



Assembly drawings of PoPola in-vessel components of EP10

ITER Project Japan Domestic Agency

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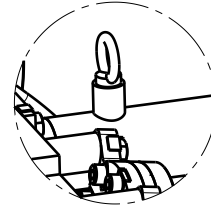
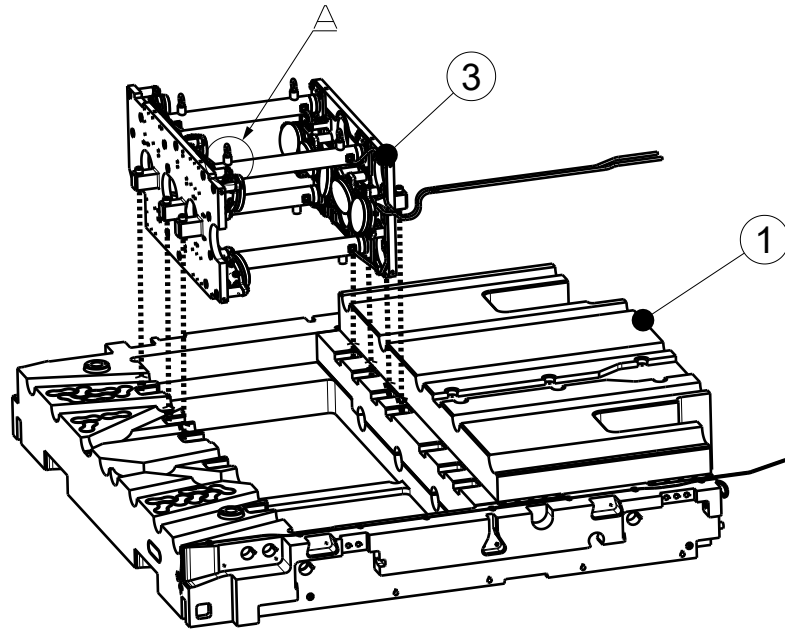


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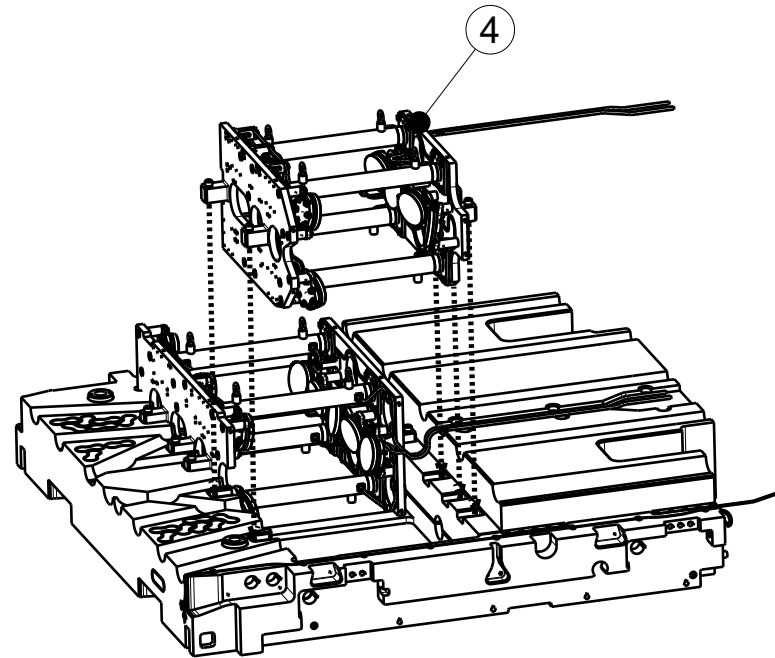
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1. To place UEMM

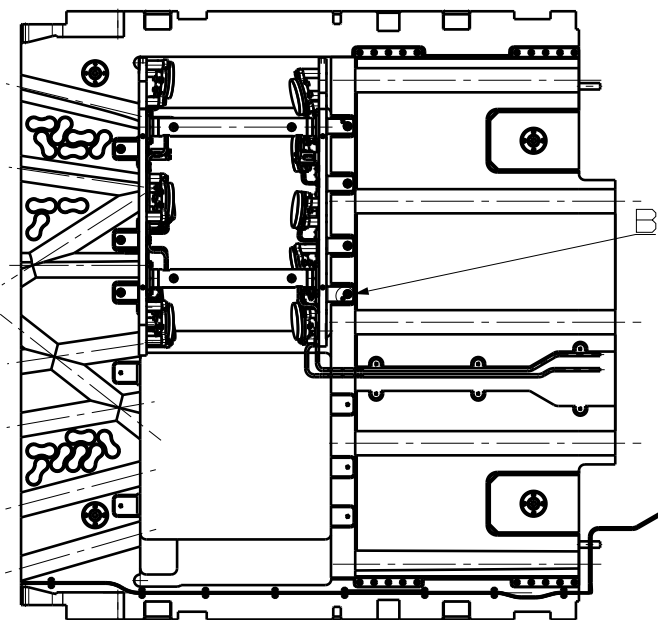


Part A Details (1 : 6)
Eye bolt (M10, x4)

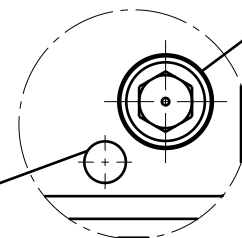
3. To install LEMM in the same manner with UEMM.



2. To tighten captive bolts by using hex key



Captive bolt (M12, x7)

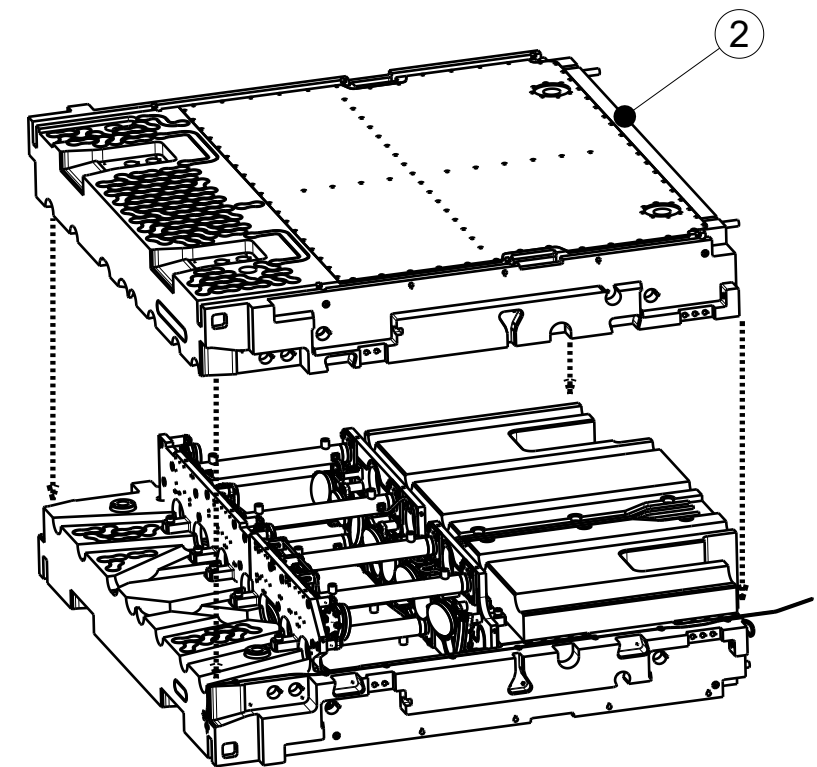


pin hole (Φ11, x2)

Part B Details (1 : 2)

Note :
Pin hole of UEMM fit guide pins of DSM.

4. To assembly DSM



Note :
Port Integrator will assembly DSM.
Assembly of DSM is beyond the scope of this drawing.

QTY.	Part number	NAME OF PART
1	1	EP10_DSM2_RIGHT
1	2	EP10_DSM2_LEFT
1	3	EPP_UPPER_MIRROR_MODULE_ASM
1	4	EPP_LOWER_MIRROR_MODULE

DRAWN BY Jun Takamizawa	DATE 2022/03/08	DRAWING TITLE Assembly Drawing (PoPola in-EPP10 mirror module)				
CHECKED BY Ryota Imazawa	DATE 2022/03/08	SIZE A3	SCALE 1:25	SHEET 1/1	REV 0	



55.C6 Manufacturing Assessment of PoPola Mirror Modules in Equatorial Port Plug 10

ITER Project Japan Domestic Agency

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Change log

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1	Outline	4
2	Overview of Manufacturing Process	5
3	Manufacturing of Mirrors	7
3.1	Heatsink	7
3.2	Cooling pipe.....	8
3.3	Shells for HIP joint.....	9
3.4	Mirror HIP process.....	10
3.5	Mirror Mount Assembly.....	11
3.6	Tungsten Mirror	12
3.7	Mirror assembly	13
4	Manufacturing of Other Components.....	14
4.1	Base Plate.....	14
4.2	Base Plate Brazing Process	16
4.3	Pipe Support.....	18
4.4	Rod.....	19
4.5	Reducer	20
4.6	1/4-inch cooling pipe.....	21
4.7	Connecting Rod.....	22
4.8	Interface pipe.....	24
5	Assembly of Mirrors and Other Components.....	25
5.1	UEMM/LEMM Base Plate First Assembly.....	25
5.2	UEMM/LEMM Base Plate Second Assembly	27
5.3	UEMM/LEMM Final Assembly	29
5.4	Mirror Angle Adjustment	31
5.5	Baking Procedure for Degassing.....	31
5.6	EMM Final Assembly	31
6	Conclusion	32
	Appendix A. List of purchases.....	33

1 Outline

This document clarifies manufacturing procedure of the mirror module in equatorial port plug (EPP10) in order to justify the manufacturability.

The mirror module is called EMM (EPP Mirror Module) and consists of two parts. The upper part is called UEMM (Upper EMM) and the lower one is called LEMM (Lower EMM). Figure 1-1 shows the overview of EMM.

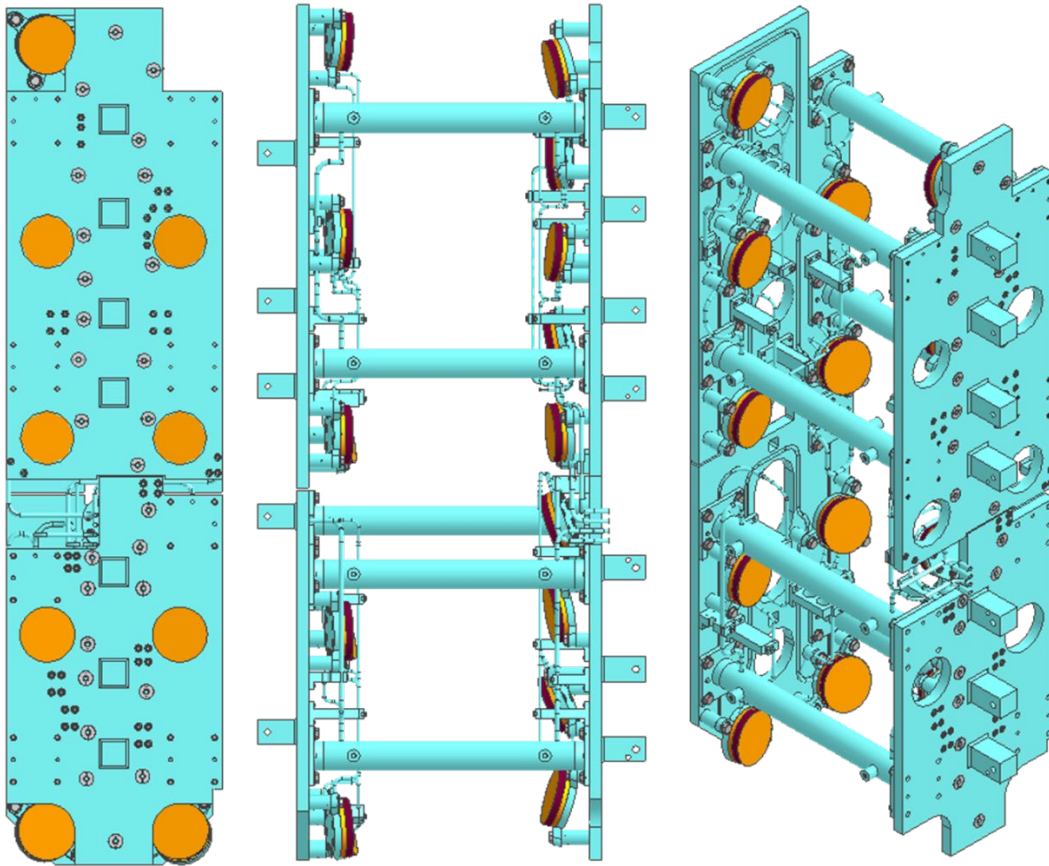


Figure 1-1. Overview of EMM

2 Overview of Manufacturing Process

Figure 2-1 shows the Gantt chart of manufacturing EMM, which is divided to three parts;

- manufacturing of mirrors (described in Section 3),
- manufacturing of other components (described in Section 4) and
- the assembly (described in Section 5).

