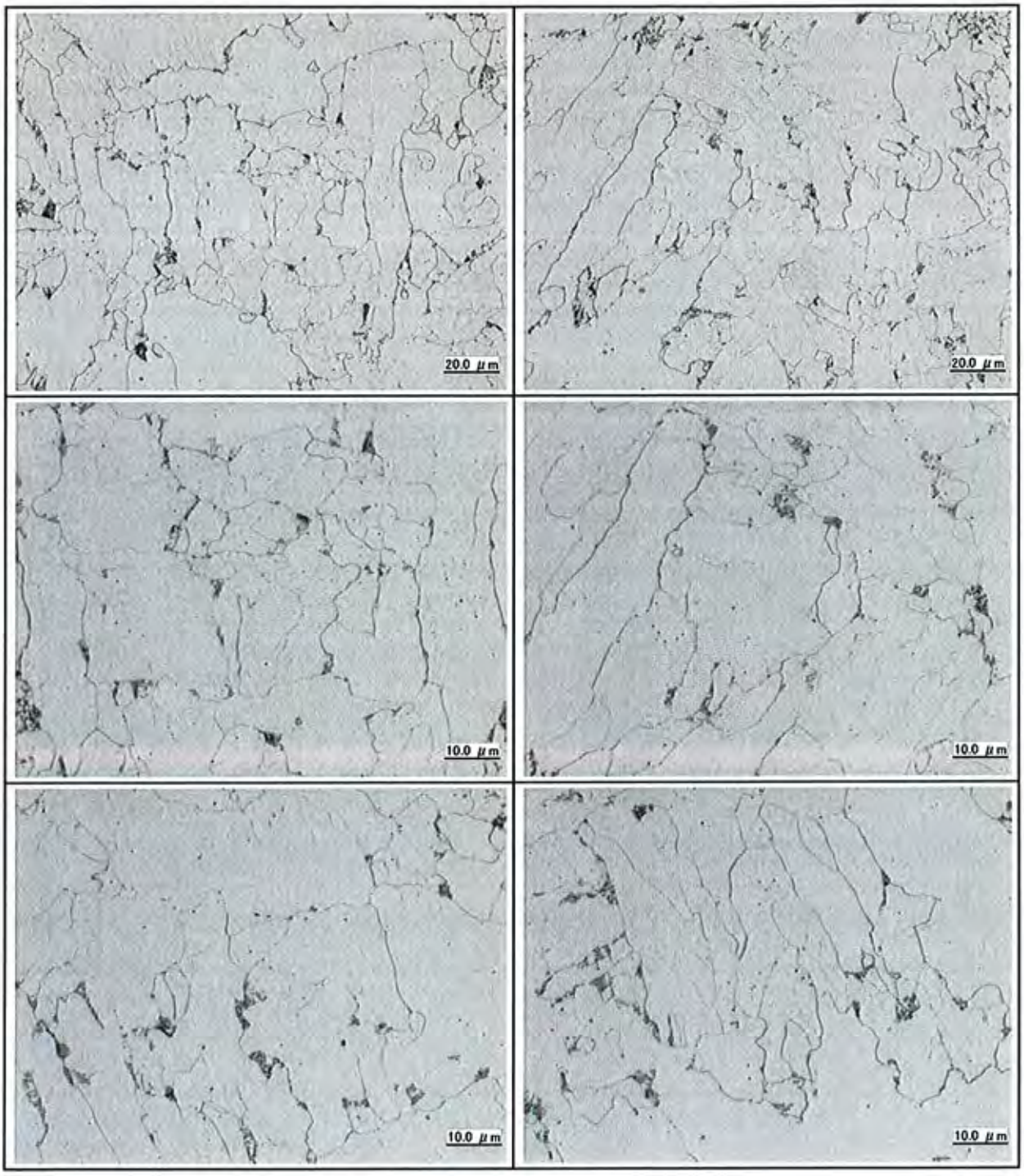


Photo I -28 Microstructure observation at cross section of sample tube
〔Platen-SH (Fine Grain HAZ)〕



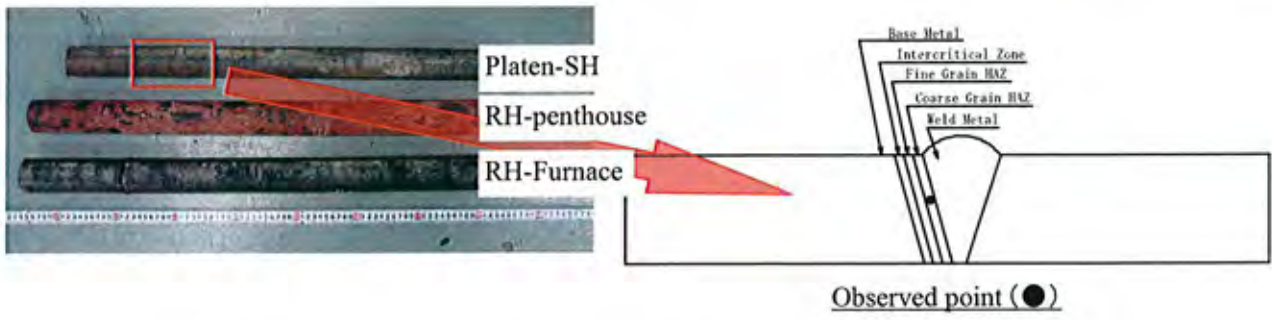
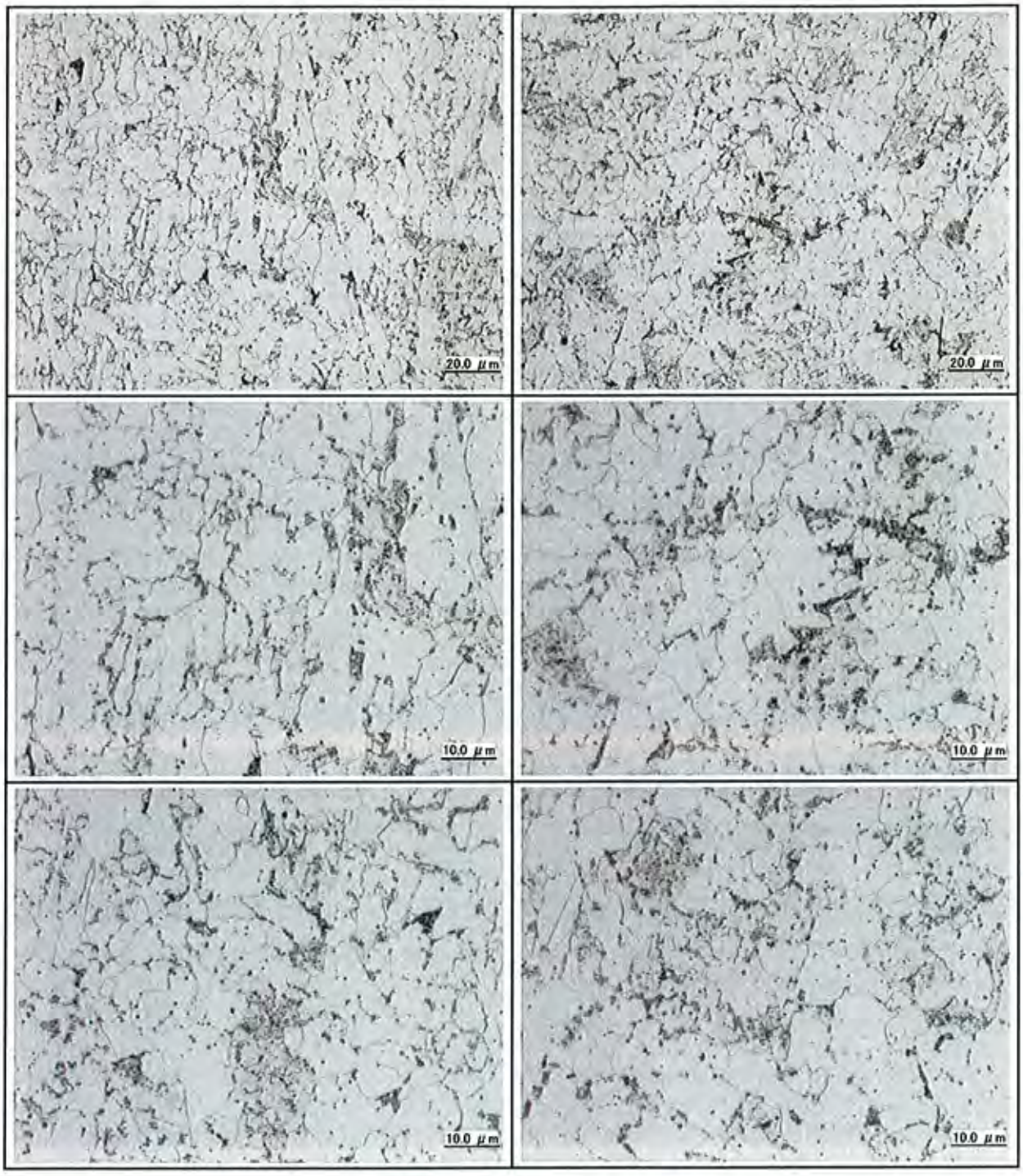


Photo I -29 Microstructure observation at cross section of sample tube
〔Platen-SH (Coarse Grain HAZ)〕



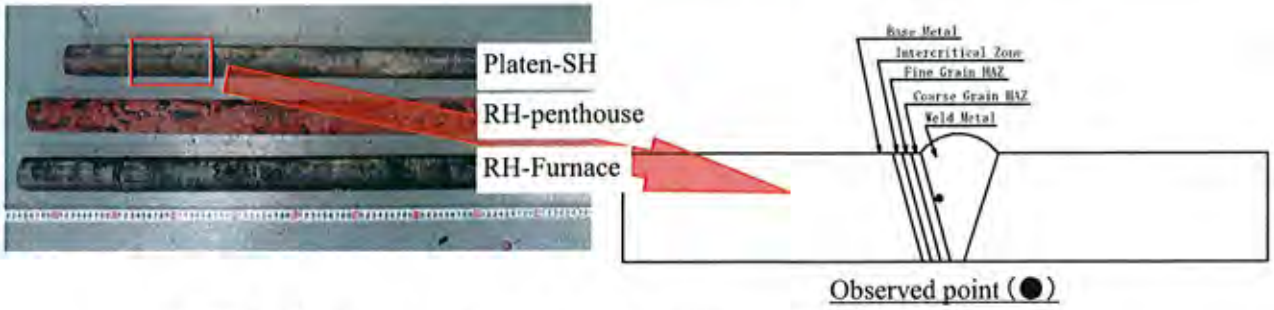
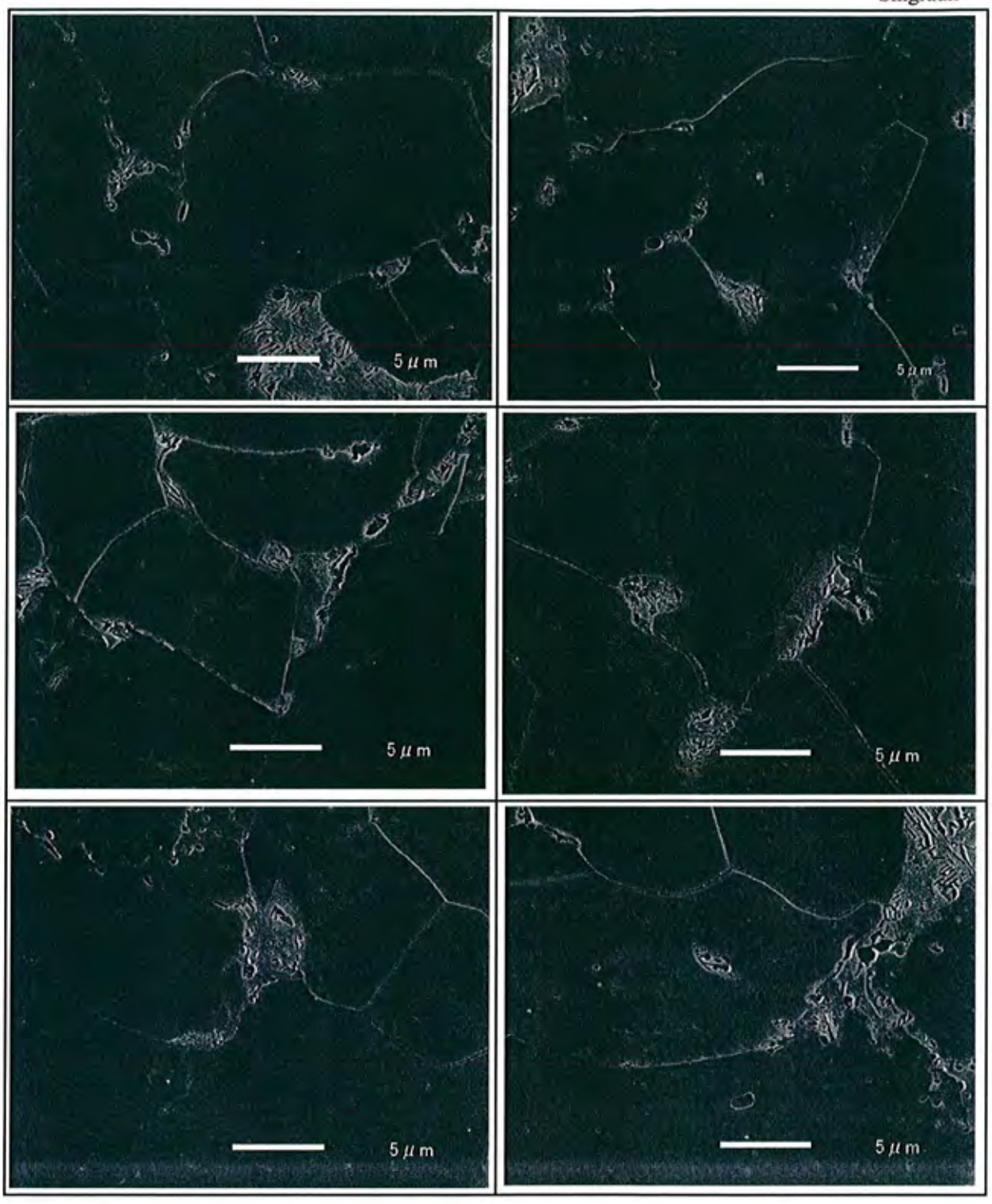


Photo Ⅰ-30 Microstructure observation at cross section of sample tube
〔Platen-SH（Weld Metal）〕



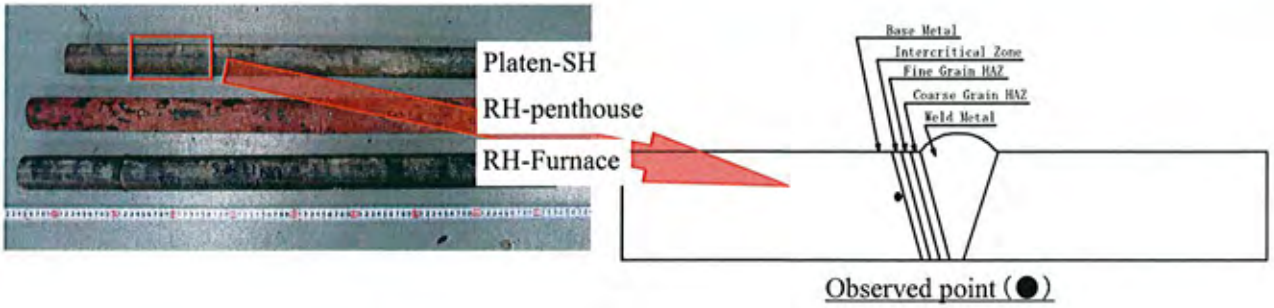
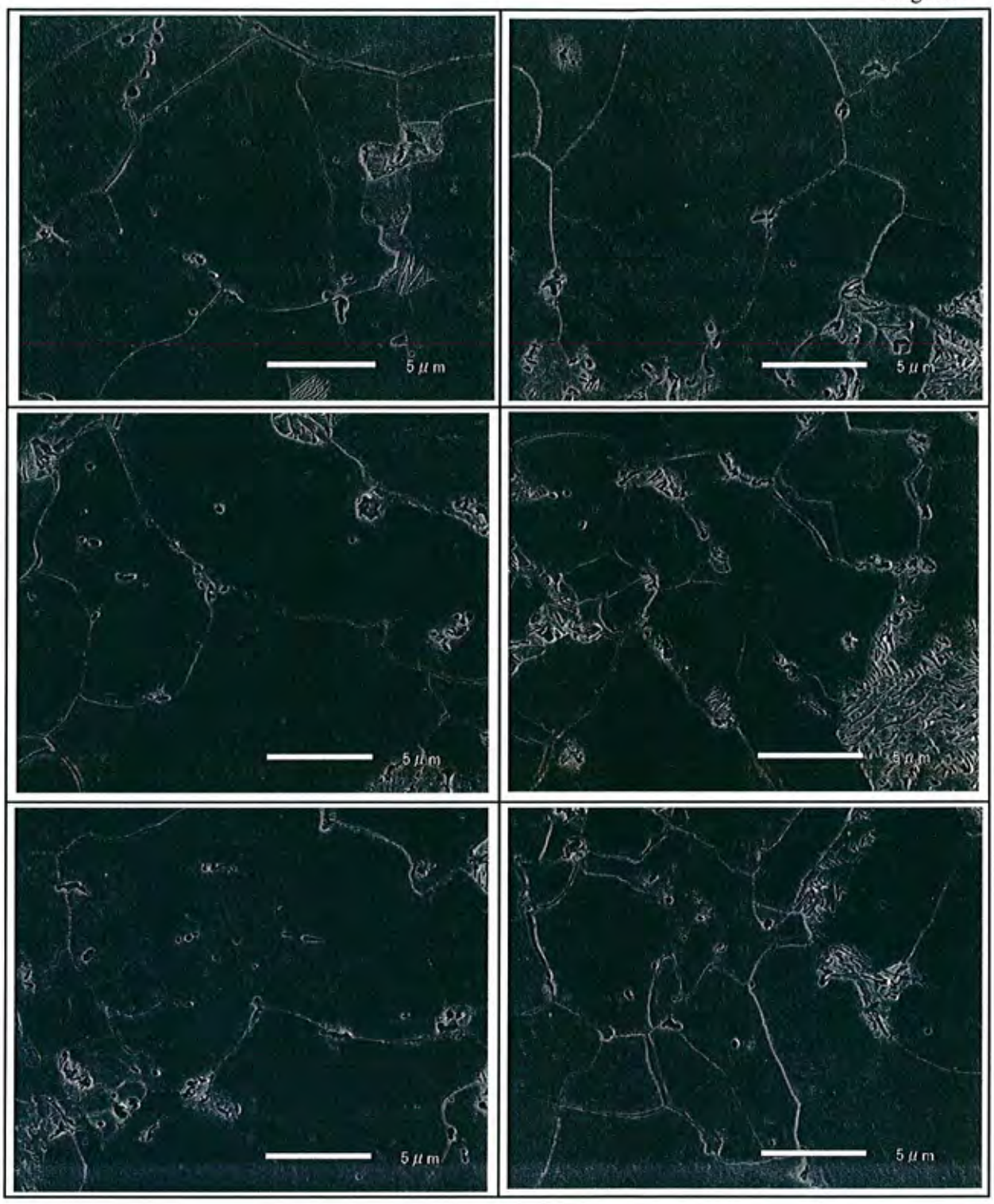


Photo I -31 Precipitates along grain boundary by SEM observation
〔Platen-SH (Base Metal)〕



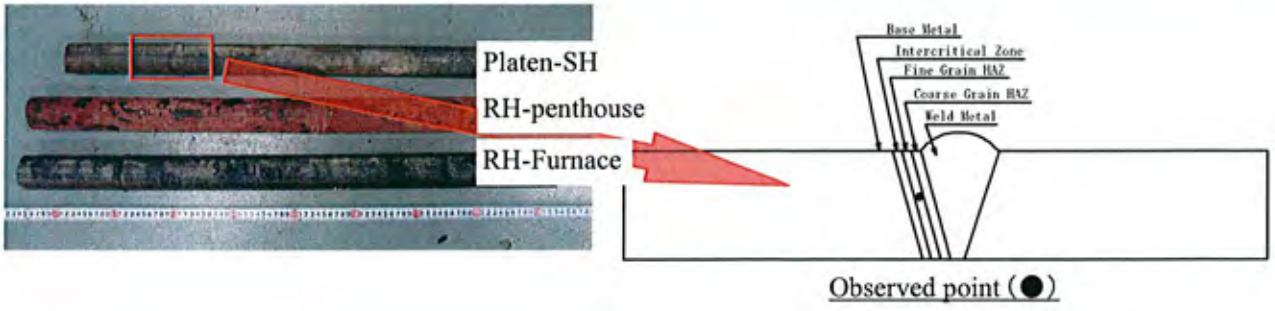


Photo I -32 Precipitates along grain boundary by SEM observation
〔Platen-SH (Fine Grain HAZ)〕