The manufacturing of mirrors and that of other components will be carried out in parallel. The lead time is approximately 18 months in total. The authors supposed that delivery time of tungsten bolts will be three months and that of SS316LN-IG material will be long as approximately one year.

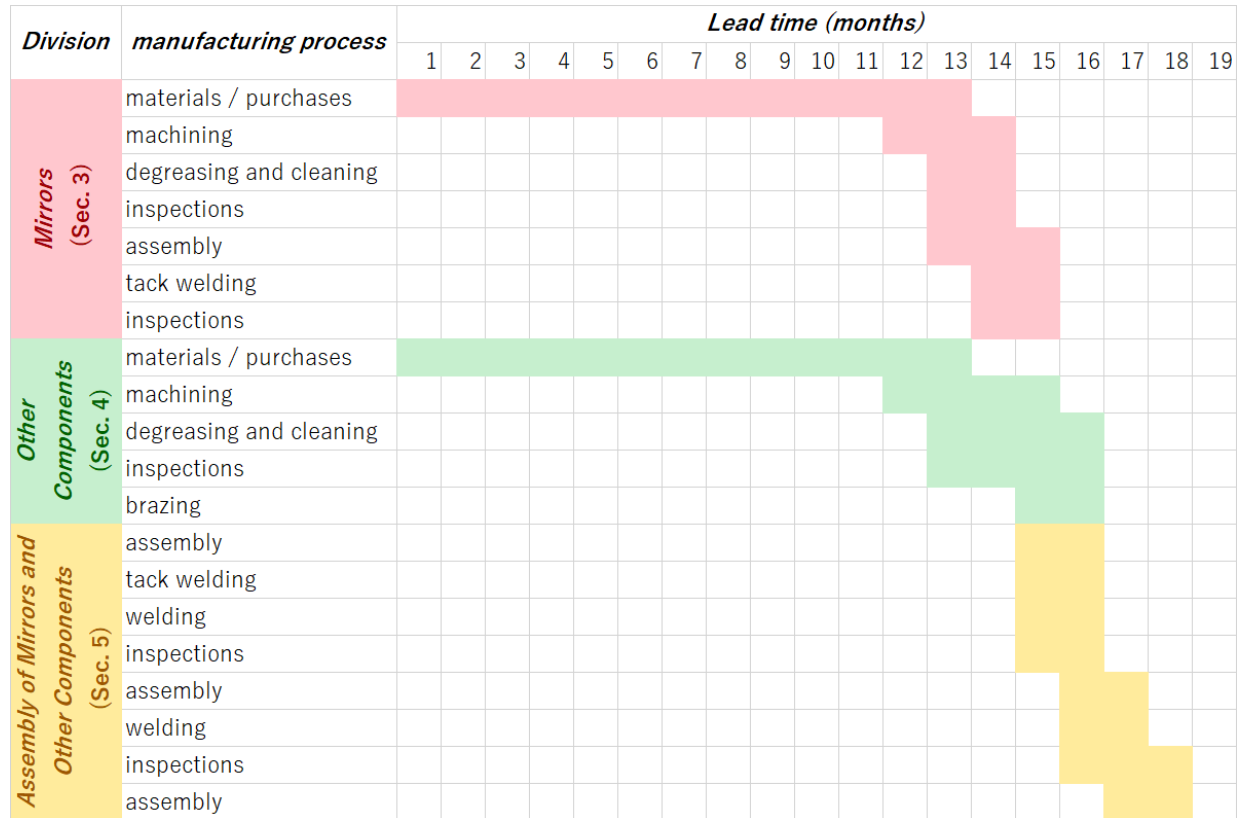


Figure 2-1 Gantt chart of manufacturing EMM

Figure 2-2 shows the list of the drawings, and the drawings highlighted by pink, green and yellow referred by Section 3, Section 4 and Section 5, respectively. The drawings are attached to this document separately. The manufacturing process of EMM is classified into 0th to 7th levels, and the drawings of each level are shown in Figure 2-2. This drawing structure means that a part that is specified by a drawing at a certain level is composed by parts that are specified by drawings at lower level. For instance, the part of 0EMM-001 is composed by the parts of 1UEMM-001 and 1LEMM-001. Then, the part of 1UEMM-001 is composed by the parts of 2UEMM-001, 2UEMM-002, 2EMM-001 and 2EMM-002.

When the drawing numbers are in bold in Figure 2-2, it means that the drawing is just for the representative part and that drawings of similar parts are omitted here. Taking into account the purpose of this document that is only to specify the manufacturing procedure, the drawings for the all similar parts are not necessary because the similar parts will be manufactured with the same machine, the same manufacturing procedure and same special process such as welding.

When the drawing numbers are in red in Figure 2-2, it means that the same drawing can be used for different products because the parts of the same drawing can be used for both LEMM and UEMM.

ITEM	Manufacturing process		0	1	2	3	4	5	6	7
	Title /Quantity									
EMM	EMM final assembly drawing / 1		0EMM-001							
UEMM	UEMM final assembly drawing / 1			1UEMM-001						
	UEMM M1 base plate second assembly drawing / 1				2UEMM-001					
	UEMM M1 base plate first assembly drawing / 1					3UEMM-001				
	UEMM M1 base plate brazing process drawing / 1						4UEMM-001			
	UEMM M1 base plate / 1							5UEMM-001		
	Mirror assembly / 5						4EMM-001			
	Tungsten mirror / 5							5EMM-001		
	Mirror mount assembly / 5							5EMM-002		
	Mirror HIP process drawing / 5								6EMM-001	
	Heatsink / 5									7EMM-001
	Cooling pipe / 5									7EMM-002
	Shells for HIP joint / 5									7EMM-003
	Pipe support / 7						4EMM-002			
	Rod / 15						4EMM-003			
	Reducer / 2					3EMM-001				
	1/4-inch pipe / 6					3EMM-002				
	UEMM M2 base plate second assembly drawing / 1				2UEMM-002					
	UEMM M2 base plate first assembly drawing / 1					3UEMM-002				
	UEMM M2 base plate brazing process drawing / 1						4UEMM-002			
	UEMM M2 base plate / 1							5UEMM-002		
	Mirror assembly / 5						4EMM-001			
	Tungsten mirror / 5							5EMM-001		
	Mirror mount assembly / 5							5EMM-002		
	Mirror HIP process drawing / 5								6EMM-001	
	Heatsink / 5									7EMM-001
	Cooling pipe / 5									7EMM-002
	Shells for HIP joint / 5									7EMM-003
	Pipe support / 6						4EMM-002			
	Rod / 15						4EMM-003			
	Reducer / 2					3EMM-001				
	1/4-inch pipe / 6					3EMM-002				
	Connecting rod / 4				2EMM-001					
	Interface pipe / 2				2EMM-002					
LEMM	LEMM final assembly drawing / 1			1LEMM-001						
	LEMM M1 base plate second assembly drawing / 1				2LEMM-001					
	LEMM M1 base plate first assembly drawing / 1					3LEMM-001				
	LEMM M1 base plate brazing process drawing / 1						4LEMM-001			
	LEMM M1 base plate / 1							5LEMM-001		
	Mirror assembly / 4						4EMM-001			
	Tungsten mirror / 4							5EMM-001		
	Mirror mount assembly / 4							5EMM-002		
	Mirror HIP process drawing / 4								6EMM-001	
	Heatsink / 4									7EMM-001
	Cooling pipe / 4									7EMM-002
	Shells for HIP joint / 4									7EMM-003
	Pipe support / 6						4EMM-002			
	Rod / 12						4EMM-003			
	Reducer / 2					3EMM-001				
	1/4-inch pipe / 5					3EMM-002				
	LEMM M2 base plate second assembly drawing / 1				2LEMM-002					
	LEMM M2 base plate first assembly drawing / 1					3LEMM-002				
	LEMM M2 base plate brazing process drawing / 1						4LEMM-002			
	LEMM M2 base plate / 1							5LEMM-002		
	Mirror assembly / 4						4EMM-001			
	Tungsten mirror / 4							5EMM-001		
	Mirror mount assembly / 4							5EMM-002		
	Mirror HIP process drawing / 4								6EMM-001	
	Heatsink / 4									7EMM-001
	Cooling pipe / 4									7EMM-002
	Shells for HIP joint / 4									7EMM-003
	Pipe support / 5						4EMM-002			
	Rod / 12						4EMM-003			
	Reducer / 2					3EMM-001				
	1/4-inch pipe / 5					3EMM-002				
	Connecting rod / 4				2EMM-001					
	Interface pipe / 2				2EMM-002					

Figure 2-2 List of drawings for EMM at each manufacturing level. (The drawings highlighted by pink, green and yellow referred by Section 3, Section 4 and Section 5, respectively)

3 Manufacturing of Mirrors

This section describes materials, material dimensions, quantity, processing time, processing machines, manufacturing procedure, inspection and cleaning procedures of the parts that are described as the mirrors in Figure 2-1.

3.1 Heatsink

Title (Drawing number)	Heatsink (7EMM-001)
Materials	CuCrZr
Material dimensions	$\phi 130 \times 15t$
Quantity	19 (including one sample for tests)
Processing time	4 hours per heatsink
Processing machine	Multi-tasking CNC machine (Okuma Corporation MULTUSB300 or equivalent)

Manufacturing procedure

- ① A manufacturer will shape the heatsink, will cut the grooves and will finish it adjusting the thickness.
- ② The manufacturer will degrease the heatsinks with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the heatsinks.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.

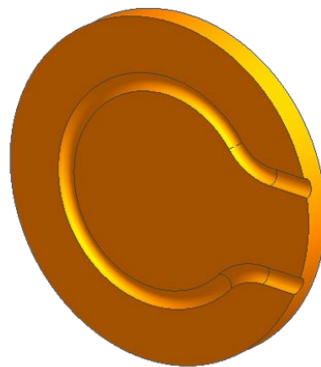


Figure 3-1 Heatsink

3.2 Cooling pipe

Title (Drawing number)	Cooling pipe (7EMM-002)
Materials	SS316LN-IG
Material dimensions	φ6.35×1t-285L
Quantity	19 (including one sample for tests)
Processing time	2 hours per pipe
Processing machine	CNC Pipe Bender (OPTON. Co. Ltd S-ECO 15 or equivalent)

Manufacturing procedure

- ① The manufacturer will shape pipes with CNC pipe bender and will cut them.
- ② The manufacturer will degrease the pipes with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the pipes.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.
- ④ The manufacturer will cover the entrance of the pipe to prevent adhesion of foreign objects.

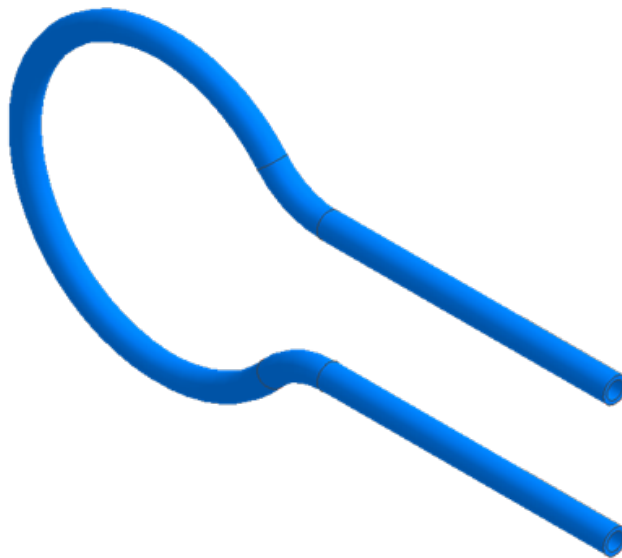


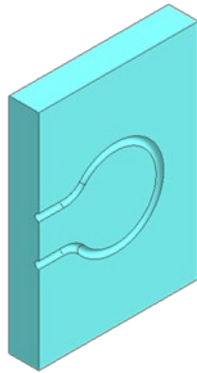
Figure 3-2 Cooling pipe

3.3 Shells for HIP joint

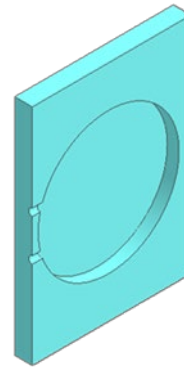
Title (Drawing number)	Shells for HIP joint (7EMM-003)
Materials	SS316LN-IG
Material dimensions	20t×140×195 30t×140×195
Quantity	19 set (including one sample for tests)
Processing time	9 hours per set of shells
Processing machine	CNC Pipe Bender (OPTON. Co. Ltd S-ECO 15 or equivalent)

Manufacturing procedure

- ① The manufacturer will finish the shape and will cut the grooves.
- ② The manufacturer will degrease the shells with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the shells.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.



(a) Bottom shell



(b) Top shell

Figure 3-3 Shells for HIP joint

3.4 Mirror HIP process

Title (Drawing number)(*)	Mirror HIP process (6EMM-001)
Materials	SS316LN-IG, CuCrZr
Material dimensions(*)	-
Quantity	19 sets (including one sample for tests)
Processing time	Total one month
Processing machine	-

[Notes] The drawing 6EMM-001 is a representative one, and the material dimensions is applicable to just 6EMM-001. The manufacturer shall prepare all drawings of the mirror HIP processes and shall evaluate the material dimensions for all the mirror HIP processes.

Manufacturing procedure

- ① The manufacturer will assemble the heatsink (7EMM-001 described in Section 3.1), cooling pipe (7EMM-002 described in Section 3.2) and shells for HIP joint (7EMM-003 described in Section 3.3) and will weld the shells by full-circled welding.
- ② The manufacturer will carry out HIP.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.
- ④ The manufacturer will cut a sample to check milli-meter order defect by visual inspection.
- ⑤ The manufacturer will check any defect in the pipe by using an endoscope.
- ⑥ When the surface is dirty, the manufacturer will clean it with ethanol-based cleaning solution.
- ⑦ The manufacturer will cover the entrance of the pipe to prevent adhesion of foreign objects.

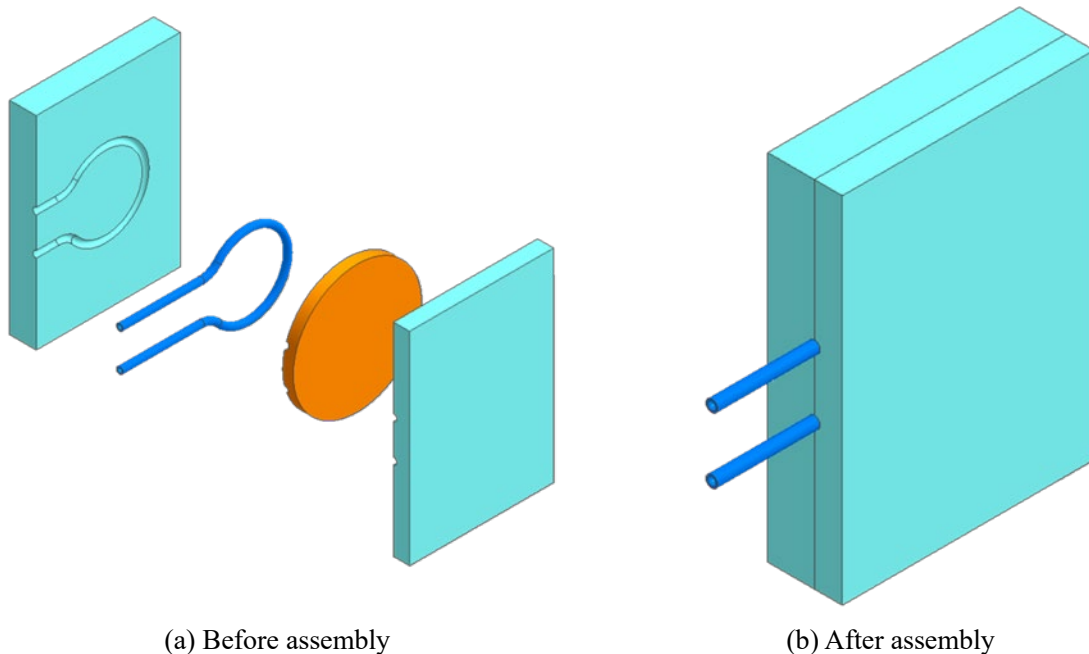


Figure 3-4 Mirror HIP process

3.5 Mirror Mount Assembly

Title (Drawing number)(*)	Mirror mount assembly (5EMM-002)
Materials	SS316LN-IG
Material dimensions(*)	-
Quantity	18
Processing time	45 hours per mirror mount assembly
Processing machine	— General purpose latch (DMG MORI CO., LTD. MH-1500G or equivalent) — Wire-cut electric discharge machine (Mitsubishi Electric Corporation MV2400R or equivalent) — Vertical CNC milling machine (OKK PCV-50 or equivalent) — Horizontal CNC milling machine (TOSHIBA MACHINE CO., LTD. BTD-200QE or equivalent)

[Notes] The drawing 5EMM-002 is a representative one, and the material dimensions is applicable to just 5EMM-002. The manufacturer shall prepare all drawings of the mirror mount assemblies and shall evaluate the material dimensions for all the mirror mount assemblies.

Manufacturing procedure

- ① The manufacturer will cut the joined parts described in Section 3.4 and will shape the mirror mount assembly roughly by WEDM (Wire-cut Electric Discharge Machine).
- ② The manufacturer will finish the outer shape (e.g. cylindrical parts) with the pipe left (see the middle of Figure 3-5).
- ③ The manufacturer will apply water pressure of 7.0 MPaG to the pipe and check any defect on it. After inspections, the manufacturer will cut the pipe at the specified length.
- ④ The manufacturer will fix the joined parts on the processing machine at an angle specified in drawing and will cut three tabs.
- ⑤ The manufacturer will drill holes in the tabs and will cut ventilation grooves on the tabs.
- ⑥ The manufacturer will degrease the assemblies with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the assemblies.
- ⑦ The manufacturer will confirm whether major dimensions comply with the drawings.
- ⑧ The manufacturer will clean the inside of the pipes and will cover the entrance of the pipes to prevent adhesion of foreign objects.

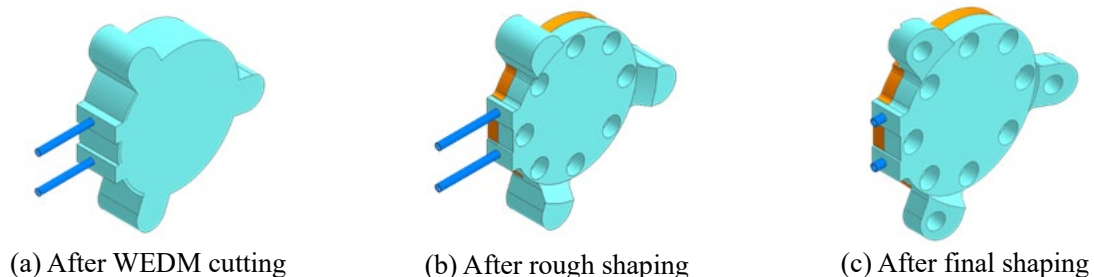


Figure 3-5. Mirror mount assembly

3.6 Tungsten Mirror

Title (Drawing number)	Tungsten mirror (5EMM-001)
Materials	Pure tungsten
Material dimensions	φ125×20t
Quantity	18 (9 flat mirrors and 9 curvature mirrors)
Processing time	30 hours per mirror
Processing machine	— Vertical CNC milling machine (MAKINO V33 or equivalent) — Oscar Type polishing machine or equivalent

Manufacturing procedure

- ① The manufacturer will shape the mirror, will cut internal threads and will adjust the thickness with a vertical CNC milling machine.
- ② The manufacturer will polish the surface of the mirrors roughly by using Oscar type polishing machine with rough abrasive.
- ③ The manufacturer will finish the surface of the mirrors with fine abrasive.
- ④ The manufacturer will clean the surface to remove dusts with cleaning fluid (alcohol) and with lens cleaning paper dedicated for optical elements. The manufacturer will pay attention so as not to damage the characteristics of the surface state or material, and the cleaning procedure will be minimized. The manufacturer will take pictures of the mirror surface in high-resolution before and after cleaning to compare them.
- ⑤ The manufacturer will confirm whether major dimensions comply with the drawings.
- ⑥ The manufacturer will check the surface roughness with laser interferometer at arbitrary area with a diameter of 60 mm. The measurement will be several times and the measurement area will be overlapped.
- ⑦ The manufacturer will measure the curvature radius with CMM (Coordinate Measuring Machine) to calculate the focal length.
- ⑧ The manufacturer will measure the reflectivity of the mirrors by using a laser, a detector etc.
- ⑨ The manufacturer will protect the surface of the mirror with plastic film of FUTAMURA CHEMICAL CO., LTD. (self-adhesive OPP film FSA or equivalent).

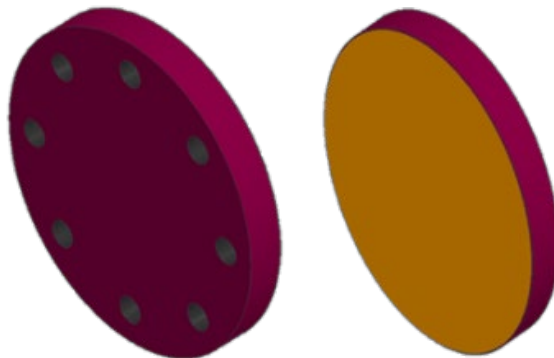


Figure 3-6 Tungsten Mirror

3.7 Mirror assembly

Title (Drawing number)(*)	Mirror assembly (4EMM-001)
Materials	W, CuCrZr, SS316LN-IG
Material dimensions(*)	-
Quantity	18
Processing time	1.5 hours per mirror assembly
Processing machine	TIG welding machine (DAIHEN Corporation DT300P or equivalent)

[Notes] The drawing 4EMM-001 is a representative one, and the material dimensions is applicable to just 4EMM-001. The manufacturer shall prepare all drawings of the mirror assembly and shall evaluate the material dimensions for all the mirror assemblies.