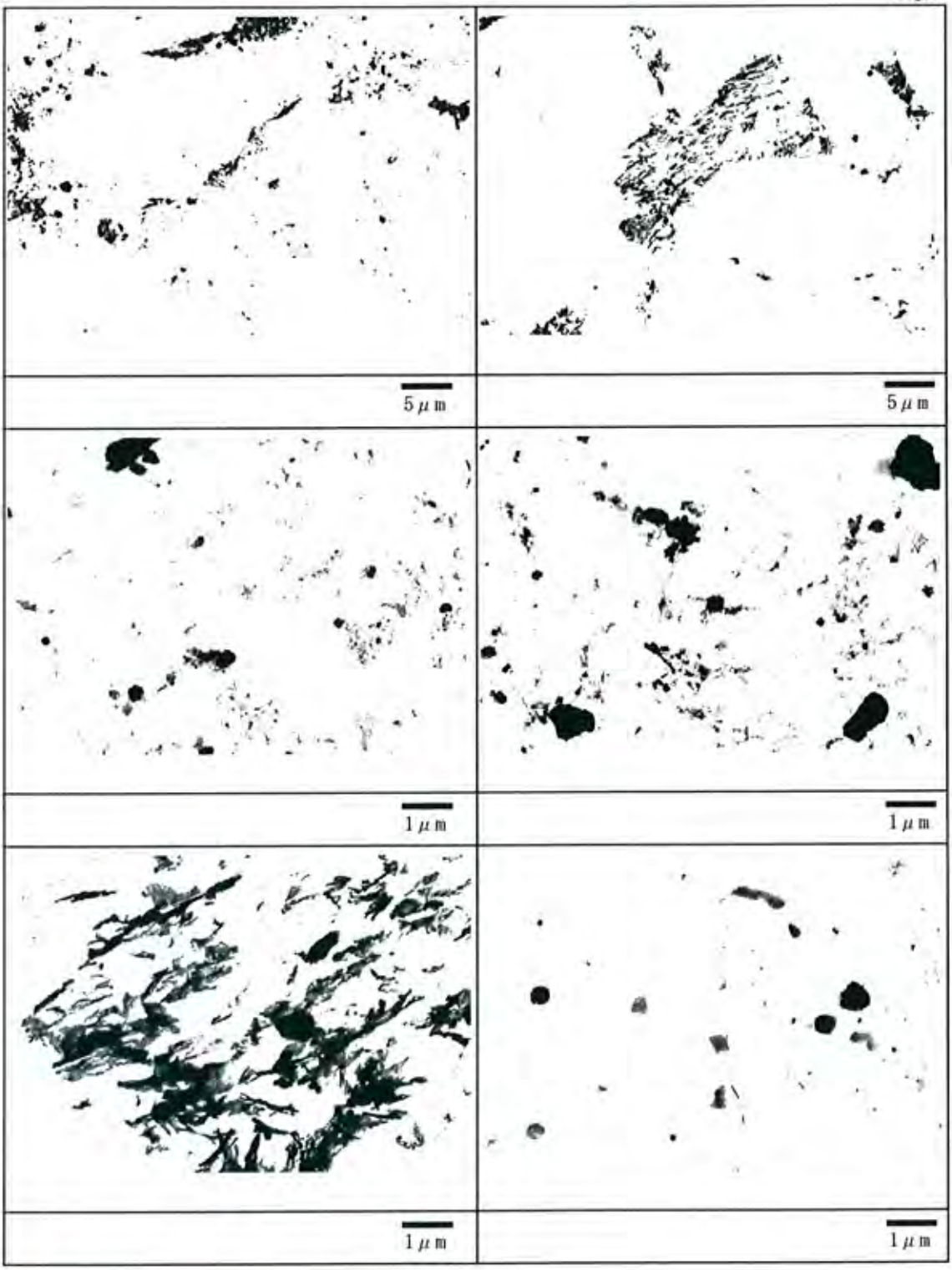
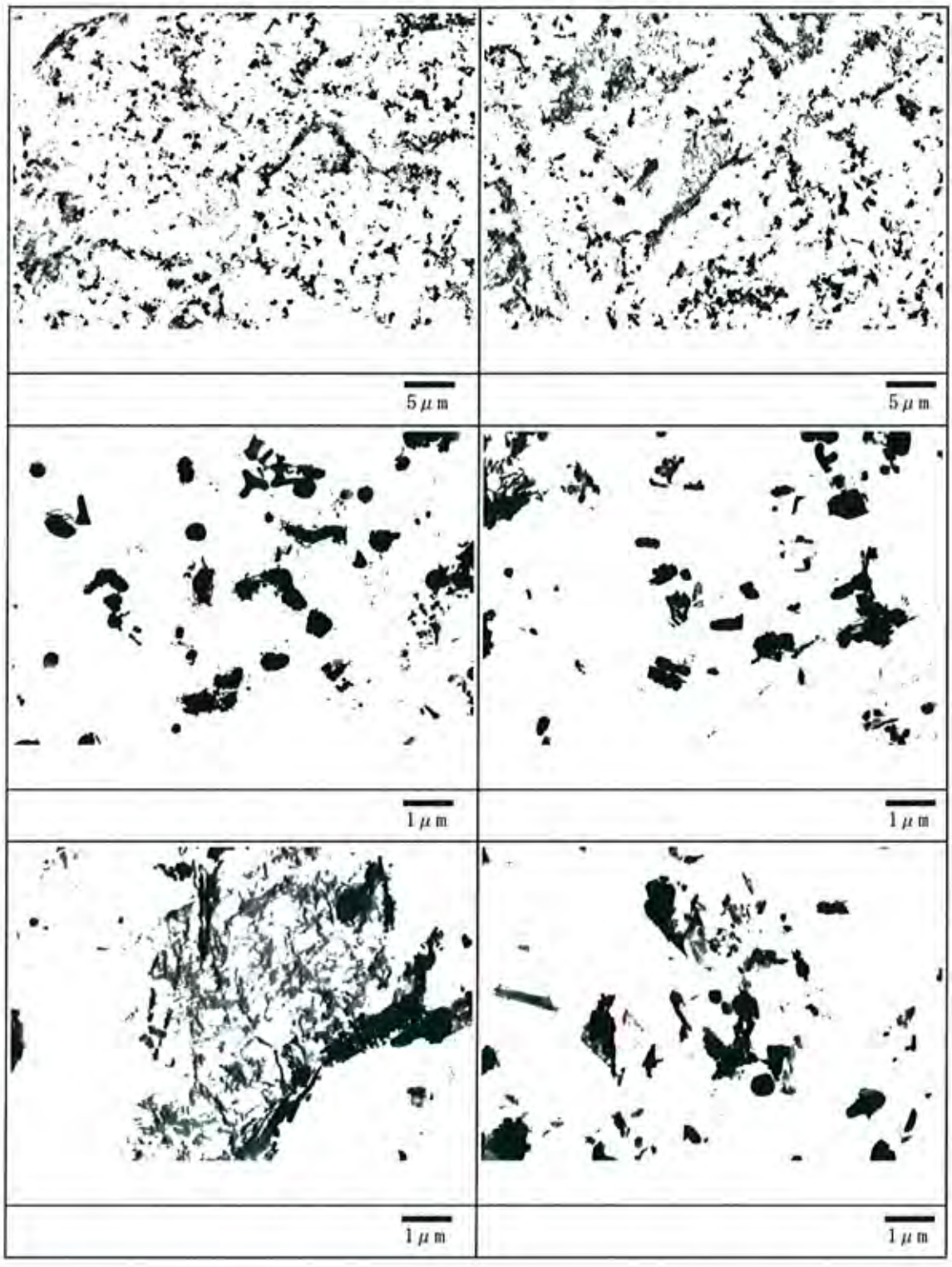


Photo I -33 Precipitates distribution by TEM observation [Platen-SH (Base Metal)]



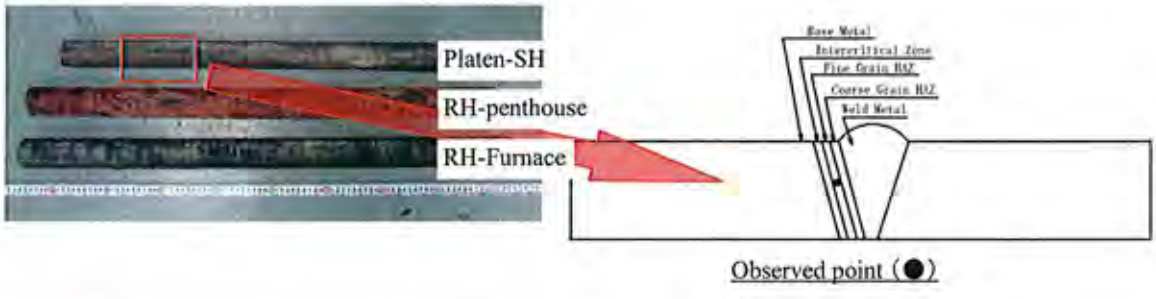


Photo I -34 Precipitates distribution by TEM observation〔Platen-SH (Fine Grain HAZ)〕

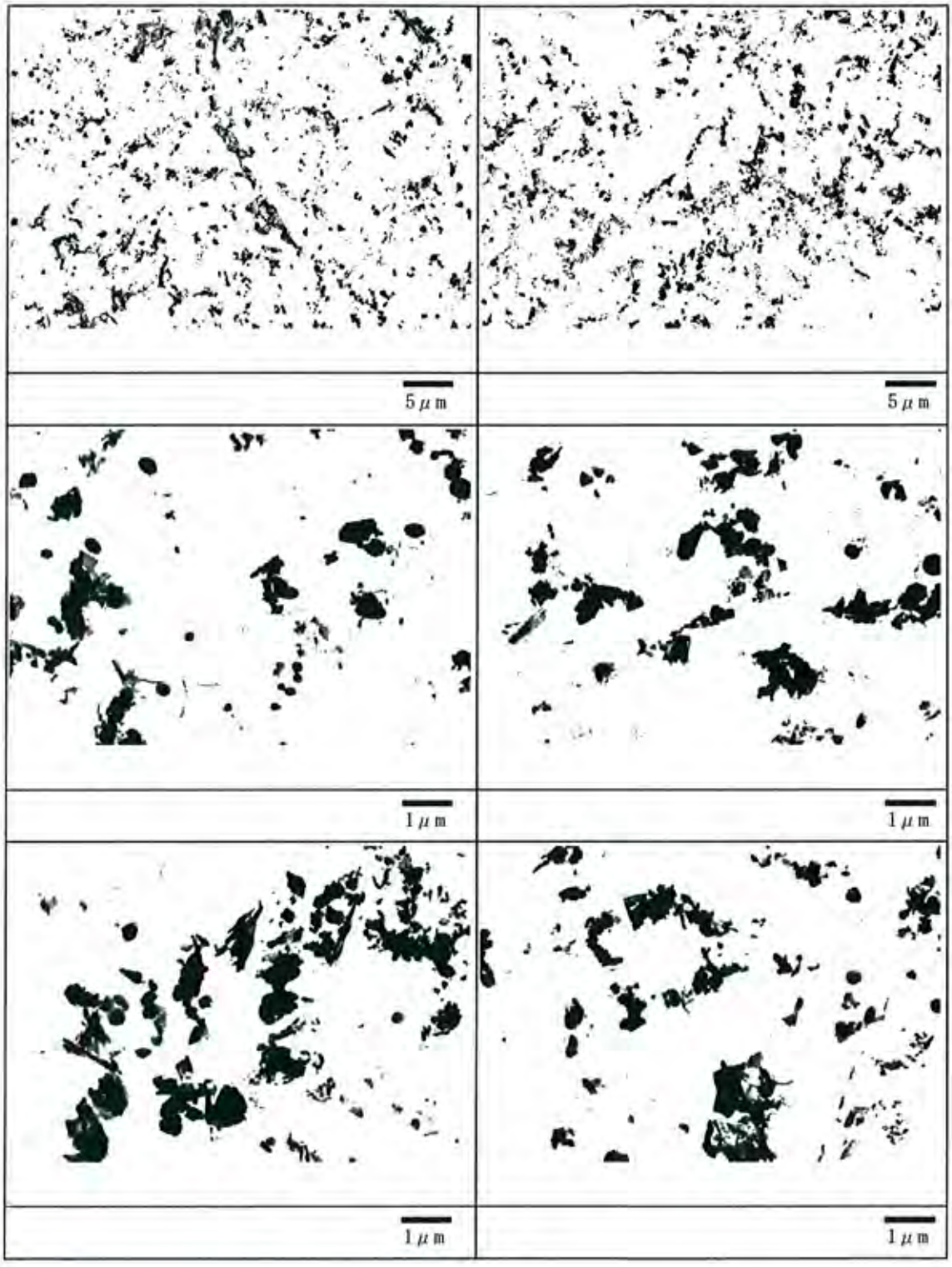


Photo I -35 Precipitates distribution by TEM observation〔Platen-SH (Coarse Grain HAZ)〕