Manufacturing process

- ① The manufacturer will protect the surface of the tungsten mirror with plastic film of FUTAMURA CHEMICAL CO., LTD. (self-adhesive OPP film FSA or equivalent).
- ② The manufacturer will join the tungsten mirror (described in Section 3.5) and the mirror mount assembly (described in Section 3.6) with DLC coated Tungsten bolts.
- ③ The manufacturer will put a washer on each tungsten bolt and will weld at four points between the mirror mount assembly and the washer to prevent loosening of the bolts.
- ④ The manufacturer will check the thermal distribution of the surface of the mirror by using an infrared camera to check any cold spot when cooling water temperature is rapidly changed.
- ⑤ When the surface is dirty, the manufacturer will clean it with ethanol-based cleaning solution.

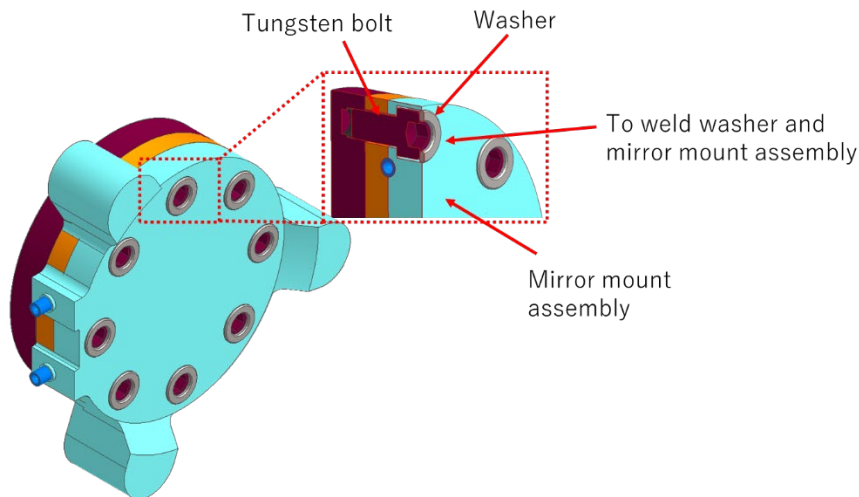


Figure 3-7 Assembly of tungsten mirror and mirror mount assembly

4 Manufacturing of Other Components

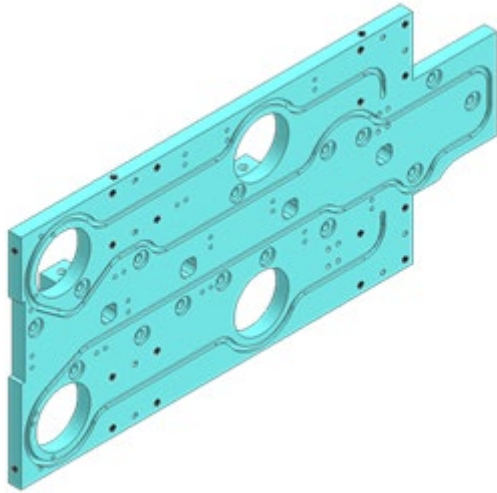
This section describes materials, material dimensions, quantity, processing time, processing machines, manufacturing procedure, inspections and cleaning procedures of the components other than mirrors that was called “other components” in Figure 2-1.

4.1 Base Plate

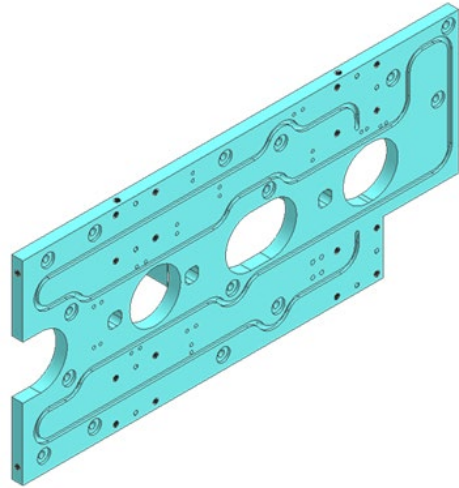
Title (Drawing number)	UEMM M1 base plate (5UEMM-001) LEMM M1 base plate (5LEMM-001) UEMM M2 base plate (5UEMM-002) LEMM M2 base plate (5LEMM-002)
Materials	SS316LN-IG
Material dimensions	125t x 450 x 970 (5UEMM-001) 125t x 450 x 750 (5LEMM-001) 115t x 450 x 995 (5UEMM-002) 115t x 450 x 765 (5LEMM-002)
Quantity	4
Processing time	150 hours per plate
Processing machine	— Electric discharge machine (Mitsubishi Electric Corporation MV2400R or equivalent) — Vertical CNC milling machine (OKK MCV820 or equivalent) — Horizontal CNC milling machine (TOSHIBA MACHINE CO., LTD. BTD-200QE or equivalent)

Manufacturing procedure

- ① The manufacturer will cut the shape roughly from the material plate and will remove the internal stress by heat treatment (immediate cooling after 1050 to 1150 degrees Celsius heating).
- ② The manufacturer will cut the grooves on the base plate and will drill the holes in the plate.
- ③ The manufacturer will finish the outer shape of the base plate and will drill counterbores in the plate.
- ④ The manufacturer will confirm whether major dimensions comply with the drawings.
- ⑤ The manufacturer will degrease the plates with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the plates.

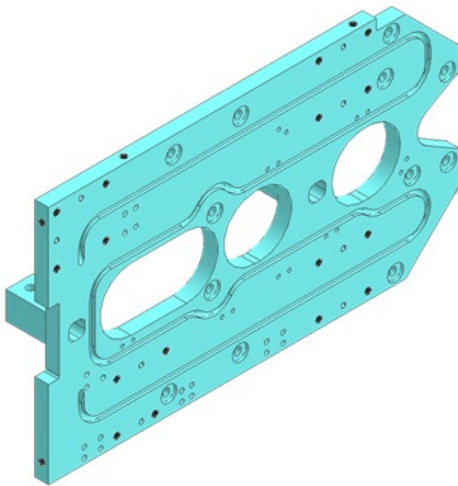


(a) 5UEMM-001

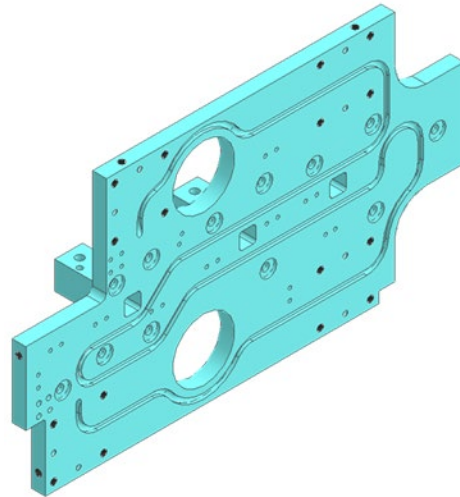


(b) 5UEMM-002

Figure 4-1 Base plates of UEMM



(a) 5LEMM-001



(b) 5LEMM-002

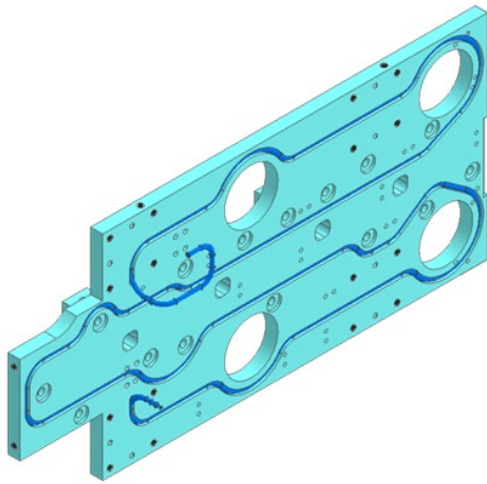
Figure 4-2 Base plates of LEMM

4.2 Base Plate Brazing Process

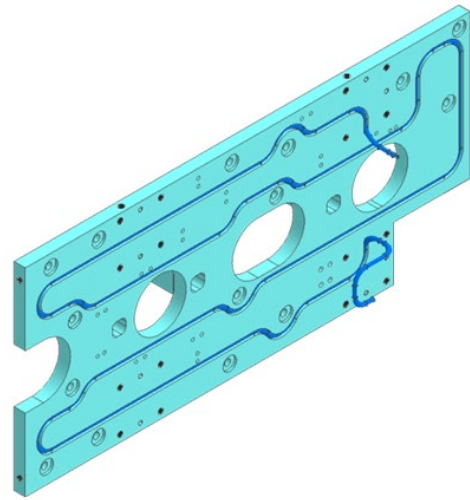
Title (Drawing number)	UEMM M1 base plate brazing process (4UEMM-001) LEMM M1 base plate brazing process (4LEMM-001) UEMM M2 base plate brazing process (4UEMM-002) LEMM M2 base plate brazing process (4LEMM-002)
Materials	SS316LN-IG
Material dimensions	-φ9.53×1t-3200～4950L (total 16000mm)
Quantity	4
Processing time	3 months (total)
Processing machine	— CNC Pipe Bender (OPTON. Co. Ltd S-ECO 15 or equivalent) — Automatic welding machine (SWAGELOK orbital welding system series 4,5 or equivalent) — Spot welding machine (DAIHEN Corporation UP-8S or equivalent)

Manufacturing procedure

- ① The manufacturer will shape separated pipes roughly by using CNC pipe bender first. Then, the manufacturer will fit the bent pipes actually with the grooves of the base plate described in Section 4.1 and will adjust the shape of pipes by hand.
- ② The manufacturer will join the separated pipes. The type of welding is a butt welding, and an automatic welding machine will be used. After welding, RT inspection will be carried out to check welding joints.
- ③ The manufacturer will fit the joined pipe into the groove of the base plate and will braze the pipe to the base plate injecting BNi-6 (brazing material) between the pipe and the groove. The groove will be 2 milli meter larger than the outer diameter of the pipe, and the manufacturer shall fulfill the gap between the pipe and the groove with the brazing material.
- ④ After brazing the manufacturer will join a reducer (3EMM-001) and the pipe. The type of welding is a butt welding, and the automatic welding machine. After welding, RT inspection will be carried out to check welding joints.
- ⑤ The manufacturer will vacuum the pipe, will spray Helium gas on welded parts and will check if helium flows into the pipe by using a residual gas analyzer.
- ⑥ The manufacturer will apply water pressure of 7.0 MPaG pressure to the pipe and check any defect on it.
- ⑦ When the surface is dirty, the manufacturer will clean it with ethanol-based cleaning solution.
- ⑧ The manufacturer will clean the inside of the pipes and will cover the entrance of the pipes to prevent adhesion of foreign objects.

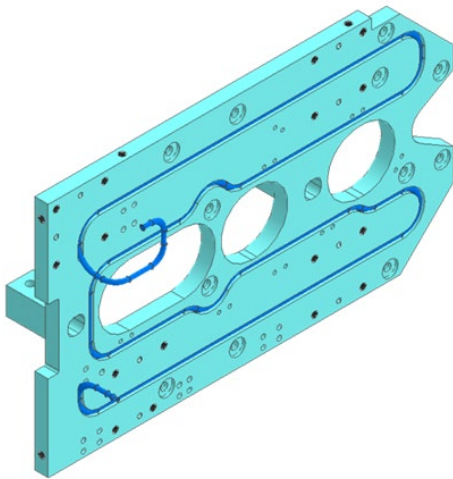


(a) 4UEMM-001

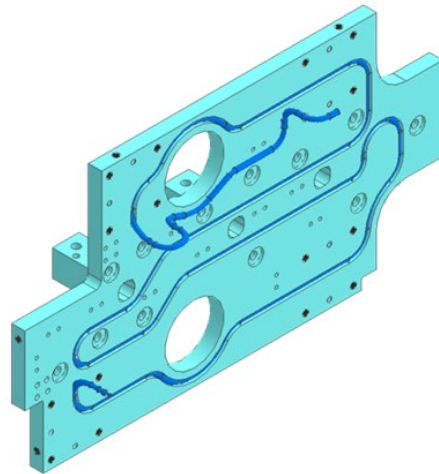


(b) 4UEMM-002

Figure 4-3. UEMM base plate brazing process



(a) 4LEMM-001



(b) 4LEMM-002

Figure 4-4. LEMM base plate brazing process

4.3 Pipe Support

Title (Drawing number) (*)	Pipe support (4EMM-002)
Materials	SS316LN-IG
Material dimensions (*)	40t×50×90 15t×25×40
Quantity	29
Processing time	12 hours per part
Processing machine	— Wire-cut electric discharge machine (Mitsubishi Electric Corporation MV2400R or equivalent) — Horizontal CNC milling machine (TOSHIBA MACHINE CO., LTD. BTD-200QE or equivalent) — Vertical milling machine (SHIZUOKA VHR-A or equivalent)

[Notes] The drawing 4EMM-002 is a representative one, and the material dimensions is applicable to just 4EMM-002. The manufacturer shall prepare all drawings of the pipe supports and shall evaluate the material dimensions for all the pipe supports.

Manufacturing procedure

- ① The manufacturer will cut the shape roughly from the material plate by WEDM and will finish the outer shape.
- ② The manufacturer will drill holes and will thread them with a tap.
- ③ The manufacturer will degrease the pipe supports with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the pipe supports.
- ④ The manufacturer will confirm whether major dimensions comply with the drawings.

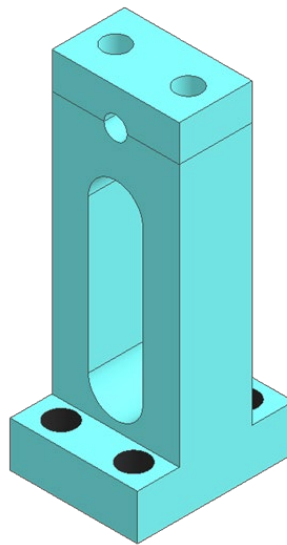


Figure 4-5. Example of pipe support

4.4 Rod

Title (Drawing number) (*)	Rod (4EMM-003)
Materials	SS316LN-IG
Material dimensions(*)	φ35-86L
Quantity	54
Processing time	2 hours per rod
Processing machine	— General purpose lathe (DMG MORI CO., LTD. MH-1500G or equivalent) — Vertical milling machine (SHIZUOKA VHR-A or equivalent)

[Notes] The drawing 4EMM-003 is a representative one, and the material dimensions is applicable to just 4EMM-003. The manufacturer shall prepare all drawings of the rods and shall evaluate the material dimensions for all the rods.

Manufacturing procedure

- ① The manufacturer will cut the material, will shape it and will make internal and external thread.
- ② The manufacturer will degrease the rods with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the rods.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.

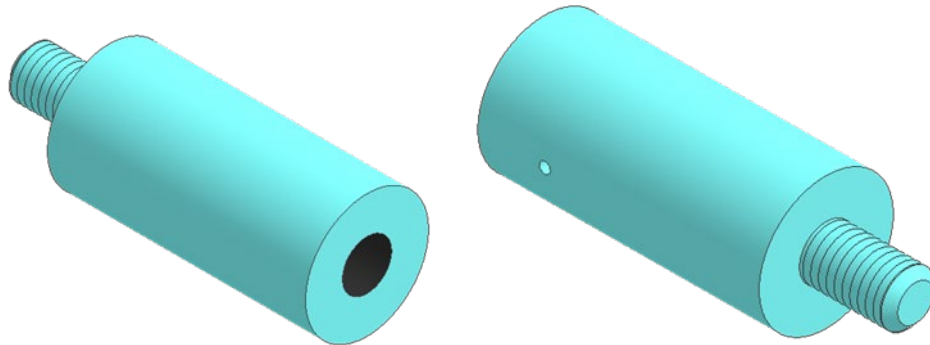


Figure 4-6. Rods

4.5 Reducer

Title (Drawing number)	Reducer (3EMM-001)
Materials	SS316LN-IG
Material dimensions	φ15-25L
Quantity	8
Processing time	2 hours per reducer
Processing machine	General purpose lathe (DMG MORI CO., LTD. MH-1500G or equivalent)

Manufacturing procedure

- ① The manufacturer will finish the outside shape first and will finish the inside shape.
- ② The manufacturer will degrease the reducers with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the reducers.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.

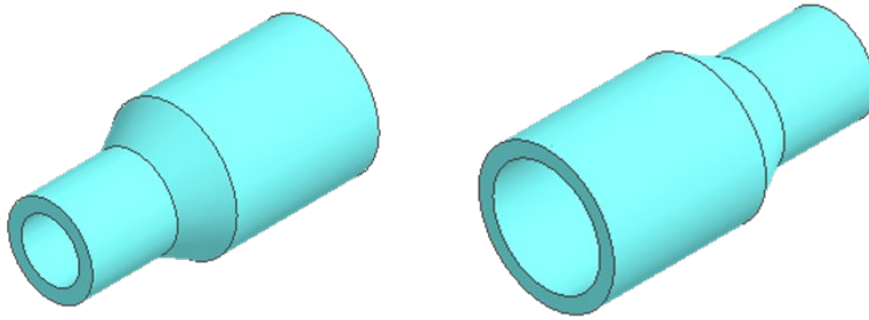


Figure 4-7. Reducer

4.6 1/4-inch cooling pipe

Title (Drawing number) (*)	1/4-inch cooling pipe (3EMM-002)
Materials	SS316LN-IG
Material dimensions(*)	$\phi 6.35 \times 1t-160L - 740L$
Quantity	22
Processing time	2 hours per pipe
Processing machine	CNC Pipe Bender (OPTON. Co. Ltd S-ECO 15 or equivalent)

[Notes] The drawing 3EMM-002 is a representative one, and the material dimensions is applicable to just 3EMM-002. The manufacturer shall prepare all drawings of the 1/4-inch cooling pipes and shall evaluate the material dimensions for all the 1/4-inch cooling pipes.

Manufacturing procedure

- ① The manufacturer will shape pipes with CNC pipe bender and will cut them.
- ② The manufacturer will degrease the pipes with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the pipes.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.
- ④ The manufacturer will clean the inside of the pipes and will cover the entrance of the pipe to prevent adhesion of foreign objects.

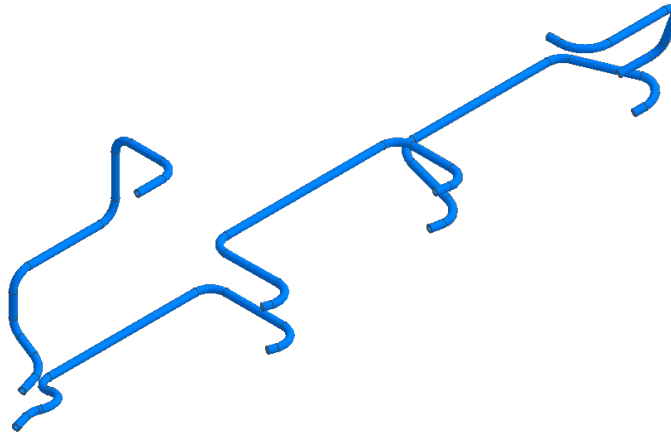


Figure 4-8. 1/4-inch cooling pipe

4.7 Connecting Rod

Title (Drawing number) (*)	Connecting rod (2EMM-001)
Materials	SS316LN-IG
Material dimensions(*)	φ60×15t-520L φ25-35L 45t×125×125
Quantity	8
Processing time	2.5 months (total)
Processing machine	— Vertical CNC milling machine (MAKINO V33 or equivalent) — TIG welding machine (DAIHEN Corporation DT300P or equivalent)

[Notes] The drawing 2EMM-001 is a representative one, and the material dimensions is applicable to just 2EMM-001. The manufacturer shall prepare all drawings of the connecting rods and shall evaluate the material dimensions for all the connecting rods.

Manufacturing procedure

- ① End plate: The manufacturer will cut the material, will shape the plate part at the dimensions of 15x125x125 mm to be finished after following procedure of welding, and will shape the part connected to the rod (Figure 4-9). The manufacturer will confirm whether major dimensions comply with the drawings.
- ② Rod: The manufacturer will cut the material at the specified length and will finish the shape of the end part of the rod (Figure 4-10). The manufacturer will confirm whether major dimensions comply with the drawings.
- ③ Pipe with flange: The manufacturer will finish the outside shape and will finish the inside shape (Figure 4-11). The manufacturer will confirm whether major dimensions comply with the drawings.
- ④ The manufacturer will degrease the parts described in the previous procedures (the end plates, the rods and the pipes with flange) with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of them.
- ⑤ The manufacturer will join the rod and the end plates by TIG welding (Figure 4-12). The total number of the weld passes are six to ten, and weld overlay is necessary. During the welding process, the manufacturer will carry out visual inspection at every pass and PT inspection at several passes to confirm whether the welding joints are full penetrated.
- ⑥ The manufacturer will join the rod and the pipes with flange by TIG welding (Figure 4-13). The total number of the weld passes are one to three, and weld overlay is necessary. The manufacturer will carry out visual inspection at every pass during the welding process and then will carry out PT inspection after welding to confirm whether the welding joints are full penetrated.
- ⑦ The manufacturer will carry out RT inspection to check any defect on the welded joint.
- ⑧ The manufacturer will weld the bosses to the rod and will carry out visual inspection and PT inspection (Figure 4-14).
- ⑨ The manufacturer will finish the shape of both end plates at the dimension of 120x120 mm and will finish the length between the both plates 570 mm with 0.1 mm parallelism.
- ⑩ The manufacturer will drill holes in the end plates and will add cutout to the end plates (Figure 4-15).
- ⑪ The manufacturer will confirm whether major dimensions comply with the drawings.
- ⑫ The manufacturer will degrease the connecting rods with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the connecting rods.