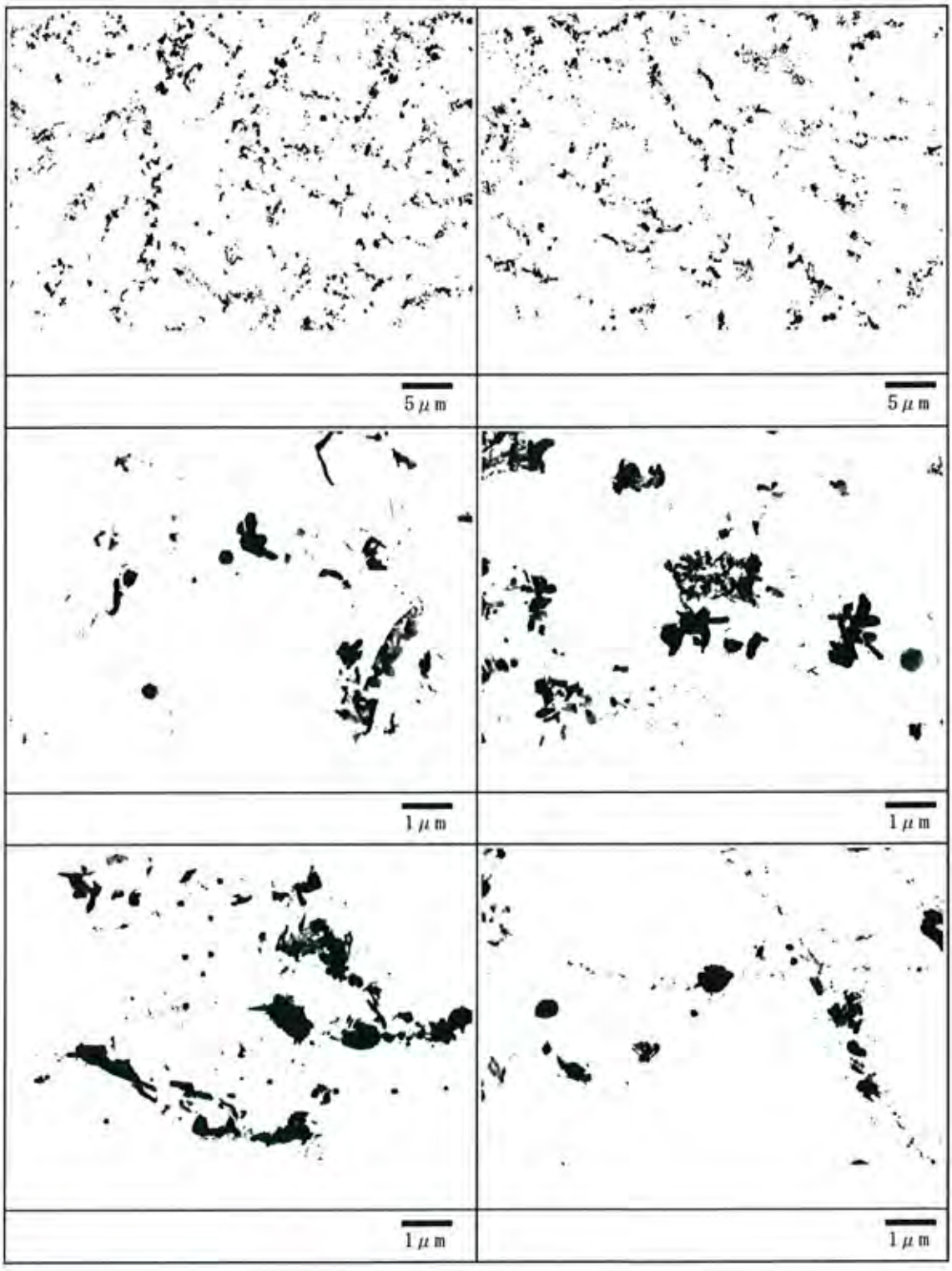


Photo I -36 Precipitates distribution by TEM observation〔Platen-SH (Weld Metal)〕

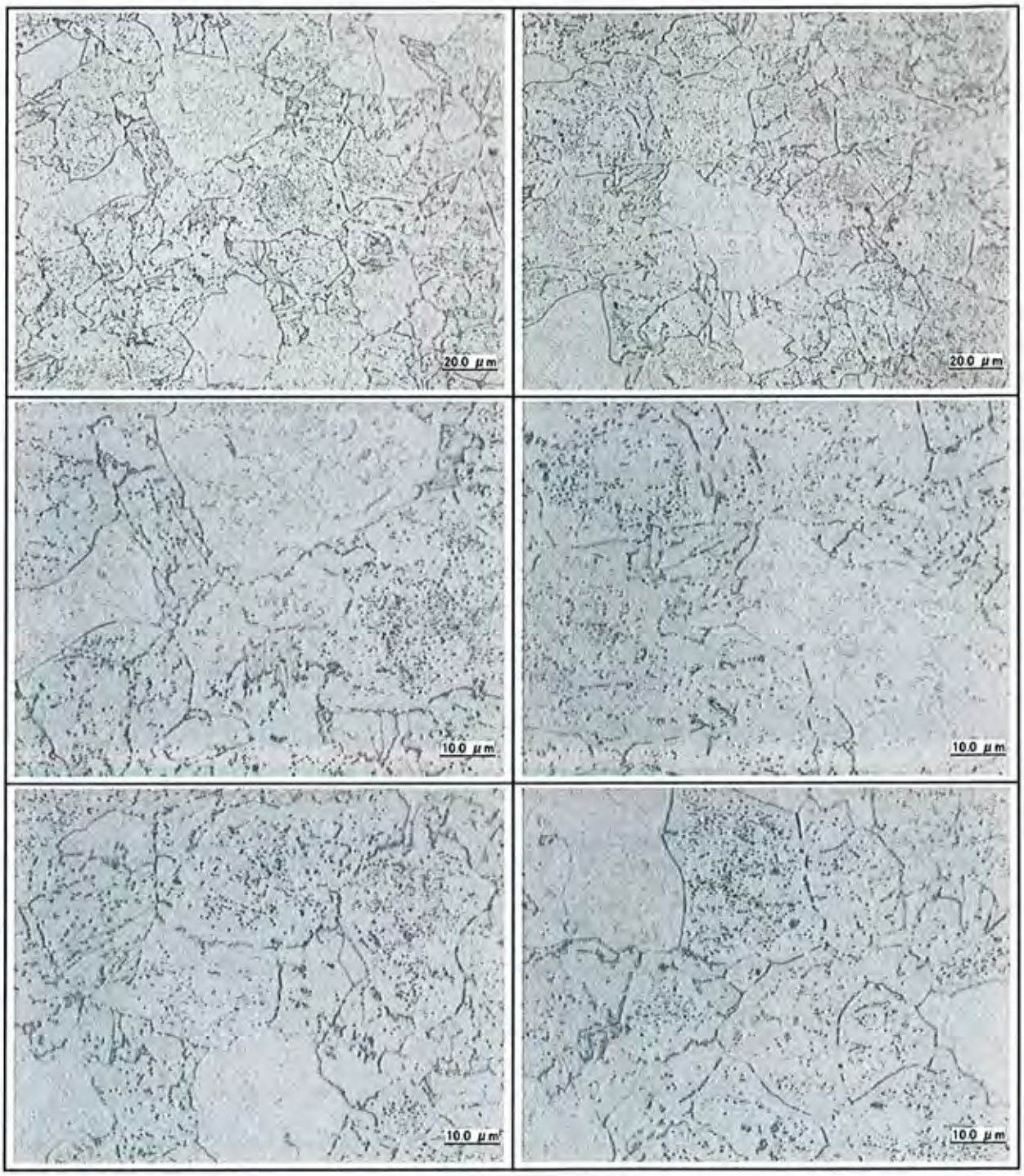
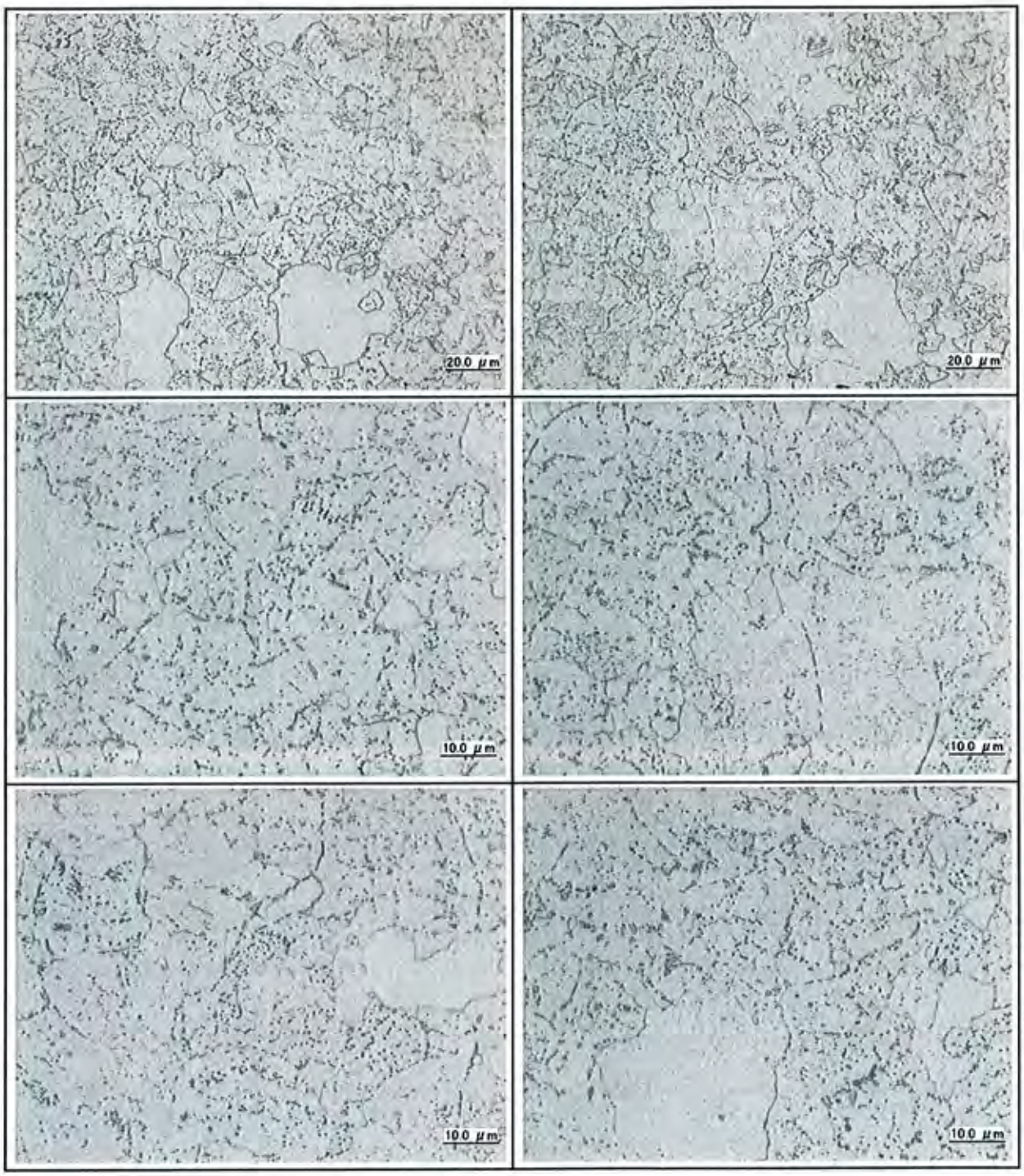


Photo I -37 Microstructure observation at cross section of sample tube
〔RH-Penthouse (Base Metal)〕



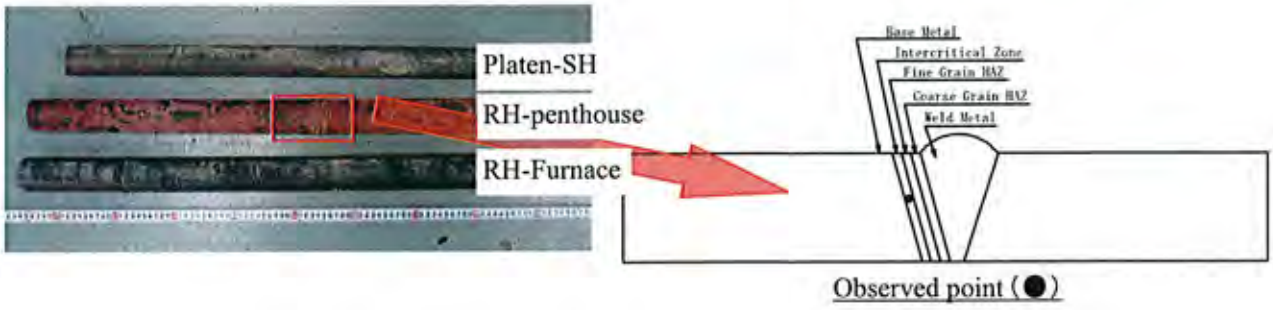
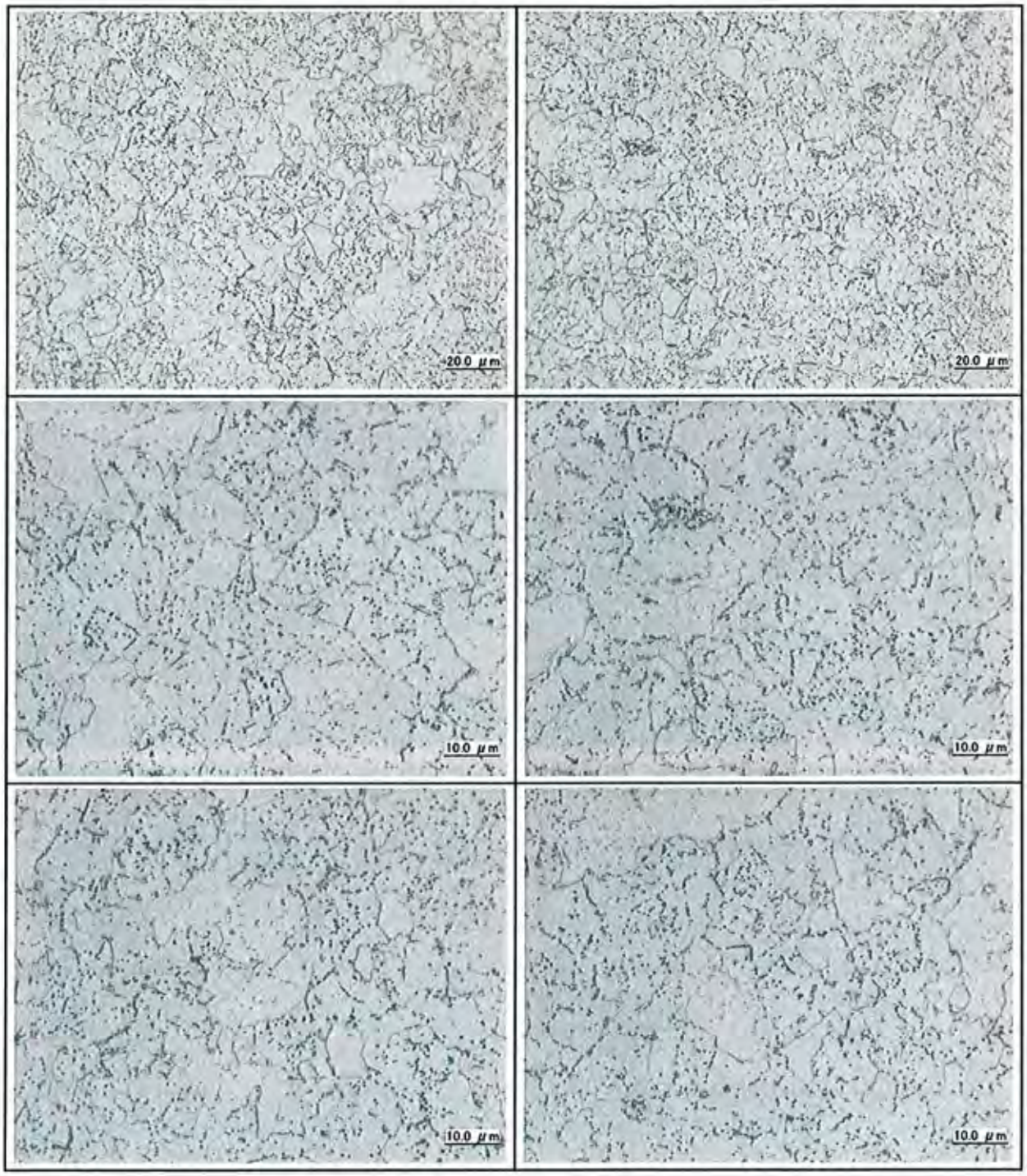


Photo I -38 Microstructure observation at cross section of sample tube
〔RH-Penthouse (Intercritical Zone)〕



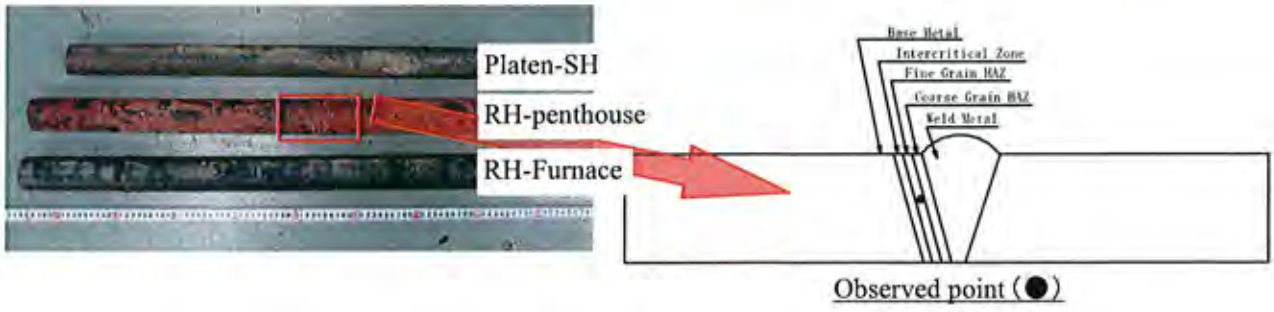


Photo I -39 Microstructure observation at cross section of sample tube
〔RH-Penthouse (Fine Grain HAZ)〕

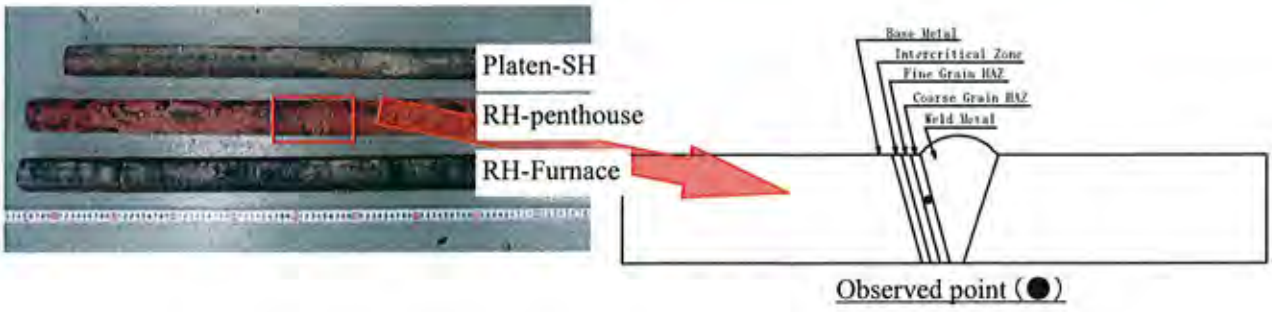


Photo I -40 Microstructure observation at cross section of sample tube
[RH-Penthouse (Coarse Grain HAZ)]

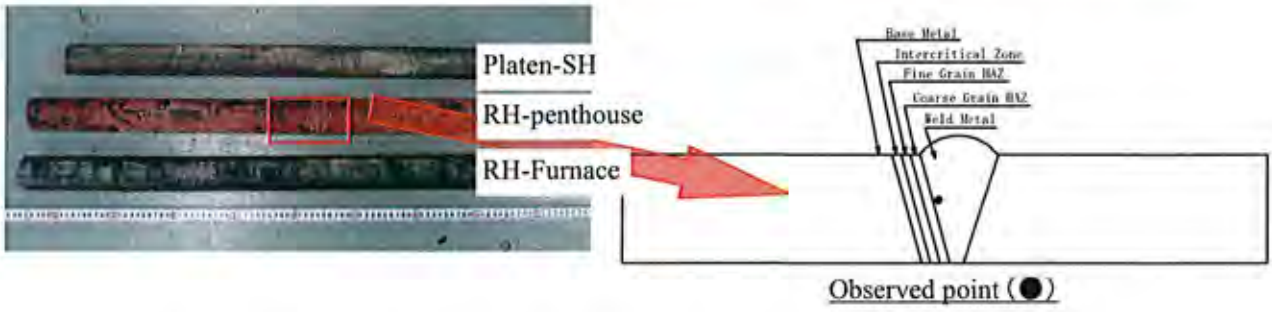
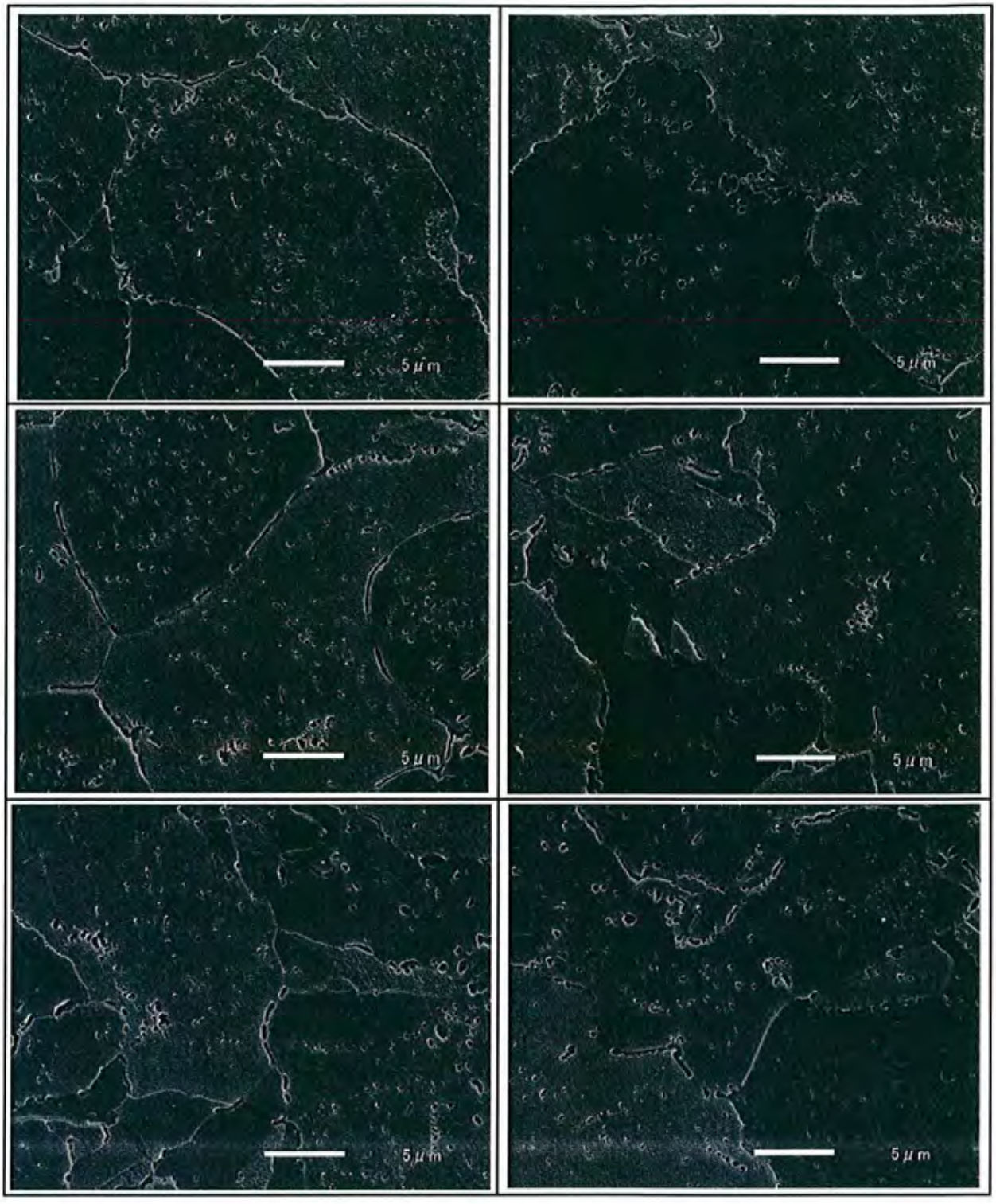


Photo I -41 Microstructure observation at cross section of sample tube
〔RH-Penthouse (Weld Metal)〕



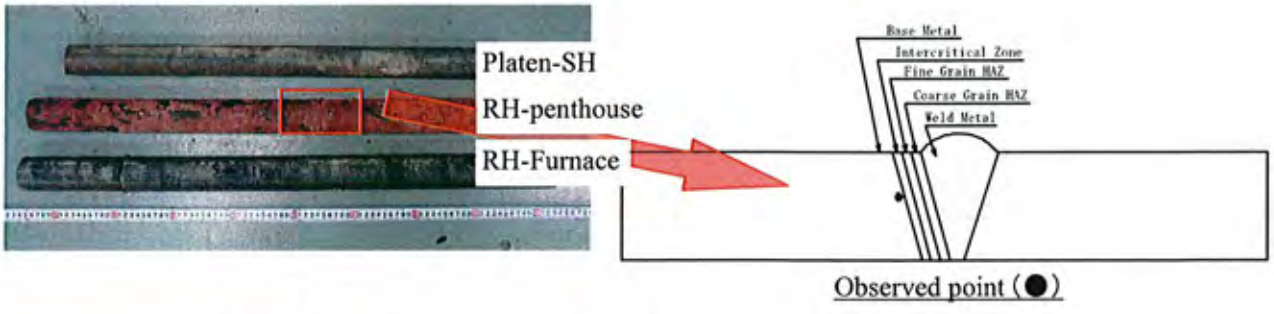
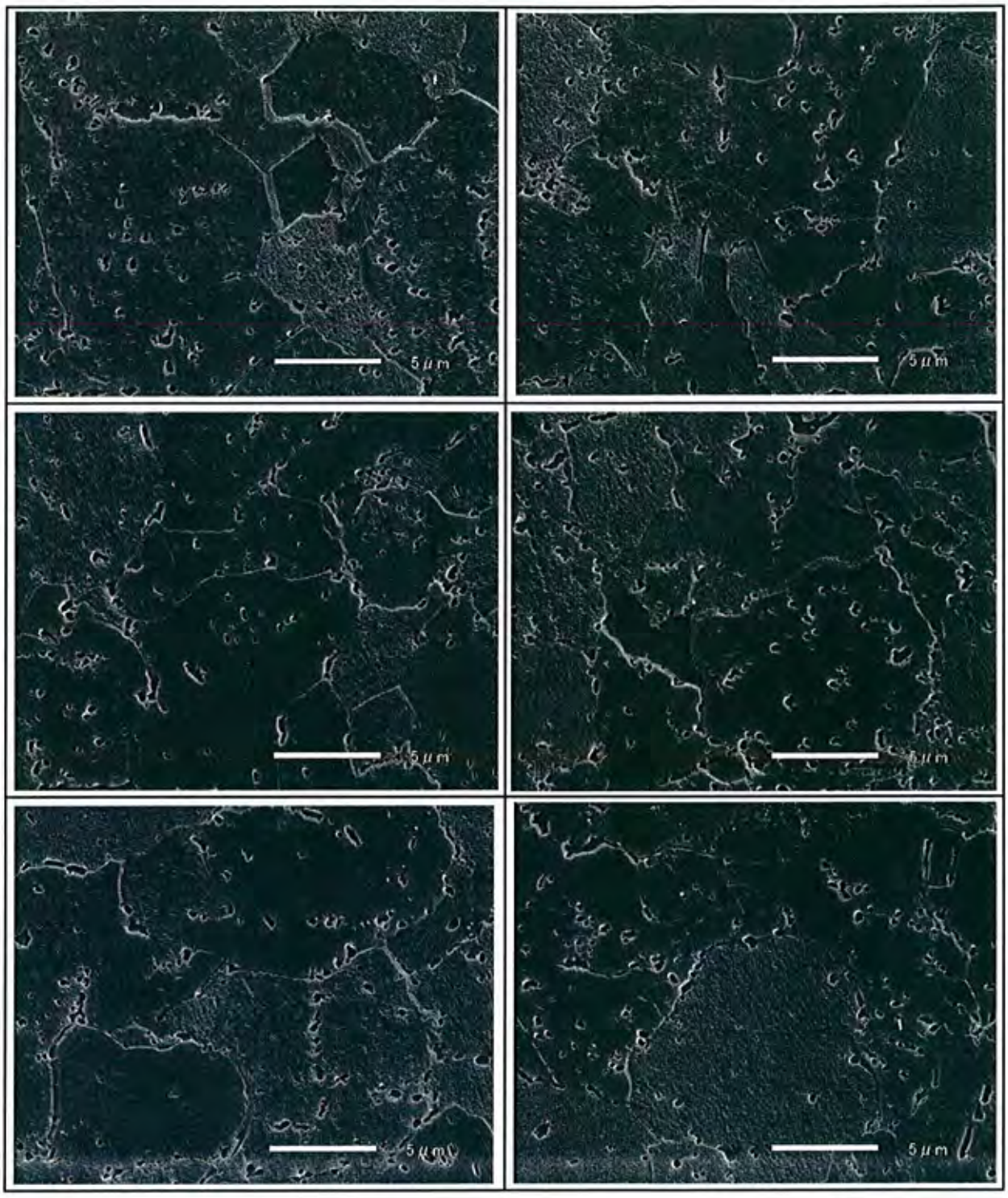