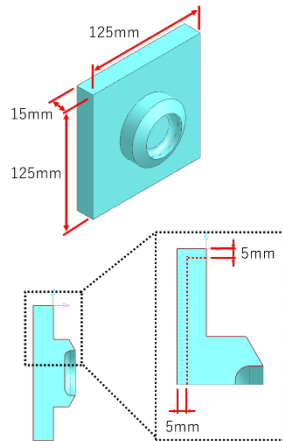


Figure 4-9 End plate

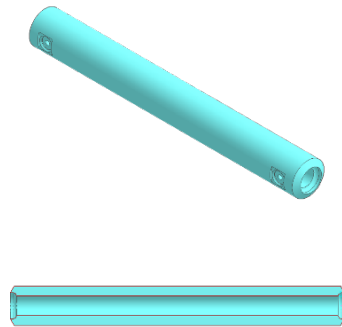


Figure 4-10 Rod

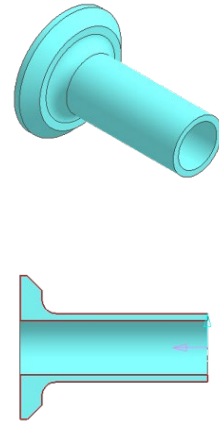


Figure 4-11 Pipe with flange

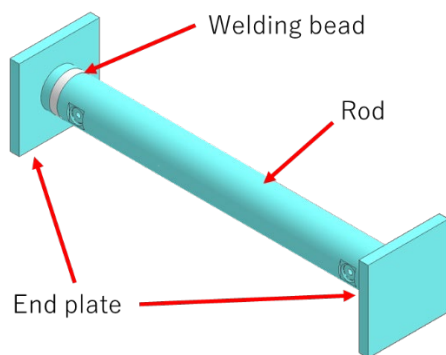


Figure 4-12 Welding rod and end plates

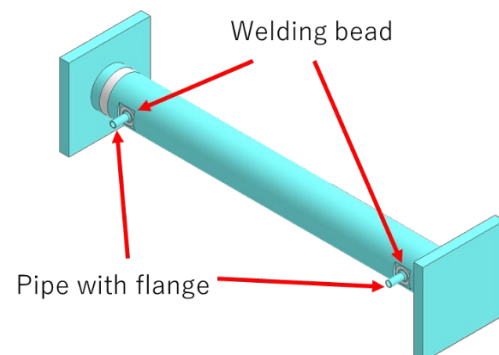


Figure 4-13 Welding rod and pipes with flange

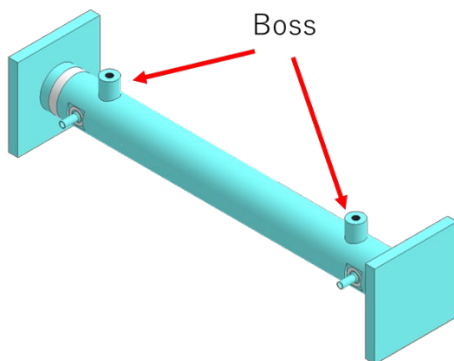


Figure 4-14 Welding rod and bosses

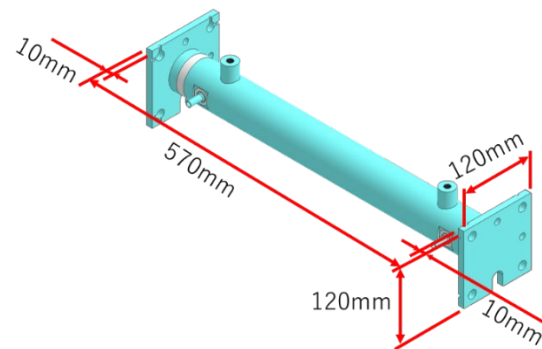


Figure 4-15 Final process of end plates

4.8 Interface pipe

Title (Drawing number) (*)	Interface pipe (2EMM-002)
Materials	SS316LN-IG
Material dimensions (*)	$\phi 9.53 \times 1t-240 \sim 615L$
Quantity	4
Processing time	2 hours per pipe
Processing machine	CNC Pipe Bender (OPTON. Co. Ltd S-ECO 15 or equivalent)

[Notes] The drawing 2EMM-002 is a representative one, and the material dimensions is applicable to just 2EMM-002. The manufacturer shall prepare all drawings of the interface pipes and shall evaluate the material dimensions for all the interface pipes.

Manufacturing procedure

- ① The manufacturer will shape pipes with CNC pipe bender and will cut them.
- ② The manufacturer will degrease the pipes with neutral detergent first and will clean them with ethanol-based cleaning solution so as not to remain processing oil on the surface of the pipes.
- ③ The manufacturer will confirm whether major dimensions comply with the drawings.
- ④ The manufacturer will clean the inside of the pipes and will cover the entrance of the pipes to prevent adhesion foreign objects.

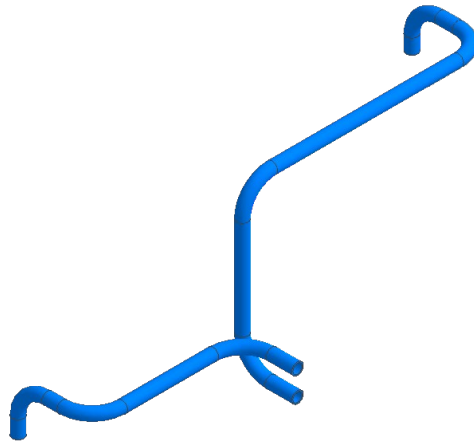


Figure 4-16. Interface pipe

5 Assembly of Mirrors and Other Components

This section describes materials, material dimensions, quantity, processing time, processing machines, manufacturing procedure, inspections and cleaning procedures of the manufacturing procedure that was called “the assembly of mirrors and other components” in Figure 2-1.

5.1 UEMM/LEMM Base Plate First Assembly

Title (Drawing number)	UEMM M1 base plate first assembly (3UEMM-001) LEMM M1 base plate first assembly (3LEMM-001) UEMM M2 base plate first assembly (3UEMM-002) LEMM M2 base plate first assembly (3LEMM-002)
Materials	W, CuCrZr, SS316LN-IG
Material dimensions	-
Quantity	4
Processing time	10 hours per assembly
Processing machine	TIG welding machine (DAIHEN Corporation DT300P or equivalent)

Manufacturing procedure

- ① The manufacturer will assemble the mirror assemblies (4EMM-001 described in Section 3.7), the pipe supports (4EMM-002 described in Section 4.3), the rods (4EMM-003 described in Section 4.4) and the base plates brazed to the cooling pipe (4UEMM-001, 4UEMM-002, 4LEMM-001, and 4LEMM-002 described in Section 4.2).
[Note]The manufacturer shall protect the surface of the Tungsten mirror (5EMM-001) with plastic film of FUTAMURA CHEMICAL CO., LTD. (self-adhesive OPP film FSA or equivalent).
- ② The manufacturer will change the position of the assemblies by using a crane. Then, the manufacturer will put washers and will conduct tack welding to prevent loosening of rods.
- ③ When the surface is dirty, the manufacturer will clean it with ethanol-based cleaning solution.

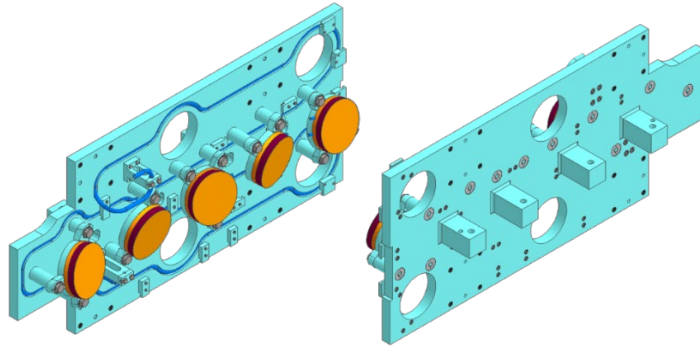


Figure 5-1. First assembly of 3UEMM-001

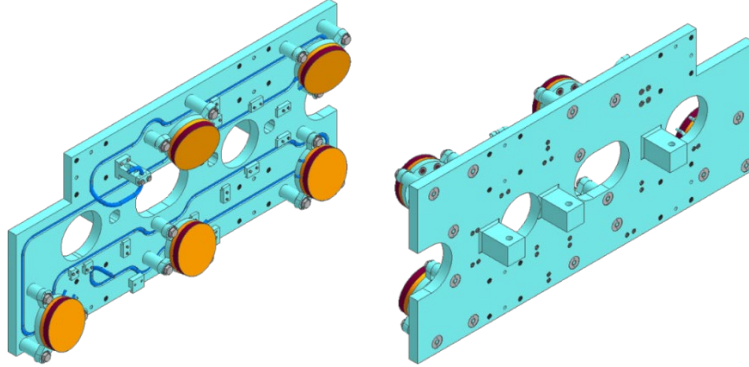


Figure 5-2. First assembly of 3UEMM-002

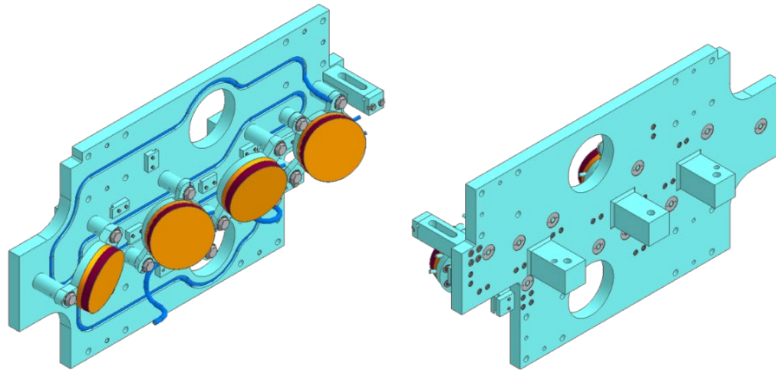


Figure 5-3. First assembly of 3LEMM-001

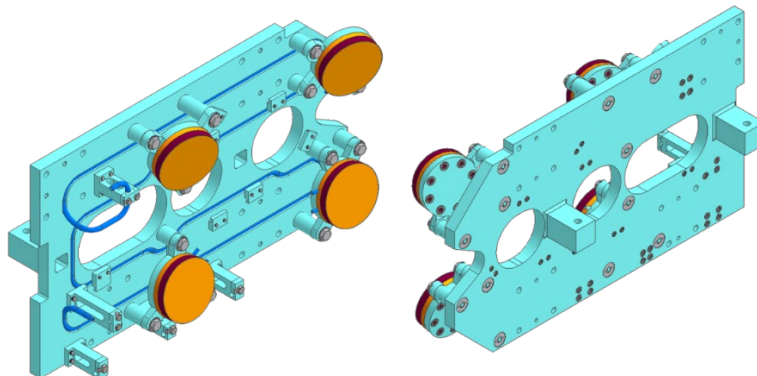


Figure 5-4. First assembly of 3LEMM-002

5.2 UEMM/LEMM Base Plate Second Assembly

Title (Drawing number)	UEMM M1 base plate second assembly (2UEMM-001) LEMM M1 base plate second assembly (2LEMM-001) UEMM M2 base plate second assembly (2UEMM-002) LEMM M2 base plate second assembly (2LEMM-002)
Materials	W, CuCrZr, SS316LN-IG
Material dimensions	-
Quantity	4
Processing time	40 hours per assembly
Processing machine	Automatic welding machine (SWAGELOK orbital welding system series 4,5 or equivalent)

Manufacturing procedure

- ① The manufacturer will weld the reducers (3EMM-001 described in Section 4.5) and the 1/4-inch cooling pipes (3EMM-002 described in Section 4.6) and will weld the pipes of the mirror assemblies (4EMM-001 described in Section 3.7) and the 1/4-inch cooling pipes. The type of welding is a butt welding, and the automatic welding machine will be used.
- ② After welding, RT inspection will be carried out to check welding joints.
- ③ The manufacturer will apply water pressure of 7.0 MPaG to the pipe and check any defect on it.
- ④ The manufacturer will vacuum the pipe, will spray Helium gas on welded parts and will check if helium flows into the pipe by using a residual gas analyzer.
- ⑤ When the surface is dirty, the manufacturer will clean it with ethanol-based cleaning solution.
- ⑥ The manufacturer will cover the entrance of the pipes to prevent adhesion of foreign objects.

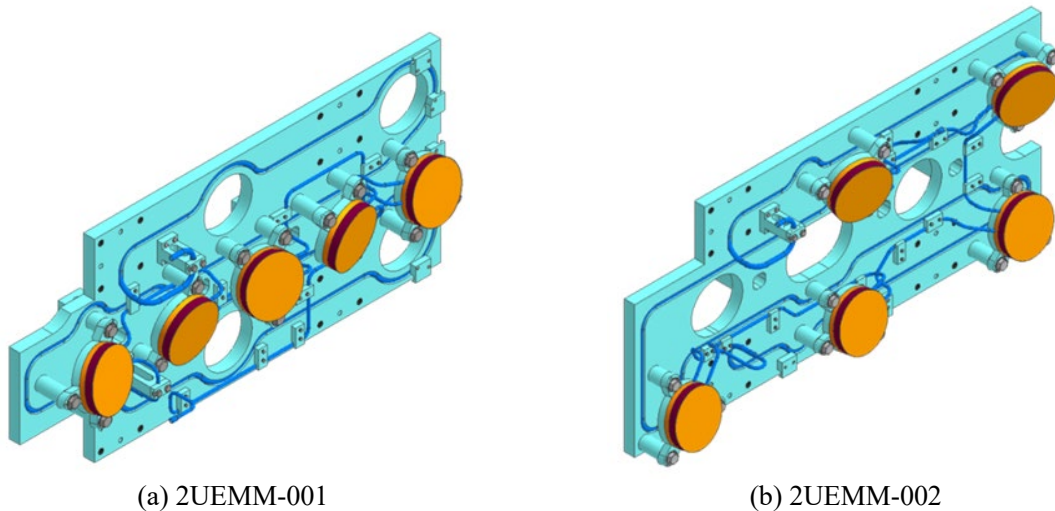
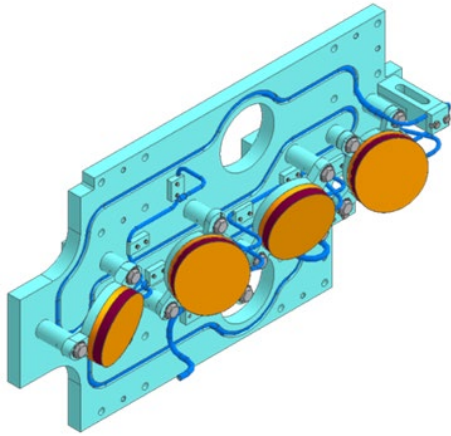
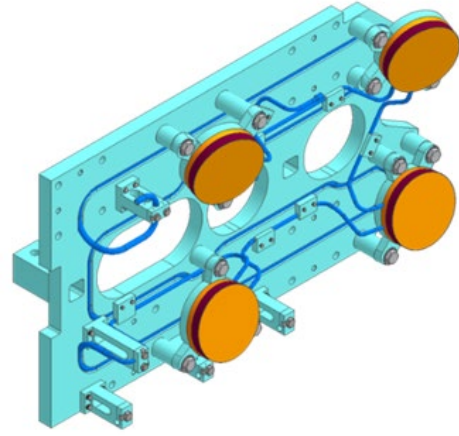


Figure 5-5. Second assembly of UEMM



(a) 2LEMM-001



(b) 2LEMM-002

Figure 5-6. Second assembly of LEMM

5.3 UEMM/LEMM Final Assembly

Title (Drawing number)	UEMM final assembly (1UEMM-001) LEMM final assembly (1LEMM-001)
Materials	W, CuCrZr, SS316LN-IG
Material dimensions	-
Quantity	4
Processing time	35 hours per assembly
Processing machine	Automatic welding machine (SWAGELOK orbital welding system series 4,5 or equivalent)

Manufacturing procedure

- ① The manufacturer will assemble the connecting rods (2UEMM-001 described in Section 4.7) and the base plates after the second assembly (2UEMM-001, 2UEMM-002, 2LEMM-001 and 2LEMM-002 described in Section 5.2)
[Note]The manufacturer shall protect the surface of the Tungsten mirror (5UEMM-001) with plastic film of FUTAMURA CHEMICAL CO., LTD. (self-adhesive OPP film FSA or equivalent).
- ② The manufacturer will attach a jig to the four connecting rods to lift it by using a crane (see Figure 5-7 and Figure 5-8).
- ③ The manufacturer will tilt it by 90 degrees and will place it slowly on the wood. Then, the manufacturer will connect eyebolts to the tabs of the connecting rods, which is on the side of the base plate, and will change the position of the sling belt (Figure 5-9 and Figure 5-10).
- ④ The manufacturer will tilt it by 90 degrees in the same way as the previous procedure and will place it on the wood with the jig attached and with the connecting rods downward (see Figure 5-11 and Figure 5-12).
- ⑤ The manufacturer will lift the base plate assembly (with the connecting rods) vertically and will remove the jig (see Figure 5-13).
- ⑥ The manufacturer will lift down the base plate assembly with the connecting rods onto the other base plate assembly and will bolt them (see Figure 5-14).
- ⑦ The manufacturer will weld the connecting rods and the interface pipes (2UEMM-002 described in 4.8). The type of welding is a butt welding, and the automatic welding machine will be used.
- ⑧ The manufacturer will vacuum the pipe, will spray Helium gas on welded parts and will check if helium flows into the pipe by using a residual gas analyzer.
- ⑨ The manufacturer will apply water pressure of 7.0 MPaG to the pipe and check any defect on it.
- ⑩ When the surface is dirty, the manufacturer will clean it with ethanol-based cleaning solution.
- ⑪ The manufacturer will cover the entrance of the pipes to prevent adhesion of foreign objects.

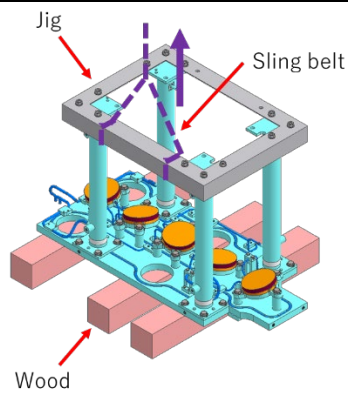


Figure 5-7. Assembly 1

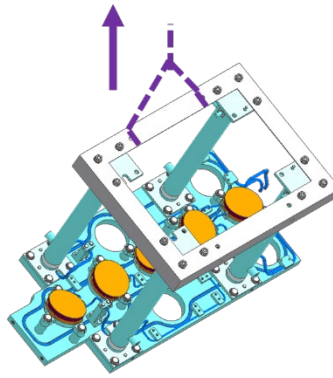


Figure 5-8. Assembly 2

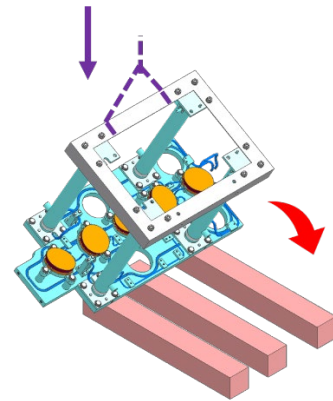


Figure 5-9. Assembly 3

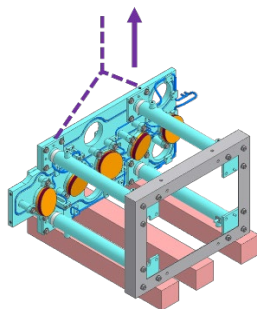


Figure 5-10. Assembly 4

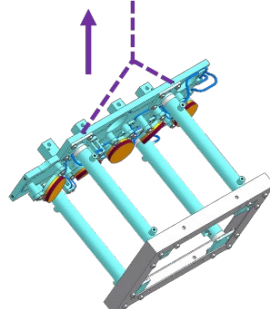


Figure 5-11. Assembly 5

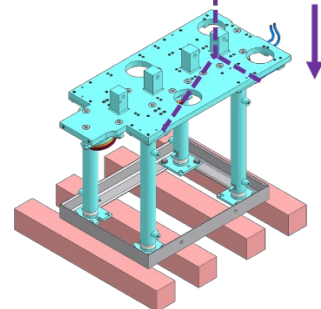


Figure 5-12. Assembly 6

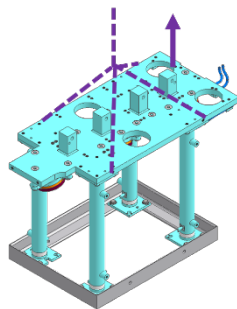


Figure 5-13. Assembly 7

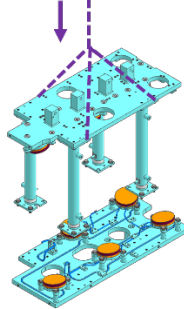


Figure 5-14. Assembly 8

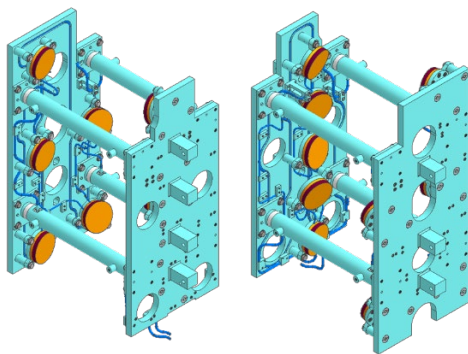


Figure 5-15. UEMM after final assembly

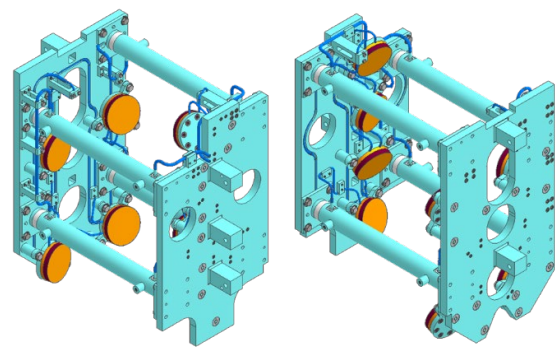


Figure 5-16. LEMM after final assembly

5.4 Mirror Angle Adjustment

The manufacturer will adjust the mirror angle so that the laser light beam reflected by the mirrors will reach the targets. The manufacturer will set the EMM, the laser incident position and the targets at the same position of the EMM installed at ITER site, vacuum windows and retroreflectors, respectively. When setting them, the manufacturer will use a laser tracker. The manufacturer will adjust the angle of the mirrors by inserting shims between the base plates and the rods.

5.5 Baking Procedure for Degassing

The manufacturer will bake out the products in vacuum to degas. The baking temperature will be 240 degrees Celsius, and the baking duration will be 24 hours. The details shall be in accordance with Section 26.2 of ITER Vacuum Handbook (ITER_D_2EZ9UM v2.5).

5.6 EMM Final Assembly

Title (Drawing number)	EMM final assembly (0UEMM-001)
Materials	W, CuCrZr, SS316LN-IG
Material dimensions	-
Quantity	1
Processing time	-
Processing machine	-

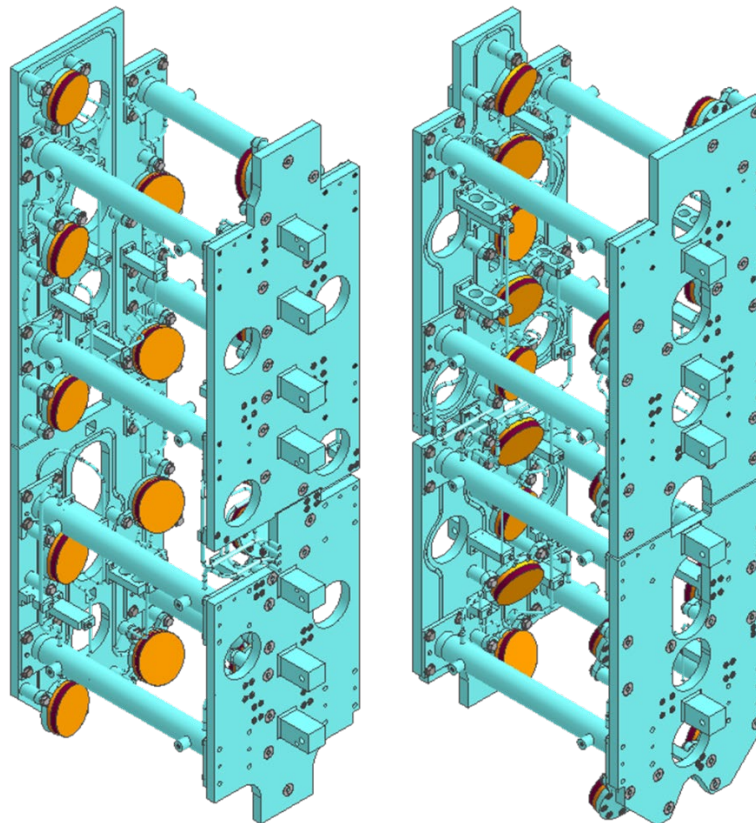


Figure 5-17. EMM

6 Conclusion

This report shows how to manufacture, inspect and assemble EMM. Since there is no unclear manufacturing process, it can be reasonably concluded that EMM is manufacturable.

Appendix A. List of purchases

Table 0-1 shows the list of purchases such as bolts and washers used for EMM.