Photo Ⅰ-42 Precipitates along grain boundary by SEM observatior
〔RH-Penthouse (Base Metal)〕



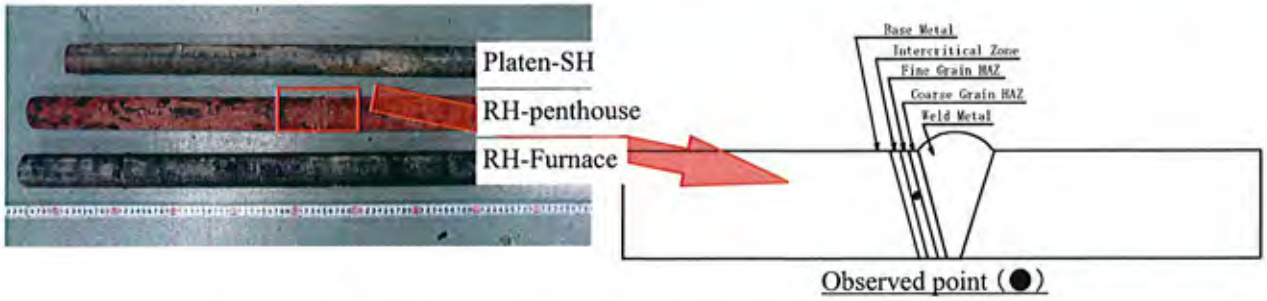
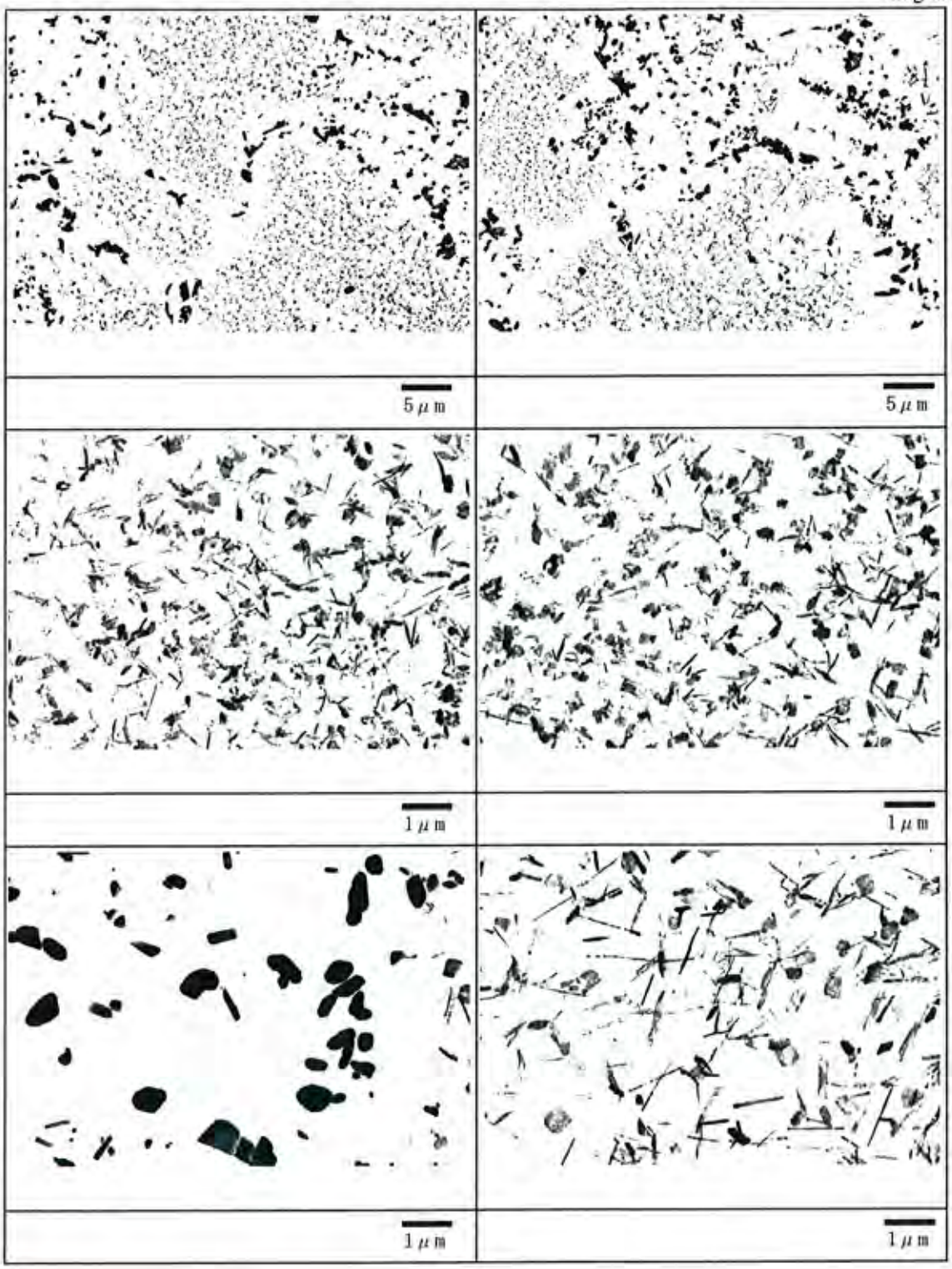


Photo Ⅰ-43 Precipitates along grain boundary by SEM observatior
〔RH-Penthouse（Fine Grain HAZ）〕



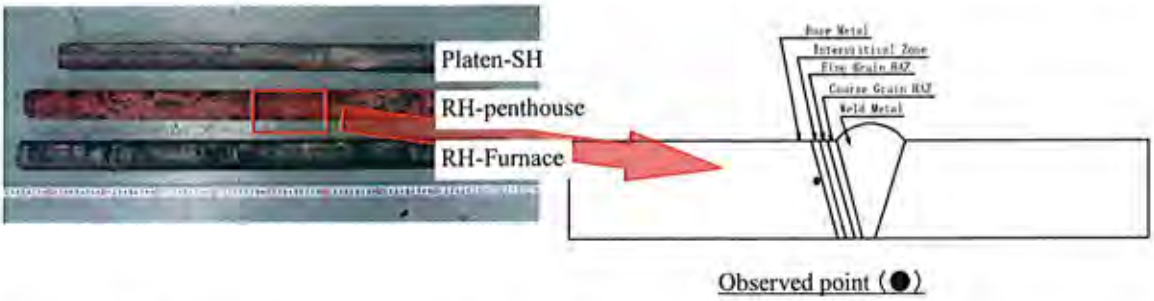
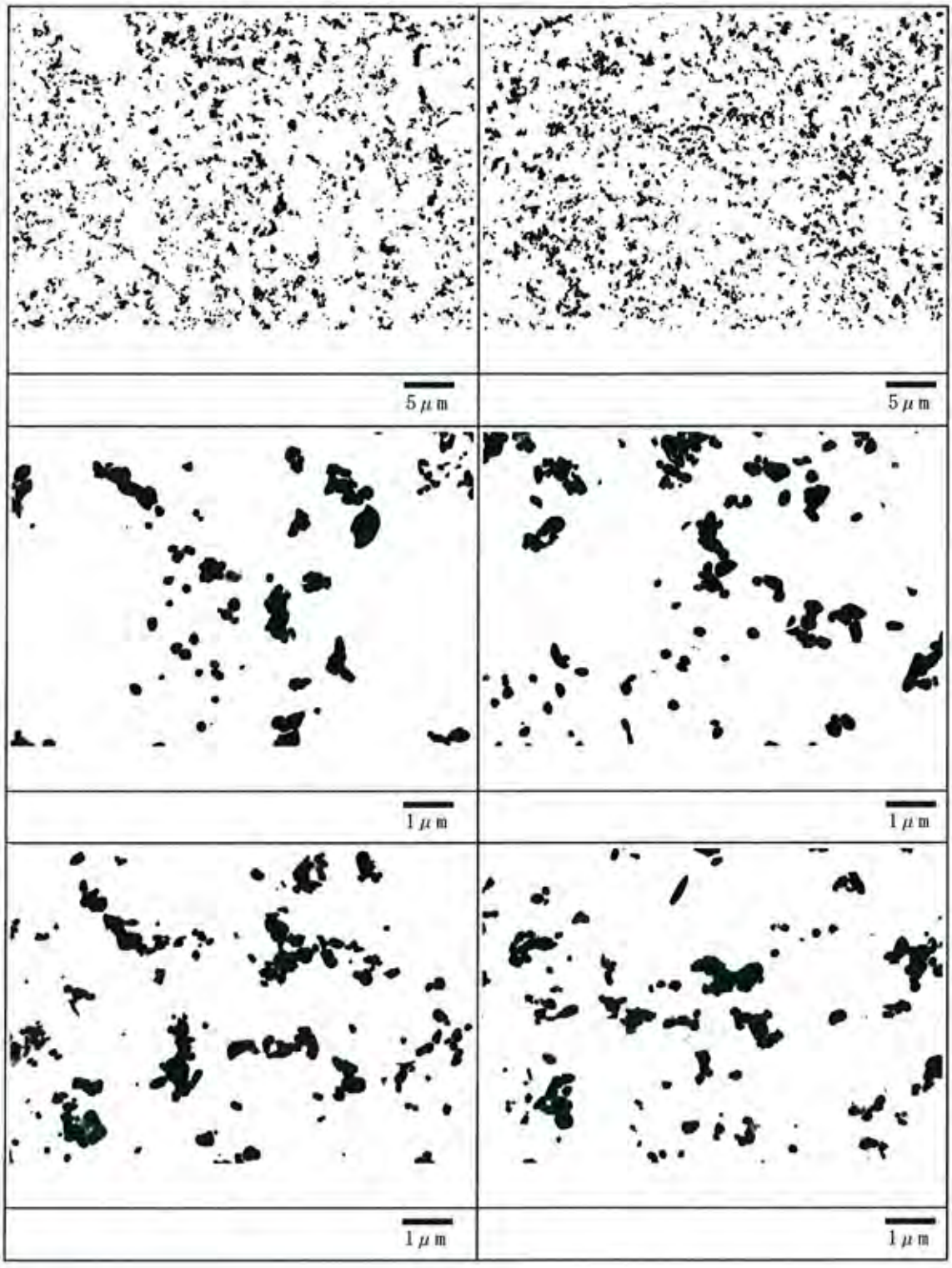
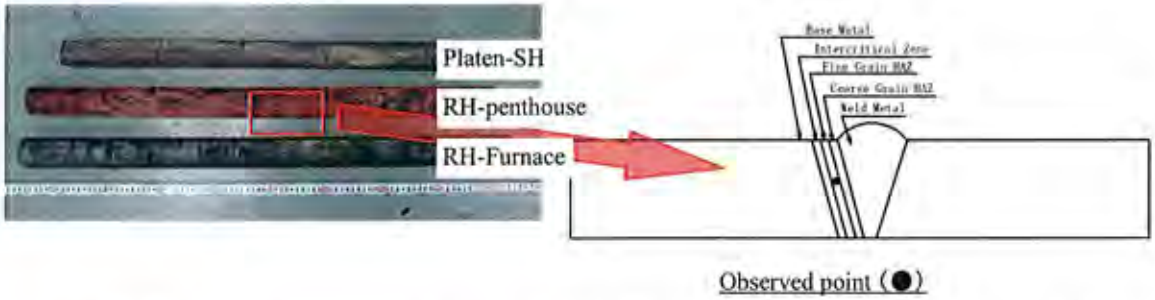


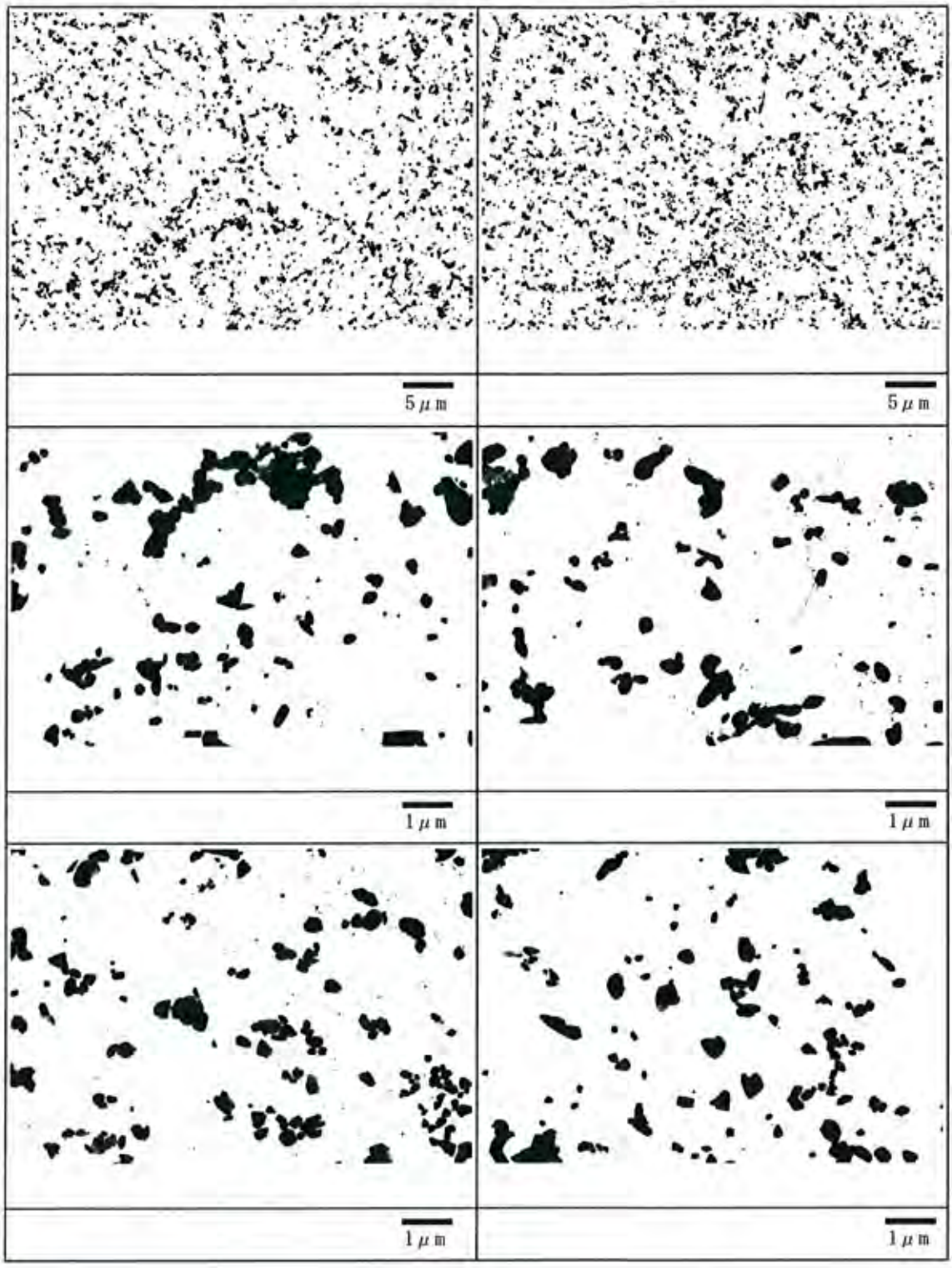
Photo I -44 Precipitates distribution by TEM observation〔RH-Penthouse (Base Metal)〕





Observed point (●)

Photo I -45 Precipitates distribution by TEM observation〔RH-Penthouse (Fine Grain HAZ)〕



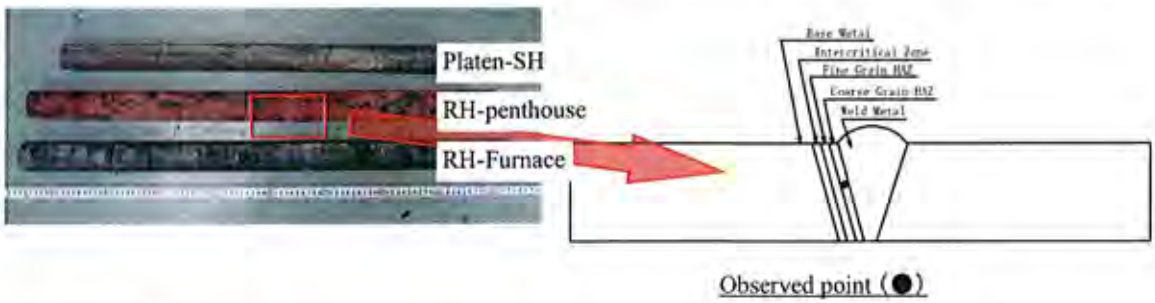
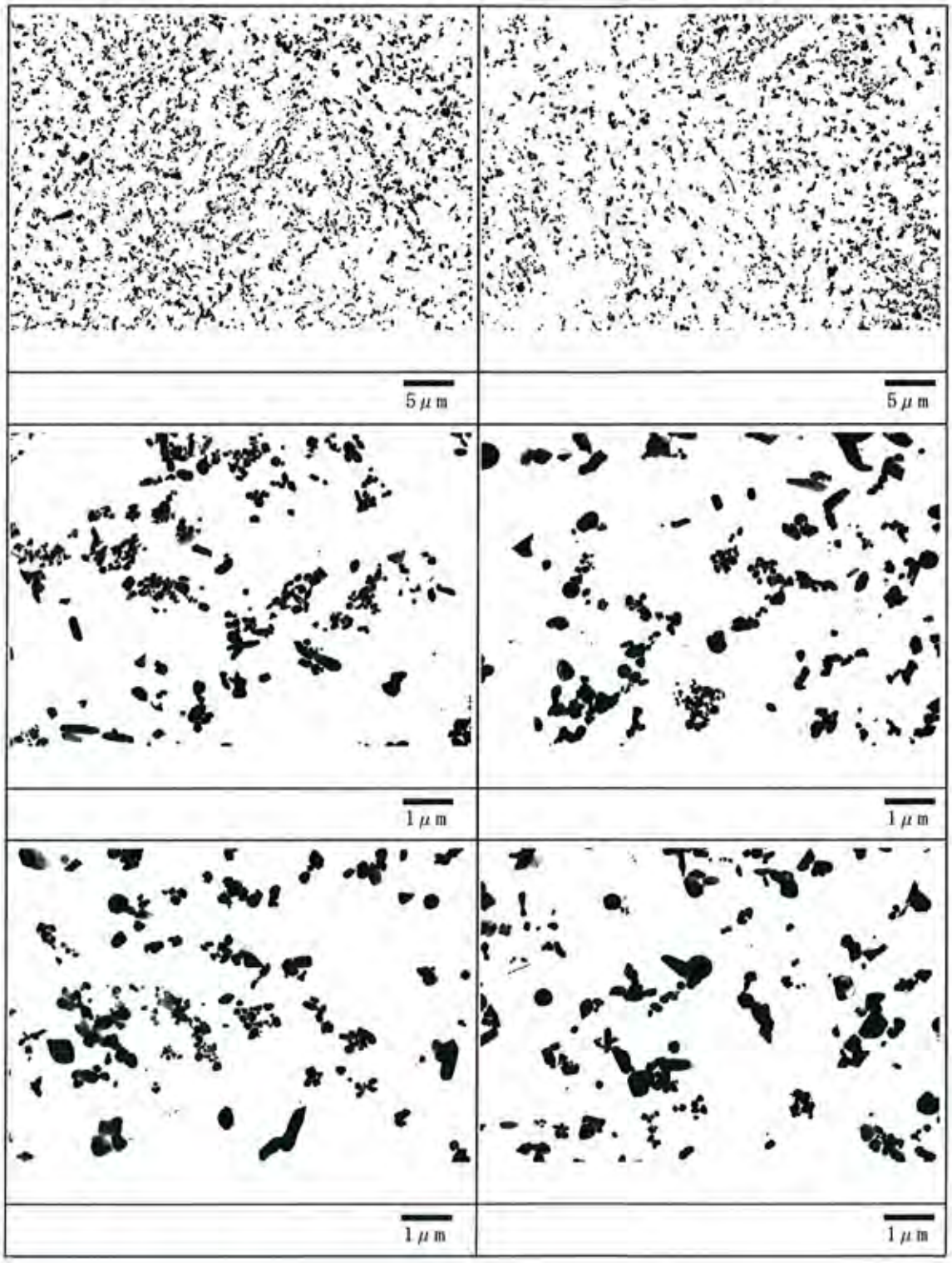


Photo I -46 Precipitates distribution by TEM observation〔RH-Penthouse（Coarse Grain HAZ）〕



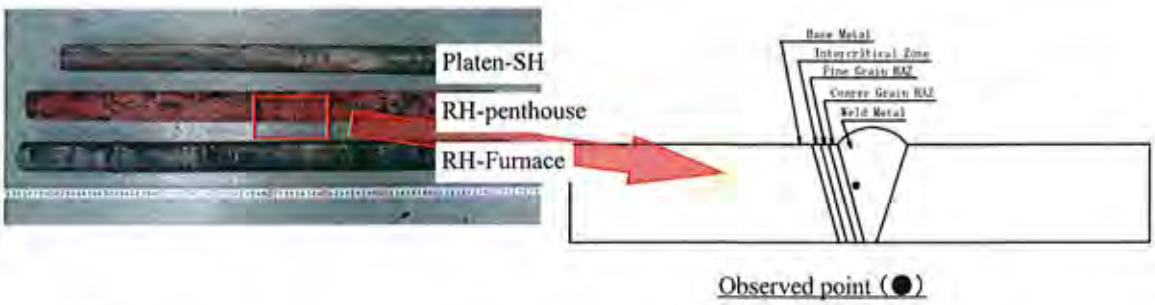
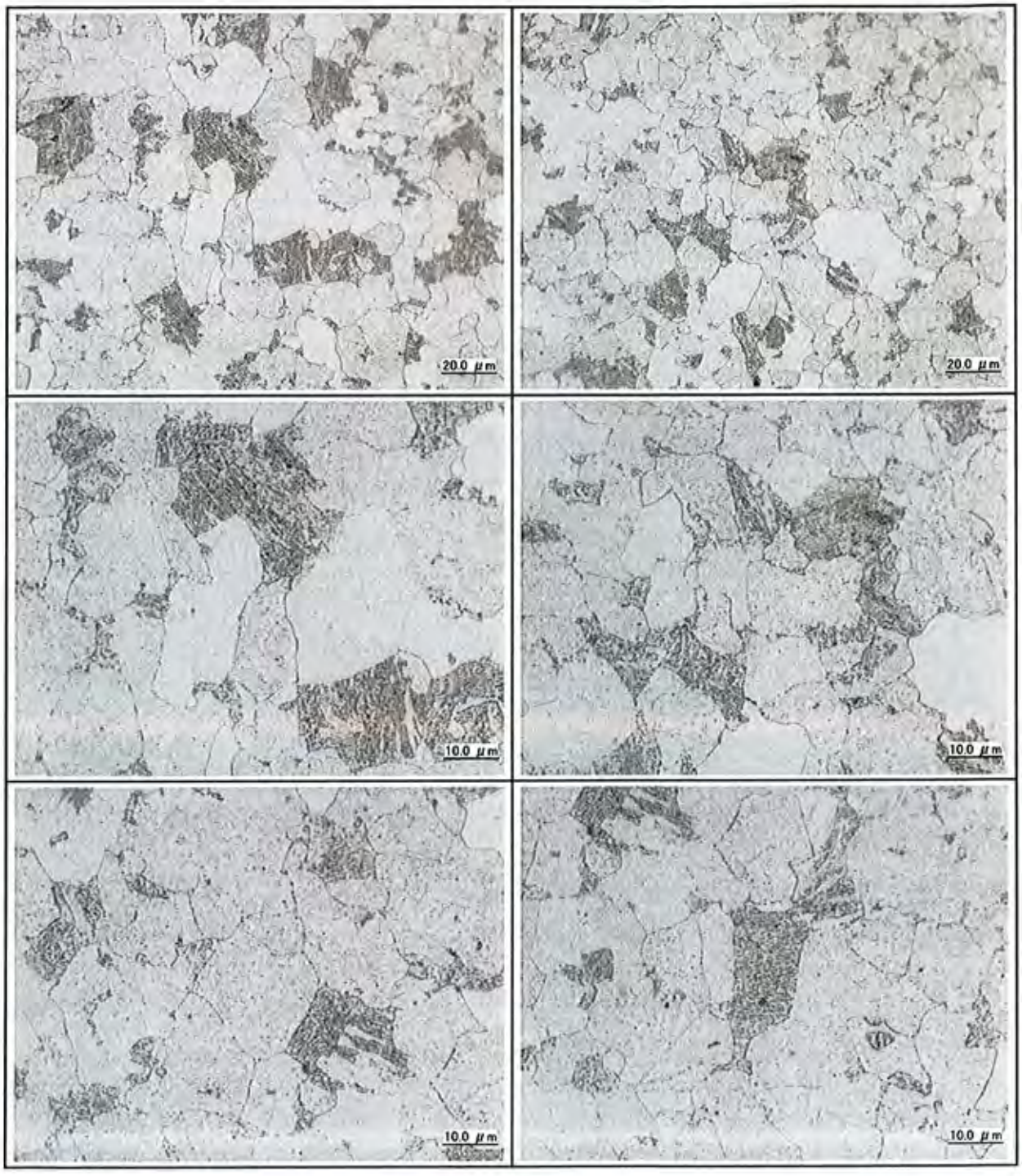


Photo I -47 Precipitates distribution by TEM observation〔RH-Penthouse (Weld Metal) 〕



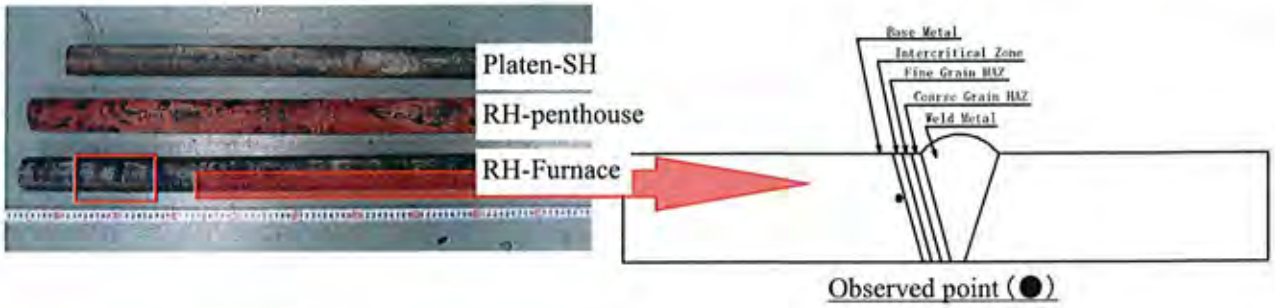
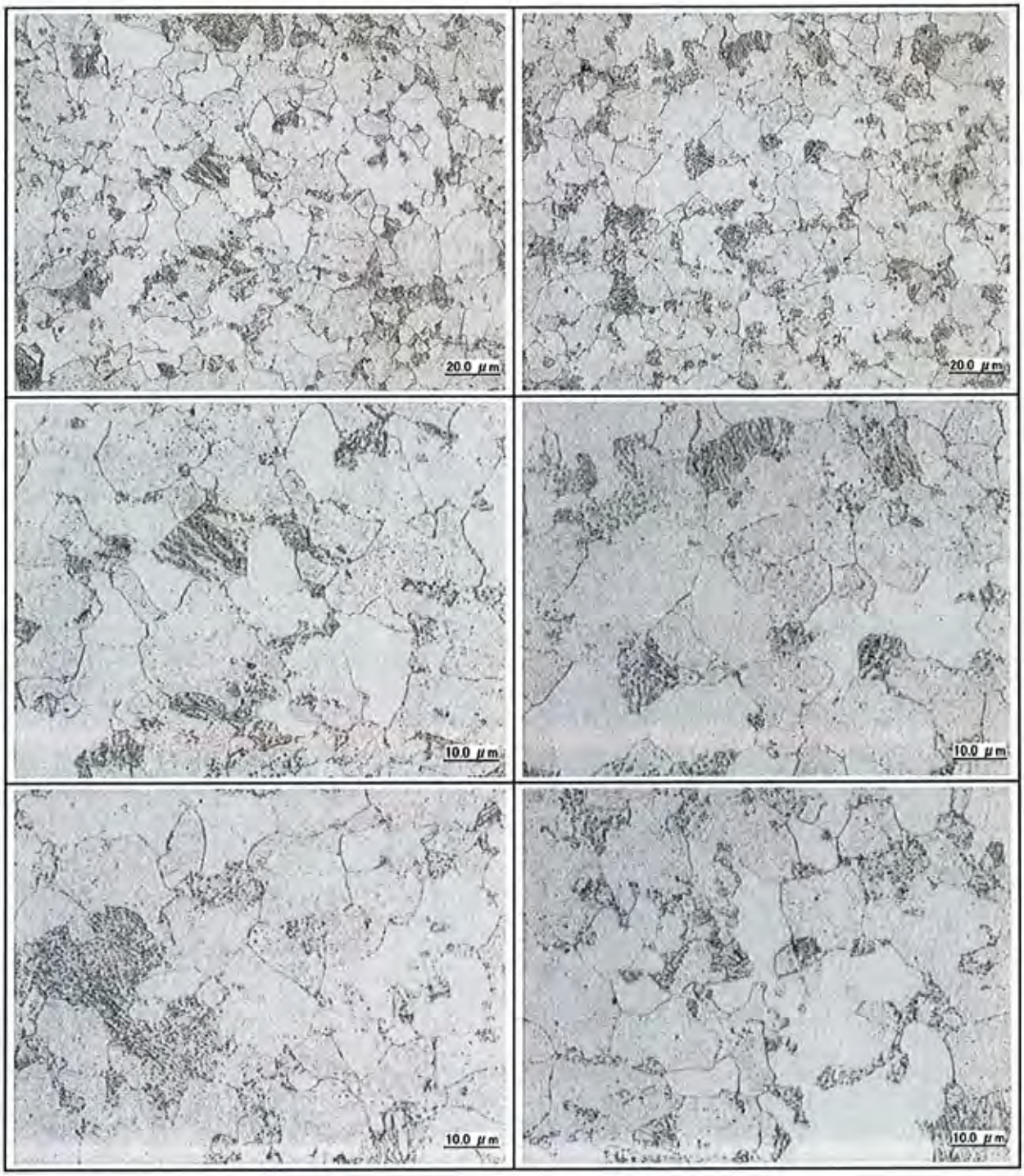


Photo I -48 Microstructure observation at cross section of sample tube
〔RH-Furnace (Base Metal)〕



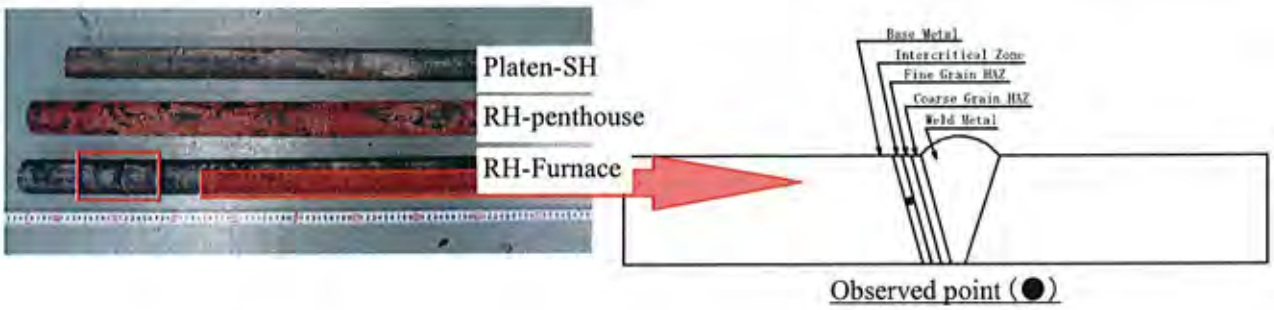
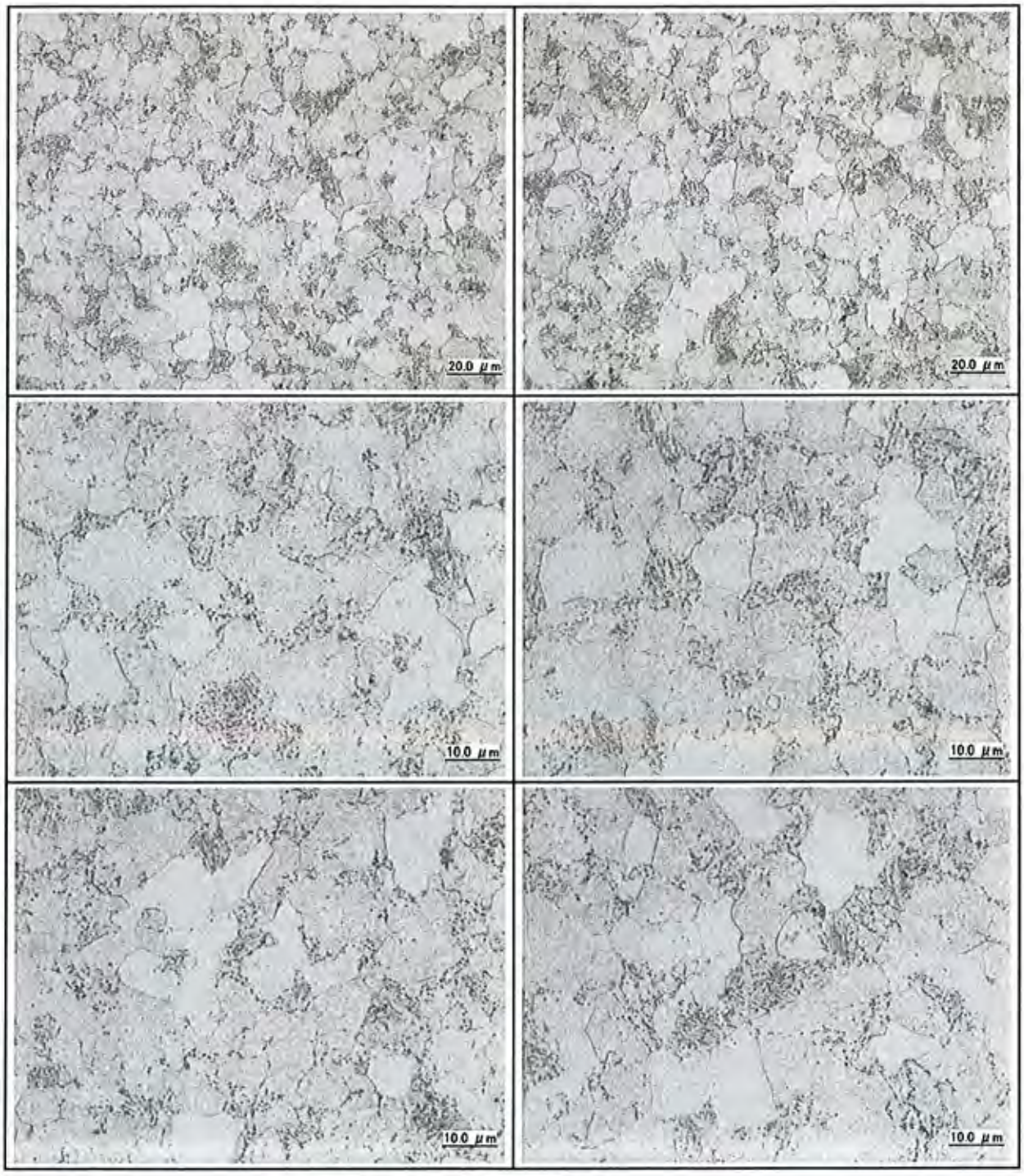


Photo I -49 Microstructure observation at cross section of sample tube
〔RH-Furnace (Intercritical Zone) 〕



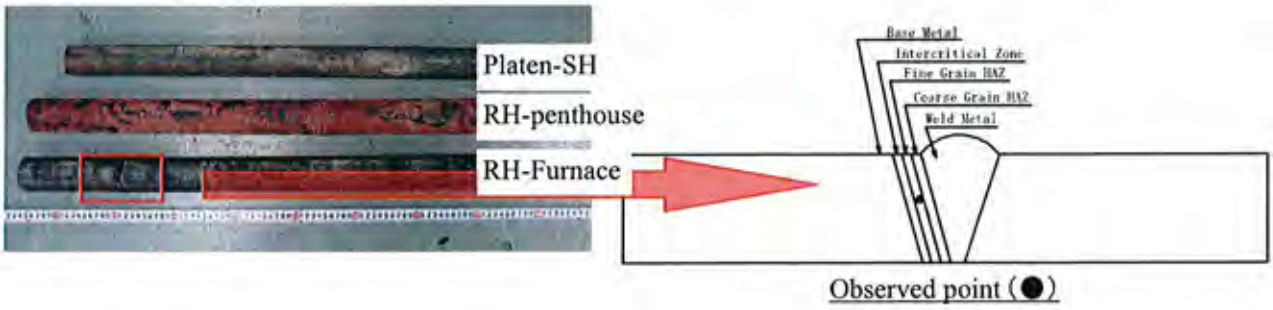
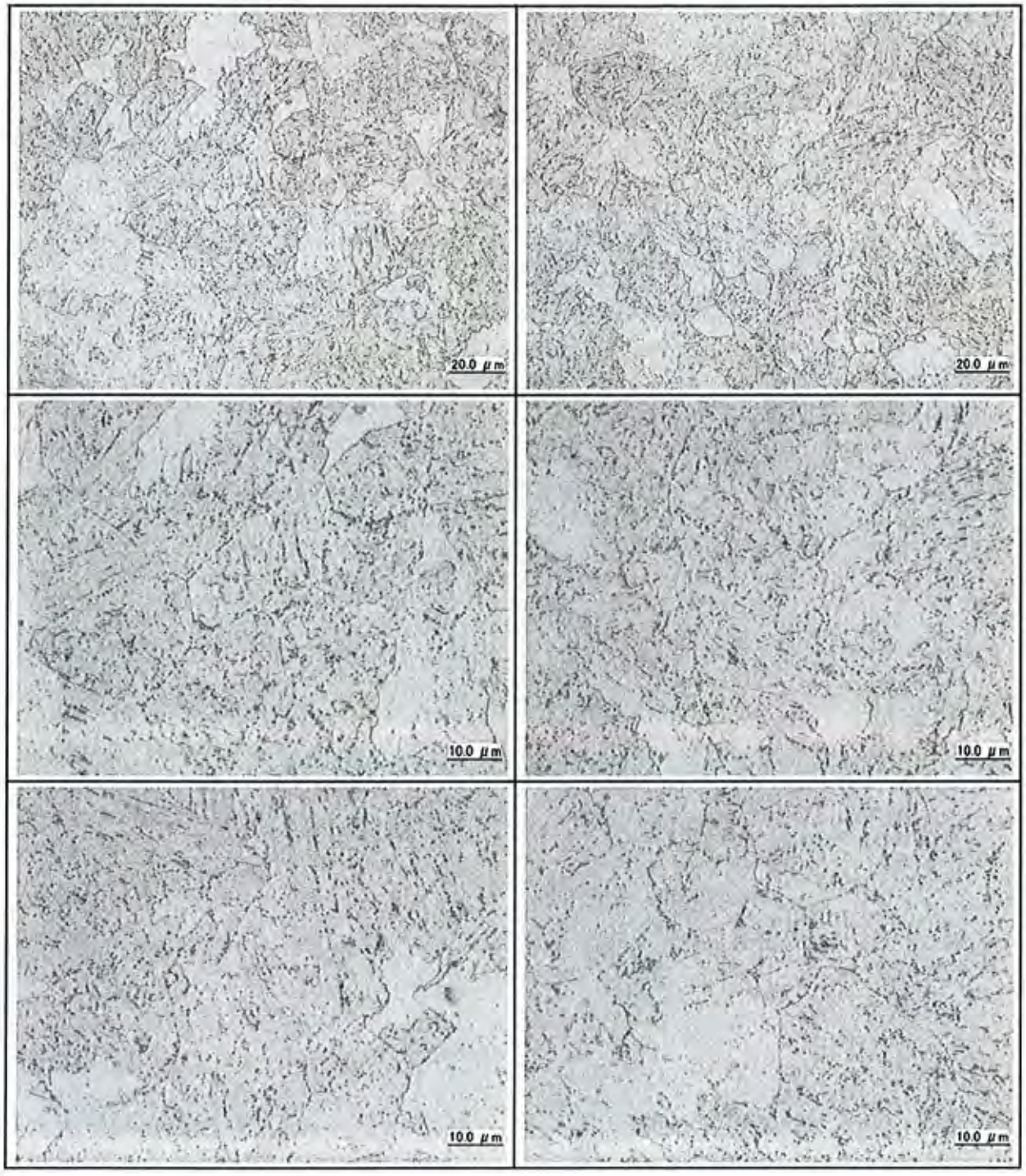


Photo I -50 Microstructure observation at cross section of sample tube
〔RH-Furnace (Fine Grain HAZ)〕



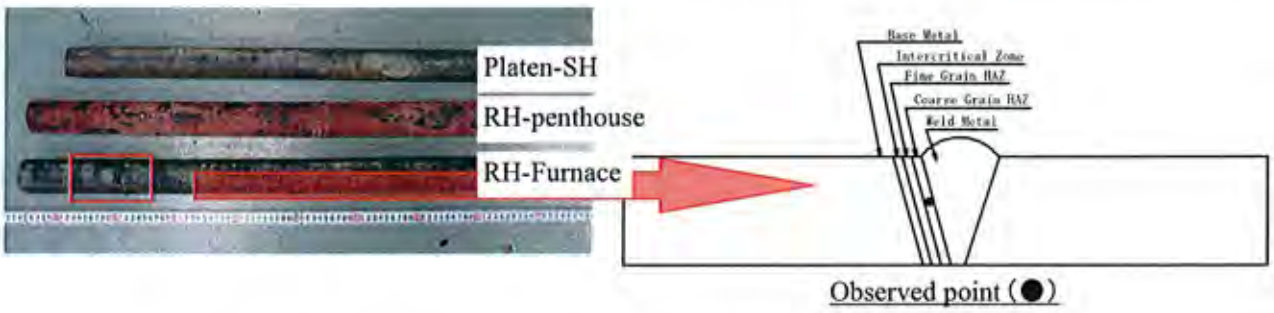
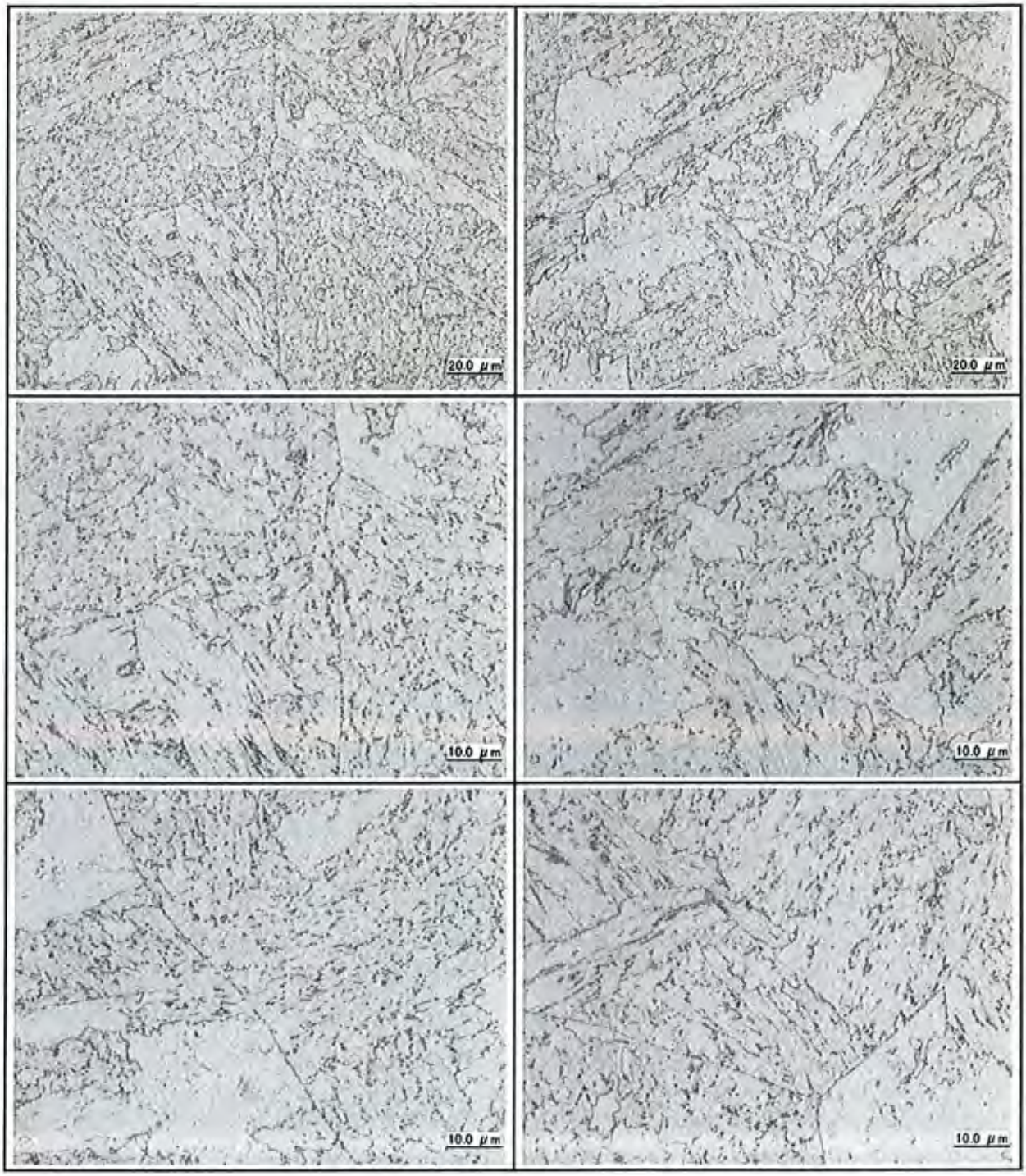


Photo I -51 Microstructure observation at cross section of sample tube
〔RH-Furnace (Coarse Grain HAZ)〕



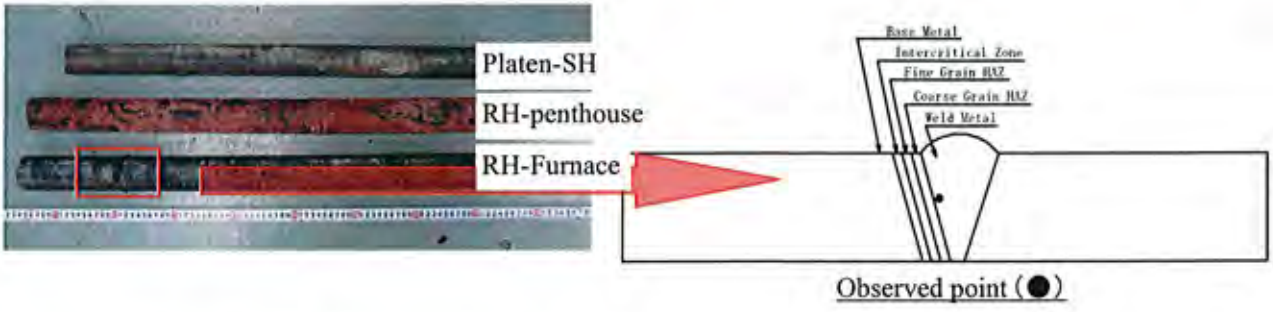
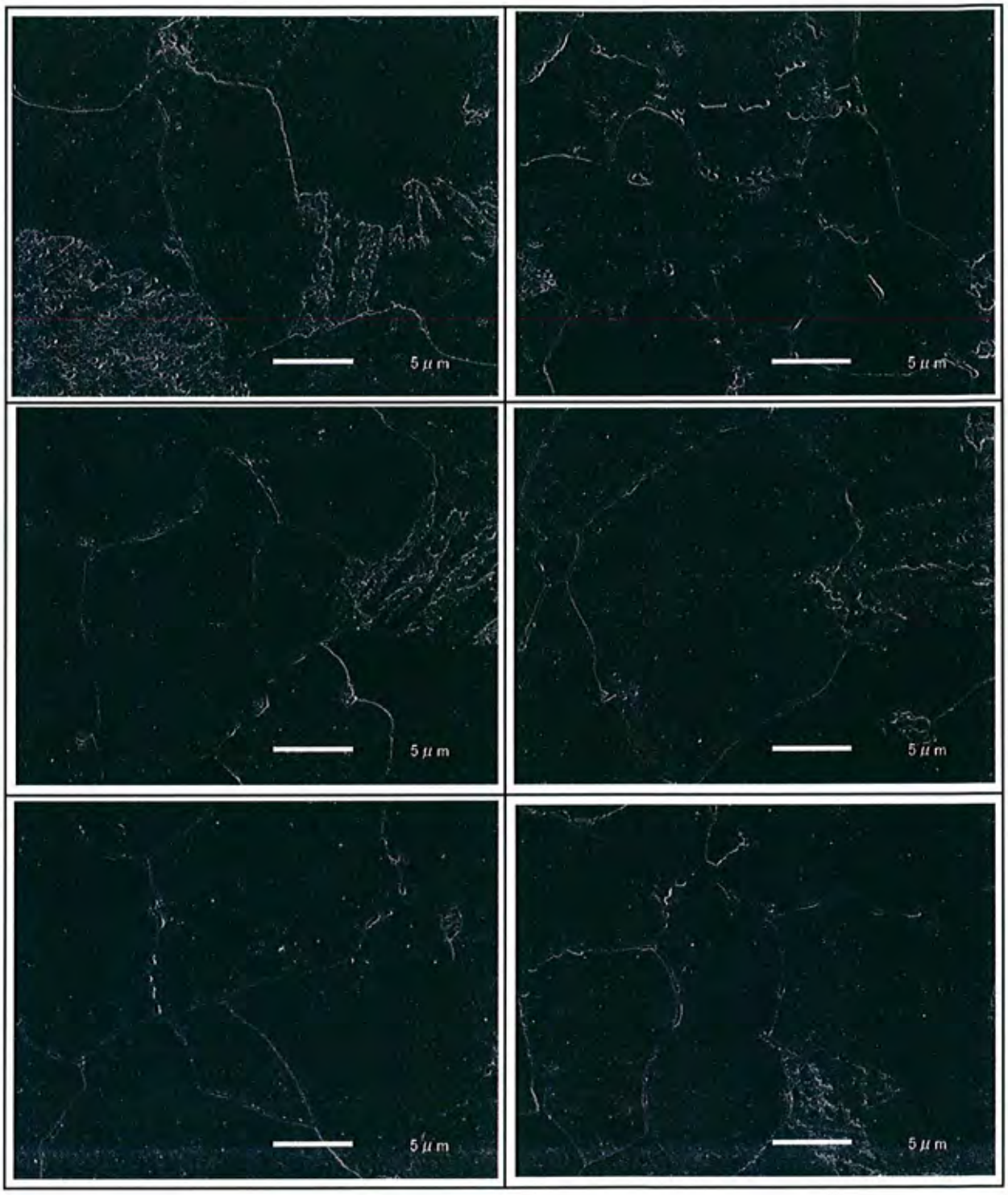


Photo I -52 Microstructure observation at cross section of sample tube
〔RH-Furnace（Weld Metal）〕



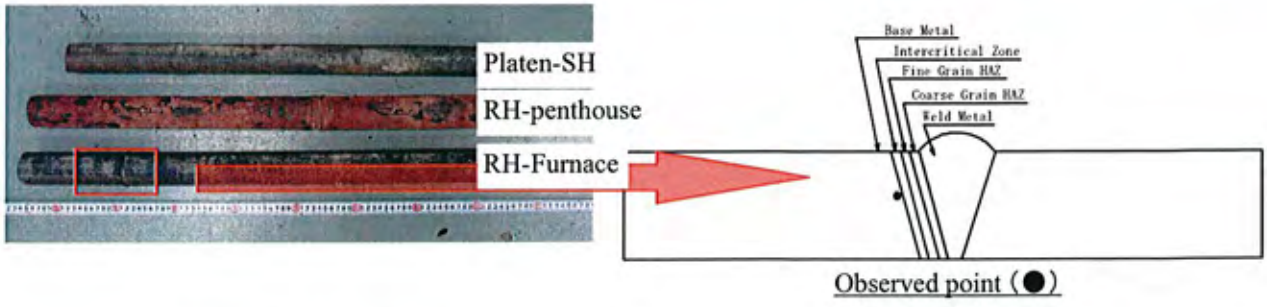
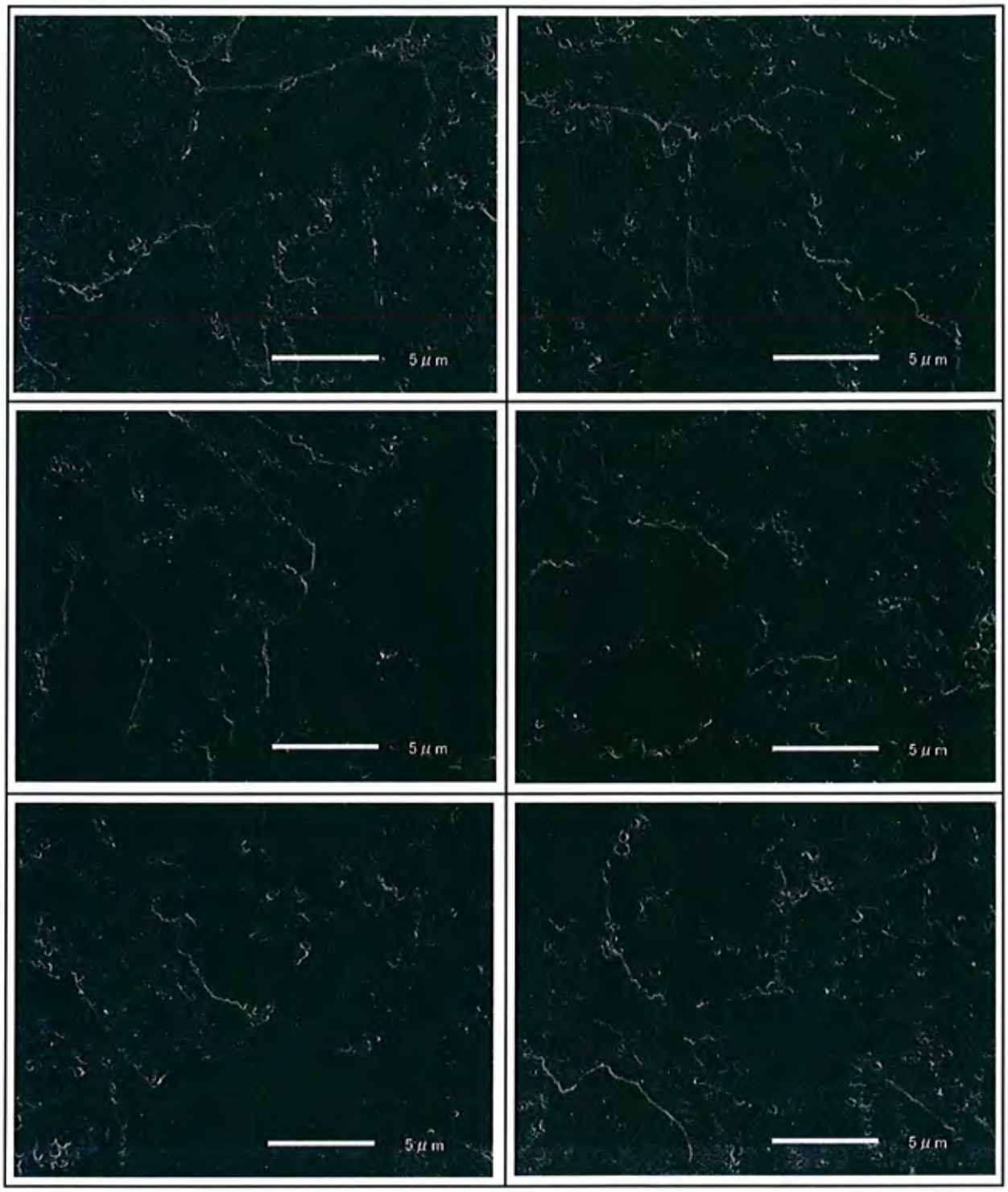


Photo I -53 Precipitates along grain boundary by SEM observatior
〔RH-Furnace (Base Metal)〕



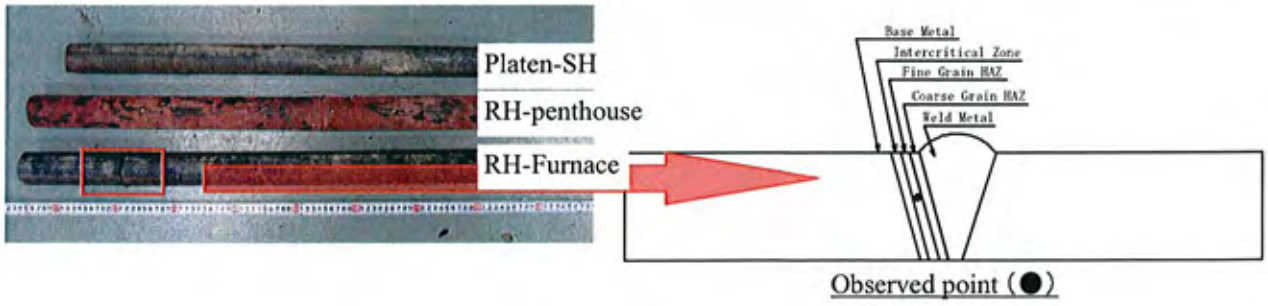
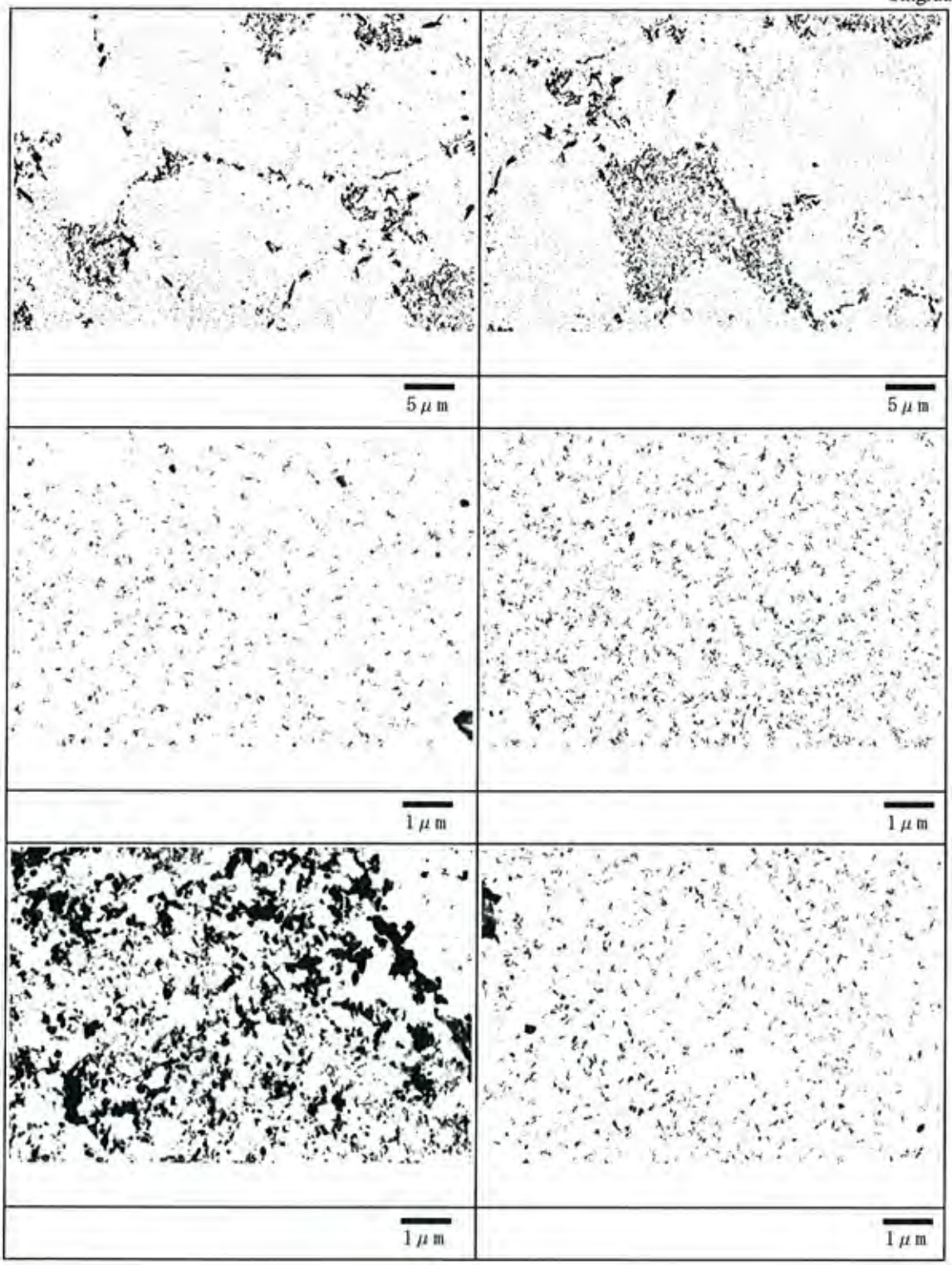


Photo I -54 Precipitates along grain boundary by SEM observatior
〔RH-Furnace (Fine Grain HAZ)〕



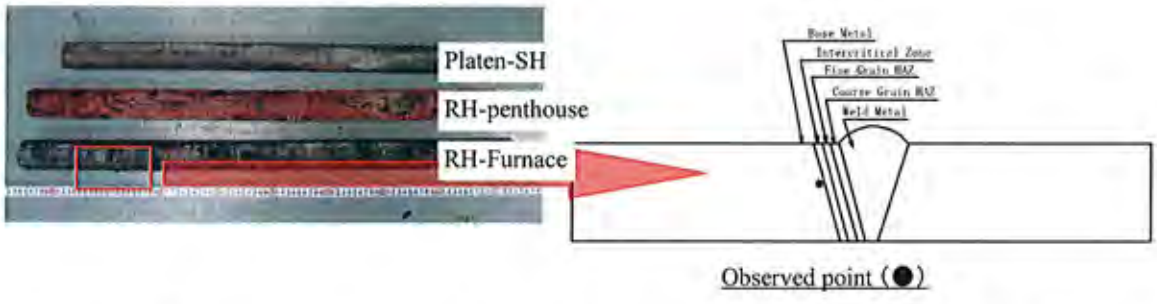
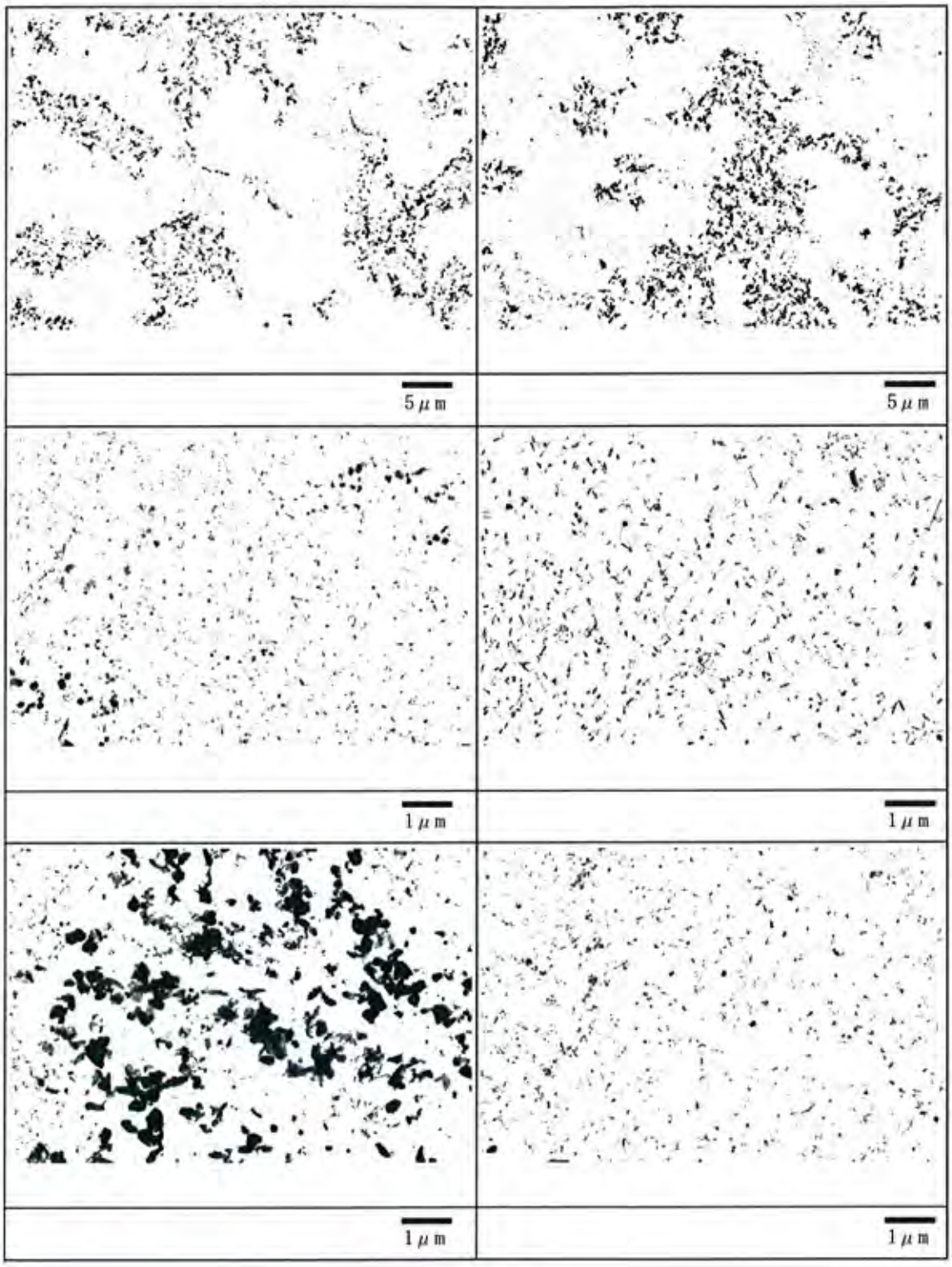


Photo I -55 Precipitates distribution by TEM observation〔RH-Furnace (Base Metal)〕



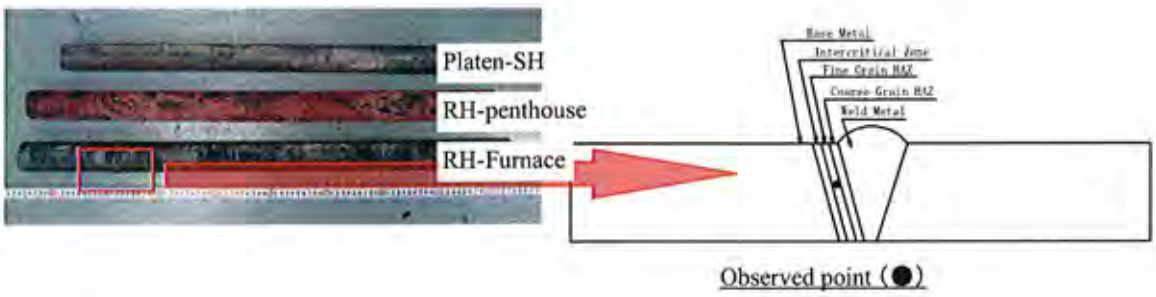
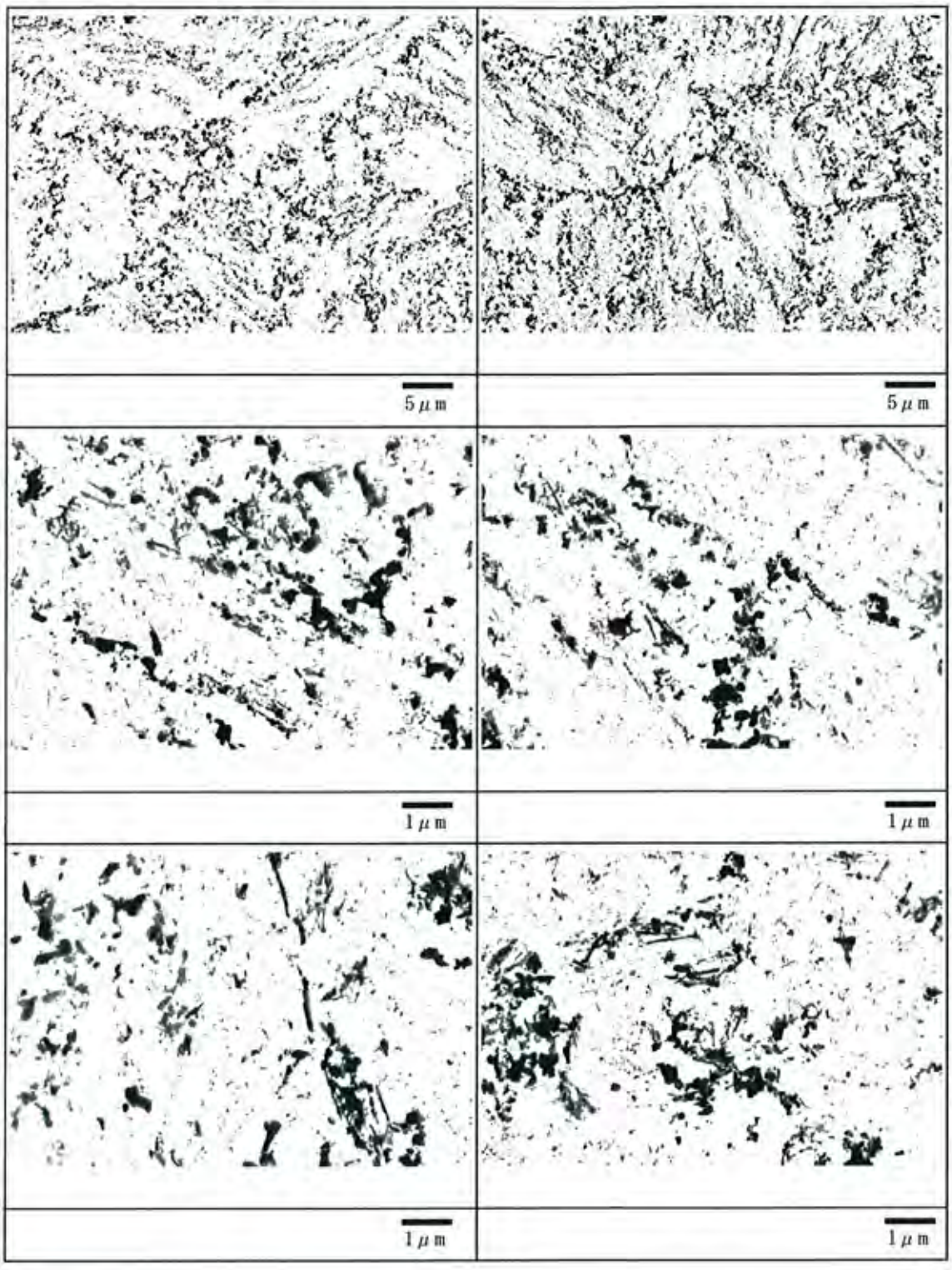


Photo I -56 Precipitates distribution by TEM observation〔RH-Furnace (Fine Grain HAZ)〕



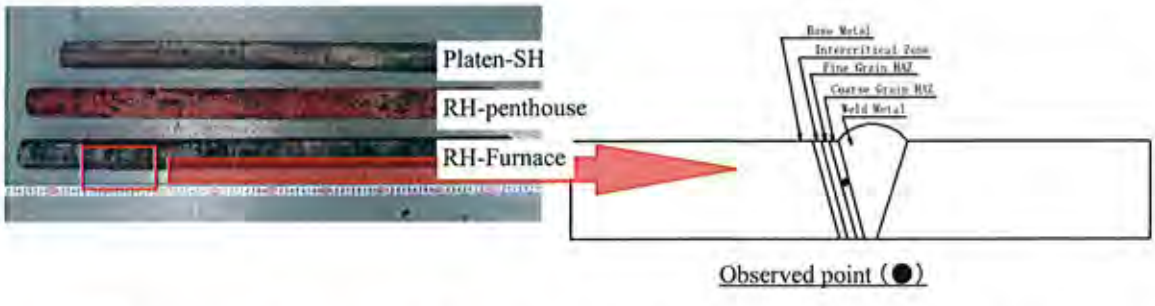
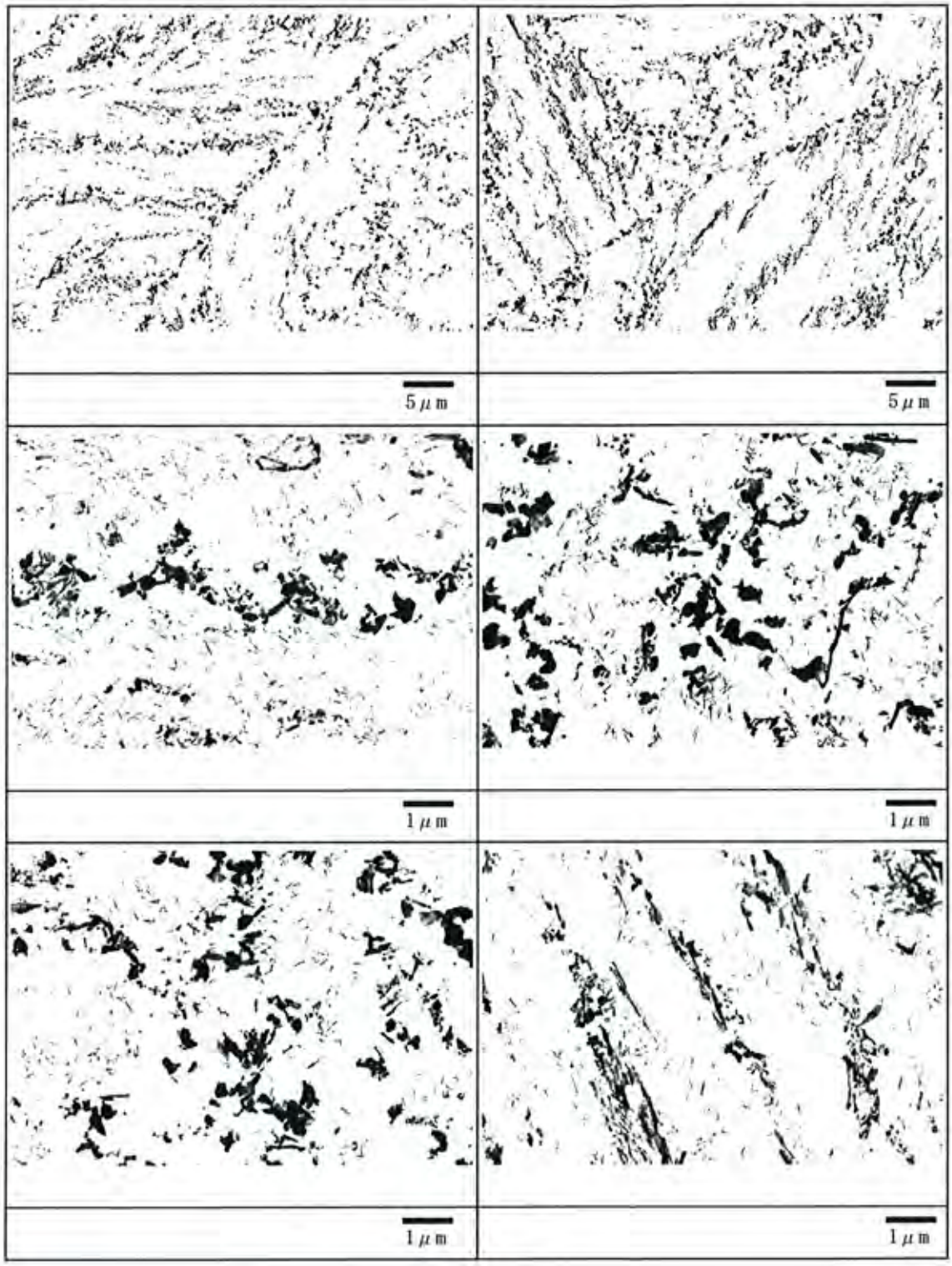


Photo I -57 Precipitates distribution by TEM observation〔RH-Furnace (Coarse Grain HAZ)〕



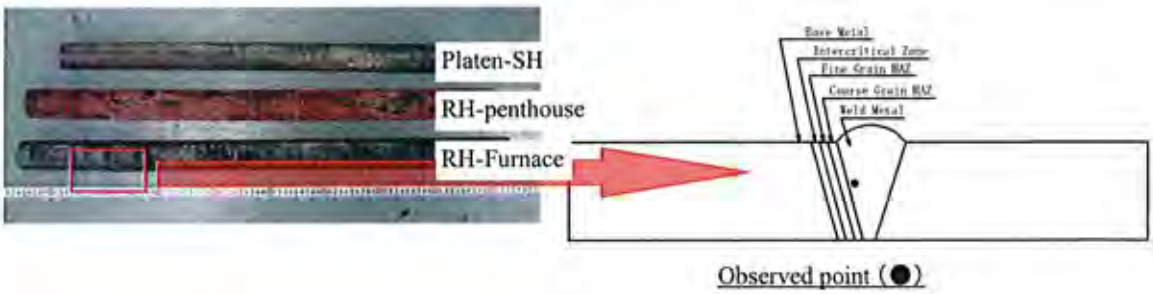


Photo I -58 Precipitates distribution by TEM observation〔RH-Furnace (Weld Metal)〕

Inspection at Unchahar #2

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

1. Unit for evaluation

Feroze Gandhi Unchahar Thermal Power Station #2 unit

2. Operation condition

(1) Cumulative operation hours: 139,098 hours

(2) Cumulative start and stop times: 96 times

3. Summary of residual life assessment results

- The highest creep life consumption ratio among evaluated pipes and headers was 50% at Main Steam Pipe-Right (Intrados) with the evaluated residual life 69,000 hours.
- The evaluated results for base metal and fine grain HAZ of Main Steam Pipe-Right (intrados, near the stop valve) were regarded as the reference, since OD measurement was not carried out. The estimated residual life in base metal varies from 8,000 to 130,000 hrs due to no OD measurements applied, while microstructure shows a little degradation. For accurate estimation of residual life, creep strain (OD) measurement along with microstructure is recommended to be carried out preferably within 8,000 hrs or practically at the earliest opportunity.
- The evaluated residual life for the other components was 96,000 hours or more.

Residual life assessment results by microstructural comparison method

Components	Location	Max. creep life consumption ratio(%)	Min. Evaluated residual life(h)	Evaluated region
Final SH Outlet Header	Circumferential weld at right side	20	270,000	Coarse grain HAZ
De-Suerheater-Left	Circumferential weld	42	96,000	Coarse grain HAZ
De-Suerheater-Right	Circumferential weld	42	96,000	Coarse grain HAZ
RH Outlet Header	Circumferential weld at left side	9	700,000	Fine grain HAZ
	Circumferential weld at right side,top	20	270,000	Coarse grain HAZ
	Circumferential weld at right side,front	20	270,000	Coarse grain HAZ
Main Steam Pipe-Right	Circumferential weld,intrados	50	69,000	Coarse grain HAZ
		(74)※	(24,000)※	Base Metal
	Circumferential weld.near the stop valve	20	270,000	Coarse grain HAZ
		(89)※	(8.000)※	Base Metal
Hot Reheat Pipe-Right	Circumferential weld	22	240,000	Fine grain HAZ

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

4. Summary of the other inspection results

(1) Visual inspection

- As results of visual inspection of boiler inside and penthouse, the decrease in thickness by erosion was observed for Water wall tubes around short soot blower, corner portion, burner portion and Platen SH and RH tube at the highest level of soot blower.
- No appearance abnormality was observed in stubs and the other weld portions for headers in penthouse.

(2) Thickness measurement

- As a result of thickness measurement for Water wall tubes at erosion area around short soot blowers near each 4 corner (101points in total), the measured thickness for a number of tubes (min.4.2mm) was less than tsr (thickness required) 6.1mm calculated with designed OD, pressure and allowable stress at the designed temperature.
- As a result of thickness measurement for mainly for outermost tubes of rear side portion of Platen SH tube (71points in total) at the highest and the second soot blower level, no measured thickness value was found to be below the designed value.

(3) OD measurement

- As a result of OD measurement for Final-SH Outlet Header-Right, De-Super Heater (Left&Right), RH Outlet Header (Left&Right),Hot Reheat Pipe-Right, the increase in measured OD to designed value was less than 1% for each component, indicating no remarkable creep strain.

(4) SUS scale deposition inspection

- As a result of SUS scale deposition inspection for Platen-SH tube (87 points;29tubes × bottom bend 3portions), SUS scale deposition was not significant with 15% fullness for 4 points, 10% fullness for 2 points and less than 10% fullness for the other portions.

(5) Dye penetrant inspection

- As a result of Dye penetrant inspection for 4 stub weld portions of # 3 panel from right of Platen-SH Inlet Header, no linear indication was detected.

(6) UT inspection

- As a result of UT inspection for 1ring of circumferential weld of Final SH outlet Header-Right, no flaw echo exceeding the criteria was detected.

(7) TOFD inspection

- As a result of TOFD inspection at the location identical to UT inspection location in Final-SH Outlet Header, no flaw echo judged as a crack was detected, although a continuous subtle flaw echoes were detected at about 80mm in depth from surface.

5. Components for residual life assessment and inspection

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

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

Table II-1 Components for residual life assessment

Component	Location	Material		Designed				
				O.D.	t	Temperature	Pressure	
		ASME	JIS	(mm)	(mm)	(℃)	(MPa)	(kg/cm^2)
Final SH Outlet Header	Circumferential weld at right side	SA335P22	STPA24	457.2	100.0	555	15.75	160.6
De-Suerheater-Left	Circumferential weld	SA335P12	STPA22	406.4	45.0	450	16.44	167.6
De-Suerheater-Right	Circumferential weld	SA335P12	STPA22					
RH Outlet Header	Circumferential weld at left side	SA335P22	STPA24	558.8	45.0	555	4.32	44.1
	Circumferential weld at right side,top	SA335P22	STPA24					
	Circumferential weld at right side,front	SA335P22	STPA24					
Main Steam Pipe-Right	Circumferential weld, intrados side	SA335P22	STPA24	355.6	50.3	540	15.74	160.5
	Circumferential weld,near the stop valve	SA335P22	STPA24					
Hot Reheat Pipe-Right	Circumferential weld	SA335P22	STPA24	508.0	28.0	540	3.69	37.6

Table II-2 Components for the other inspections

Portion	Inspection method
Water wall tube	Visual check
	Thickness measurement of tubes
Platten SH	Visual check
	Thickness measurement of tubes
	SUS scale deposition inspection
	Tube sampling for sample tube inspection (inspected in Japan).
	Creep rupture test (inspected in Japan)
Reheater	Visual check
Super heater header	Visual check
	DPT
	UT
	TOFD
	Replica inspection
De superheater pipe	Replica inspection
Reheater header	Replica inspection
Hot Reheat Pipe	Replica inspection

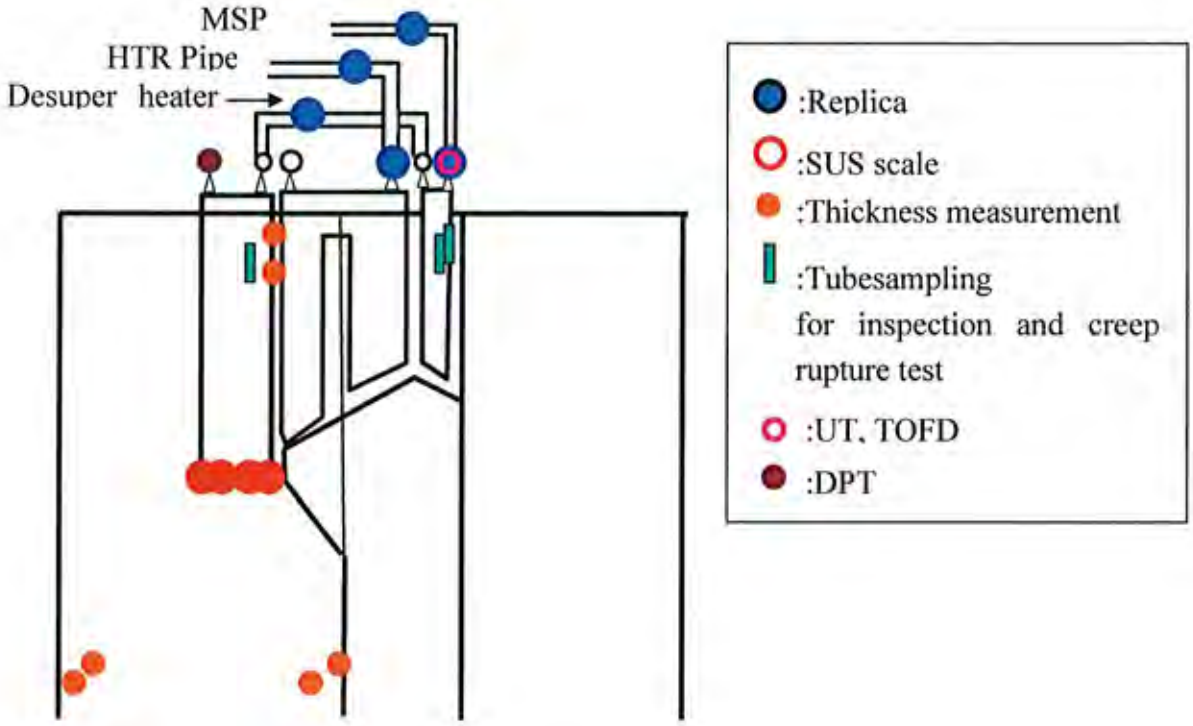


Fig. II-1 Location for each inspection

6. Items for residual life assessment

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

Table II -3 Items for residual life assessment

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

(1) Microstructure evaluation

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

a. Observed region

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

b. Observed magnification

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

(2) Carbide precipitation evaluation

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

(Observed region)

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

(Observed magnification)

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

(3) Creep void grade evaluation

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

(Observed region)

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

(Observed magnification)

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

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

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

(Observed region)

Base metal, Fine grain HAZ

(Observed magnification)

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

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

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

(Observed region)

Base metal

(Observed magnification)

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

7. Results of each observation and quantitative evaluation

7-1 Replica・extracted replica observation

(1) Final SH Outlet Header (circumferential weld at right side (SA335P22)

(Microstructure observation)

The results of microstructure observation are shown in Photo II-4-1～5.

The summary of observation results is shown in Table II-4.

- Precipitates at gain boundary were observed in base metal, intercritical zone and coarse grain HAZ.

(Creep void observation)

The results of creep void observation are shown in Photo II-4- 6～8.

The summary of observation results is shown in Table II-5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II-4-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II-4-11～14.

The summary of observation results is shown in Table II-6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal.

(2) De-Suerheater-Left (circumferential weld (SA335P12))

(Microstructure observation)

The results of microstructure observation are shown in Photo II-5-1～5.

The summary of observation results is shown in Table II-4.

- Precipitates at gain boundary were observed in base metal, intercritical zone, and fine grain HAZ.

(Creep void observation)

The results of creep void observation are shown in Photo II-5-6～8.

The summary of observation results is shown in Table II-5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II-5-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II-5-11～14.

The summary of observation results is shown in Table II-6.

- Spherodized precipitates were observed in coarse grain HAZ.

(3) De-Suerheater-Right (circumferential weld （SA335P12）)

(Microstructure observation)

The results of microstructure observation are shown in Photo II -6-1～5.

The summary of observation results is shown in Table II -4.

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

(Creep void observation)

The results of creep void observation are shown in Photo II -6-6～8.

The summary of observation results is shown in Table II -5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II -6-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II -6-11～14.

The summary of observation results is shown in Table II -6.

- No remarkable degradation of precipitates distribution was observed.

(4) RH Outlet Header (circumferential weld at left side （SA335P22）)

(Microstructure observation)

The results of microstructure observation are shown in Photo II -7-1～5.

The summary of observation results is shown in Table II -4.

- Precipitates at gain boundary were observed in base metal, intercritical zone and fine grain HAZ.

(Creep void observation)

The results of creep void observation are shown in Photo II -7-6～8.

The summary of observation results is shown in Table II -5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II -7-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II -7-11～14.

The summary of observation results is shown in Table II -6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal.
- Disappearance of fine precipitates were observed in fine grain HAZ and coarse grain HAZ.

(5) RH Outlet Header (circumferential weld at right side,top （SA335P22）)

(Microstructure observation)

The results of microstructure observation are shown in Photo II -8-1～5.

The summary of observation results is shown in Table II -4.

- Precipitates at gain boundary were observed in base metal, intercritical zone and fine grain HAZ and coarse grain HAZ.
- Precipitates free zone along grain boundary was observed in base metal.

(Creep void observation)

The results of creep void observation are shown in Photo II -8-6～8.

The summary of observation results is shown in Table II -5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II -8-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II -8-11～14.

The summary of observation results is shown in Table II -6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal. • No remarkable degradation of precipitates distribution were observed.
- Fine precipitates had disappeared in fine grain HAZ, coarse grain HAZ and weld metal.
- Fine precipitates had spherodized in fine grain HAZ and coarse grain HAZ.

(6) RH Outlet Header (Circumferential weld at right side,front （SA335P22）)

(Microstructure observation)

The results of microstructure observation are shown in Photo II -9-1～5.

The summary of observation results is shown in Table II -4.

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

(Creep void observation)

The results of creep void observation are shown in Photo II -9-6～8.

The summary of observation results is shown in Table II -5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II -9-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II -9-11～14.

The summary of observation results is shown in Table II -6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal.
- Fine precipitates had spherodized in fine grain HAZ and coarse grain HAZ.

(7) Main Steam Pipe-Right (Circumferential weld, intrados (SA335P22))

(Microstructure observation)

The results of microstructure observation are shown in Photo II-10-1～5.

The summary of observation results is shown in Table II-4.

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

(Creep void observation)

The results of creep void observation are shown in Photo II-10-6～8.

The summary of observation results is shown in Table II-5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II-10-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II-10-11～14.

The summary of observation results is shown in Table II-6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal.
- Fine precipitates had disappeared in fine grain HAZ, coarse grain HAZ and weld metal.

(8) Main Steam Pipe-Right (Circumferential weld,near the stop valve (SA335P22))

(Microstructure observation)

The results of microstructure observation are shown in Photo II-11-1～5.

The summary of observation results is shown in Table II-4.

- Precipitates at gain boundary were observed in base metal, intercritical zone and fine grain HAZ.

(Creep void observation)

The results of creep void observation are shown in Photo II-11-6～8.

The summary of observation results is shown in Table II-5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II-11-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II-11-11～14.

The summary of observation results is shown in Table II-6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal.
- Spherodized precipitates were observed in fine grain HAZ and coarse grain HAZ.

(9) Hot Reheat Pipe-Right(Circumferential weld (SA335P22))

(Microstructure observation)

The results of microstructure observation are shown in Photo II-12-1～5.

The summary of observation results is shown in Table II-4.

- Precipitates at gain boundary were observed in base metal, intercritical zone, fine grain HAZ and coarse grain HAZ.
- Precipitates free zone along grain boundary was observed in base metal and intercritical zone.

(Creep void observation)

The results of creep void observation are shown in Photo II-12-6～8.

The summary of observation results is shown in Table II-5.

- No creep void was observed in fine grain HAZ, coarse grain HAZ and weld metal.

(Grain boundary precipitates observation)

The results of grain boundary precipitates observation are shown in Photo II-12-9～10.

- Precipitates on grain boundary were observed in base metal and fine grain HAZ.

(Precipitates distribution observation)

The results of precipitates distribution observation are shown in Photo II-12-11～14.

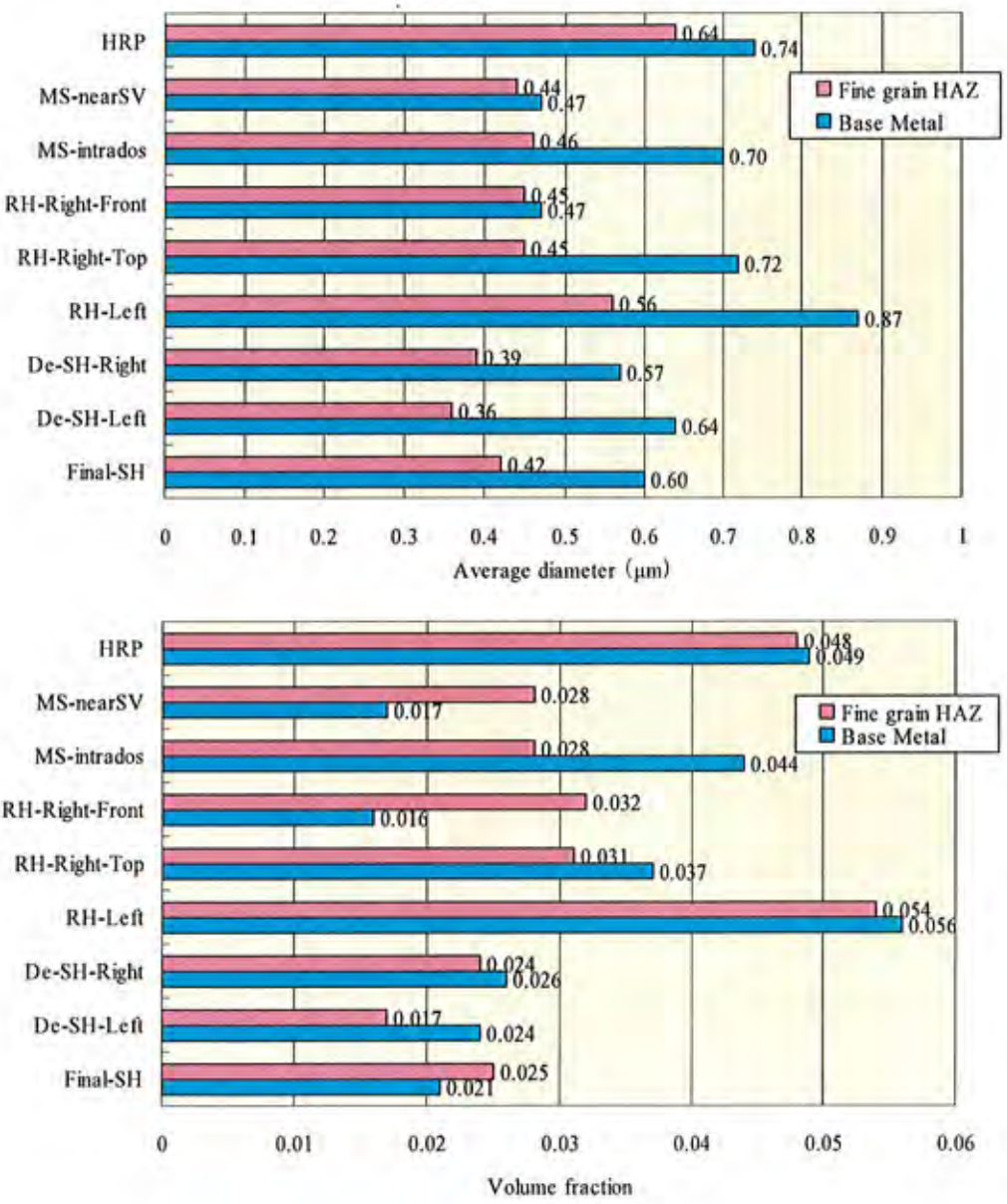
The summary of observation results is shown in Table II-6.

- Precipitates free zone along grain boundary and disappearance of fine precipitates in bainite grain were observed in base metal.
- Fine precipitates had disappeared in fine grain HAZ, coarse grain HAZ and weld metal.

7-2 Quantitative evaluation of grain boundary precipitates

The results of quantitative evaluation of grain boundary precipitates are shown in Table II -7.

- The max. value of average diameter of grain boundary precipitates was 0.87 μ m in base metal at RH Outlet Header-Left, 0.64 μ m in fine grain HAZ at Hot Reheat Pipe-Right.
- The max. value of volume fraction of grain boundary precipitates was 0.056 in base metal at RH Outlet Header-Left, 0.054 in fine grain HAZ at RH Outlet Header-Left.

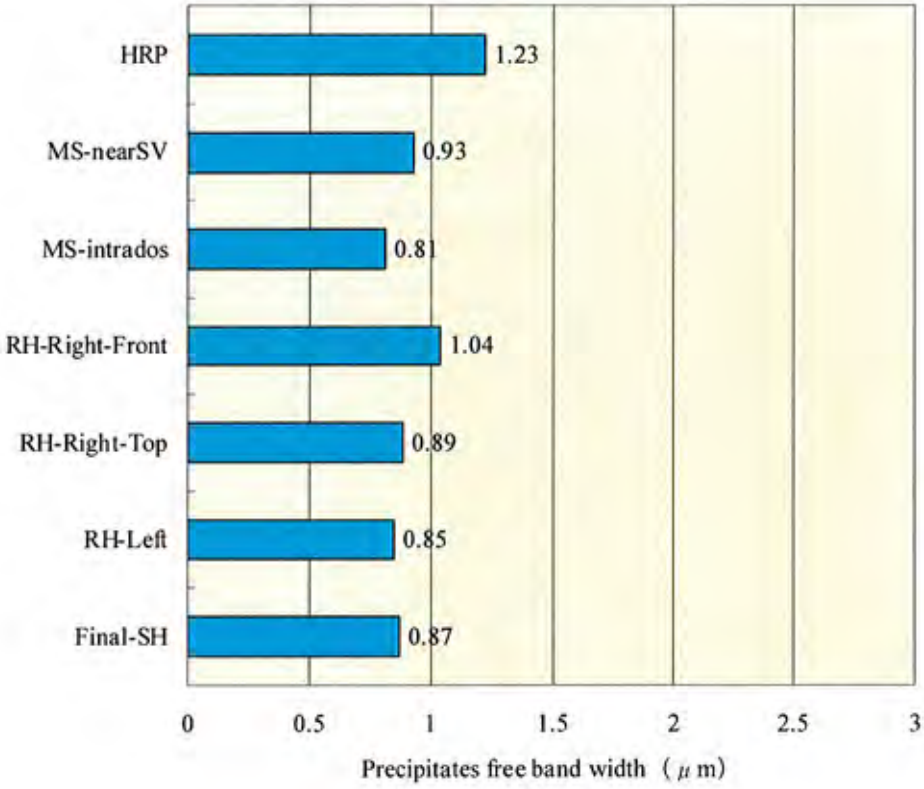


Quantitative evaluation of grain boundary precipitates〔extracted Table II -7〕

7-3 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-8.

- The quantitative evaluation was focused on base metal of SA 335 P22.
- The max. value of precipitates free band width along grain boundary was 1.23 μm at Hot Reheat Pipe-Right.



Precipitates free band width along grain boundary〔extracted Table Ⅱ-8〕

8. Residual life assessment results

8-1 Operational condition of evaluated components

Operational condition of evaluated components is shown in Table Ⅱ-9.

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.

8-2 Evaluation results

Evaluation results of residual life assessment for each components by microstructural comparison method are shown in Evaluation Results Ⅱ-1～9 and Table Ⅱ-10. The summary of evaluation results is shown in Ⅱ-11.

- The highest creep life consumption ratio among evaluated pipes and headers was 50% at Main Steam Pipe-Right (Intrados) with the evaluated residual life 69,000 hours.
- The evaluated results for base metal and fine grain HAZ of Main Steam Pipe-right (intrados, near the stop valve) were regarded as the reference, since OD measurement was not carried out. The estimated residual life in base metal varies from 8,000 to 130,000 hrs due to no OD measurements applied, while microstructure shows a little degradation. For accurate estimation of residual life, creep strain (OD) measurement along with microstructure is recommended to be carried out preferably within 8,000 hrs or practically at the earliest opportunity. For the other components, the evaluated residual life was 96,000 hours or more.

Table Ⅱ-11 Summary of residual life evaluation results

Components	Location	Max. creep life consumption ratio(%)	Min. Evaluated residual life(h)	Evaluated region
Final SH Outlet Header	Circumferential weld at right side	20	270,000	Coarse grain HAZ
De-Suerheater-Left	Circumferential weld	42	96,000	Coarse grain HAZ
De-Suerheater-Right	Circumferential weld	42	96,000	Coarse grain HAZ
RH Outlet Header	Circumferential weld at left side	9	700,000	Fine grain HAZ
	Circumferential weld at right side,top	20	270,000	Coarse grain HAZ
	Circumferential weld at right side,front	20	270,000	Coarse grain HAZ
Main Steam Pipe-Right	Circumferential weld,intrados	50	69,000	Coarse grain HAZ
		(74)※	(24,000)※	Base Metal
	Circumferential weld,near the stop valve	20	270,000	Coarse grain HAZ
		(89)※	(8,000)※	Base Metal
Hot Reheat Pipe-Right	Circumferential weld	22	240,000	Fine grain HAZ

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