Table 0-1. List of purchases for EMM

Parts	Model number	Material	Qty.	Manufacturer
Washer	FWSUS-D17.5-V10-T2	SS316L	144	MISUMI Group Inc.
Toothed lock washer	AW02	SS304	118	Nikki Trading Corp.
Washer	FWSUS-D15-V10-T2	SS316L	90	MISUMI Group Inc.
Washer with ventilation grooves	SWAS-12-VF	SS304	54	Nabeya Bi-tech Kaisha
Hexagon socket head cap screw (DLC coated)	M10-20L (custom made products)	W	144	KOYO
Hexagon head bolt	M12-25L	SS316L	54	Not specified
Hexagon head bolt	M12-30L	SS316L	64	Not specified
Hexagon socket head cap screw	M8-20L	SS316L	3	Not specified
Hexagon socket head cap screw	M8-25L	SS316L	87	Not specified



Factory Qualification Test Plan of PoPola Mirror Modules in Equatorial Port Plug 10

ITER Project Japan Domestic Agency

This document was prepared for FDR. The factory qualification test plan will be updated by a contractor who will be determined after tendering the manufacturing of PoPola mirror module in Equatorial Port Plug 10.

	Name	Affiliation	Date	Signature
Reviewers	IMAZAWA Ryota (TRO)	Plasma Diagnostics Group	17-Nov-2021	今澤 良太
Reviewers	YOKOYAMA Masahito	Plasma Diagnostics Group	18-Nov-2021	横山 真仁
Approver	HATAE Takaki (RPGL)	Plasma Diagnostics Group	19-Nov-2021	渡多江 仰紀

Change log

Branch no. (date) (IDM number)	Change description
- (17 Nov 2021) (69765M v1 0)	First version

Table of Contents

1. Purpose.....	4
2. Abbreviations	5
3. References.....	5
4. System Description	6
5. Factory qualification test plan for CCR	7
5.1. Classification of component	7
5.2. Qualification test items	7
5.2.1. Qualification of Manufacturing Connecting Rod.....	8
5.2.2. Qualification of Manufacturing Baseplate	9
5.2.3. Qualification of Manufacturing Mirror Assembly	10
5.2.4. Common Notices to Qualification	11

1. Purpose

This document is a plan (“Factory Qualification Test Plan”) prepared for the necessary qualification tests prior to manufacturing EPP mirror module (EMM) of 55.C6 Poloidal Polarimeter (PoPola). Figure 1 shows an overview of the PoPola in-vessel components. Especially, components in the scope of this documents are the mirror module in EPP10, which is called EMM.

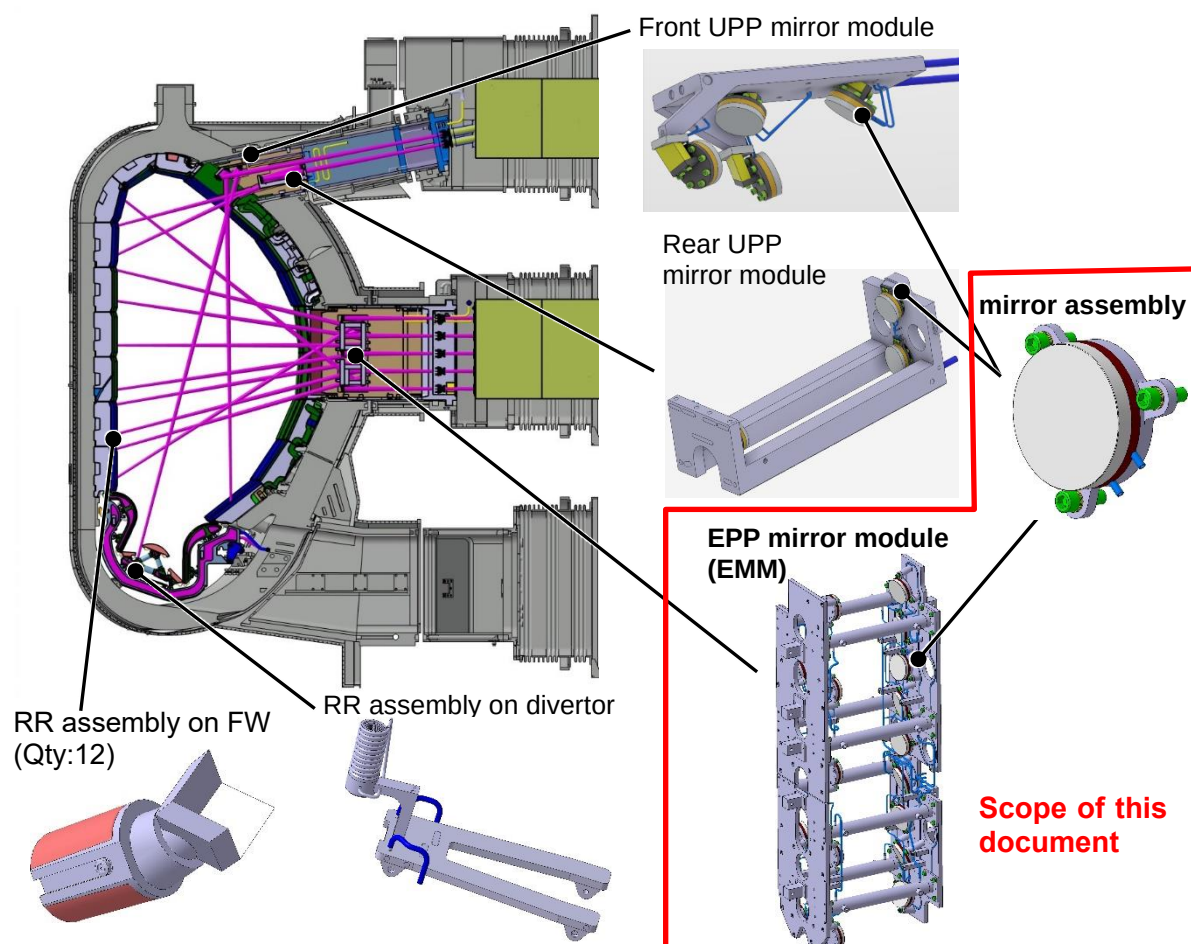


Figure 1 PoPola in-vessel components

2. Abbreviations

Abbreviations of words in this document are shown in Table 1.

Table 1 the abbreviations in this document

EMM	EPP Mirror Module
EPP	Equatorial Port Plug
EPP10	Equatorial Port Plug 10
IVH	ITER Vacuum Handbook
PoPola	Poloidal Polarimeter
TCWS	Tokamak Cooling Water System

3. References

- [1] Technical Description of PoPola Mirror Modules in Equatorial Port Plug 10, [ITER_D_696XRM](#) v1.0 (or JADA-55342DE0101)
- [2] Technical Specification of in-EPP10 components, [ITER_D_696KB9](#) v1.0 (or JADA-55342TS0106)
- [3] Summary report justifying ESPN classification, [ITER_D_696J63](#) v1.0 (or JADA-55342DE0103)
- [4] ITER Vacuum Handbook Appendix 4 Accepted Fluids, [ITER_D_2ELN8N](#) (ver.1.5)
- [5] ITER Vacuum Handbook Appendix 17, [ITER_D_2EXDST](#) (ver. 2.2)
- [6] ITER Vacuum Handbook (IVH), [ITER_D_2EZ9UM](#) (ver. 2.5)

4. System Description

PoPola is a diagnostic system to identify the magnetic field distributions inside the plasma by using a Far Infrared Red (FIR) laser with its wavelength of $118.8\mu\text{m}$ by measuring changes in polarization status of the FIR laser passing through the plasma. EMM, which is one of the components of this diagnostic system, is a reflective mirror installed into the vacuum vessel to propagate the probing laser beams.

EMM consists of mirror assemblies, connecting rods, baseplates, and pipes. Figure 2 and Figure 3 show overview of components and assemblies. Technical description [1] provides the detailed explanation about each component, and technical specification [2] provides the detailed specification that the manufacturer shall comply with.

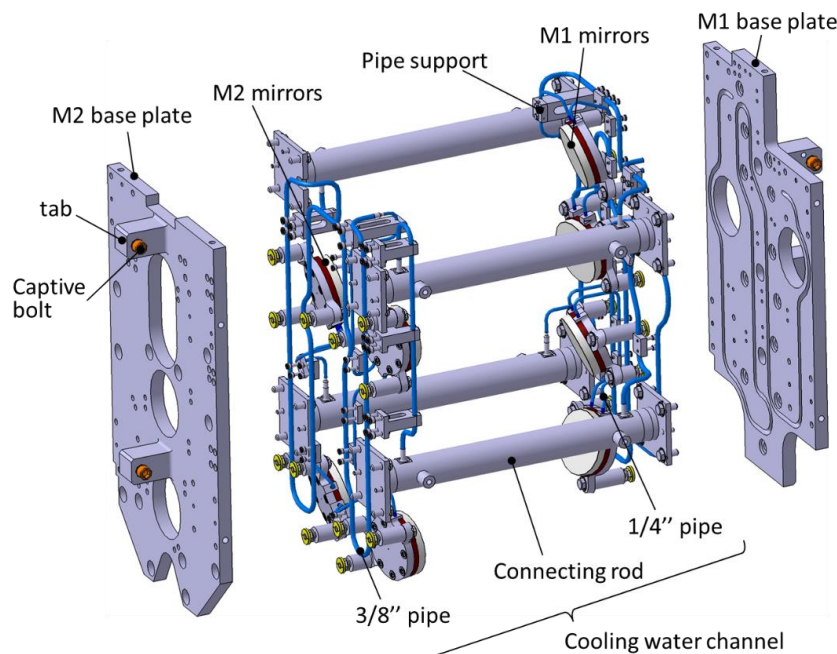


Figure 2. Components of EMM

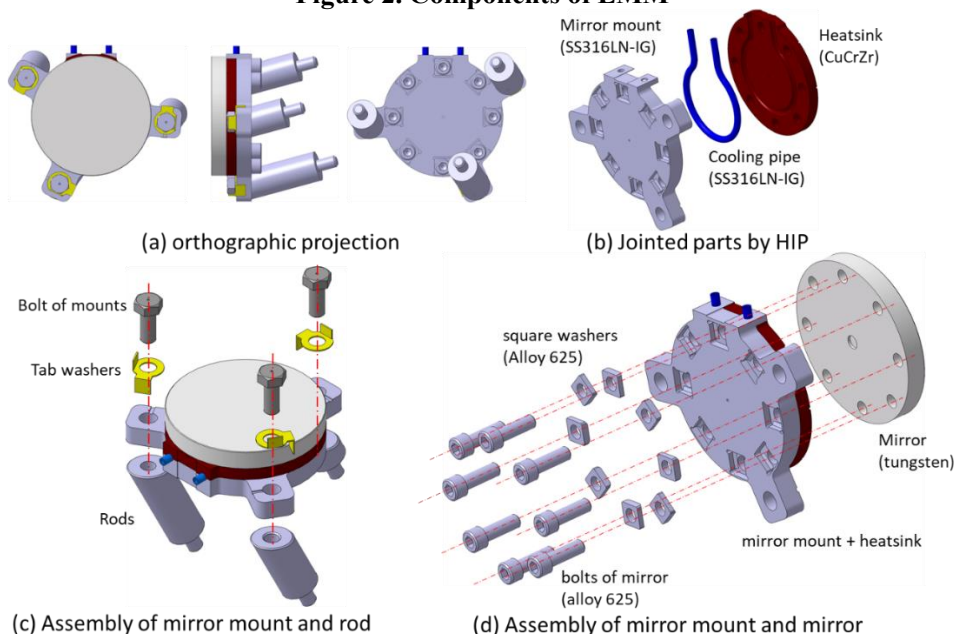


Figure 3. Components associated with mirror mount.

5. Factory qualification test plan for CCR

5.1. Classification of component

Table 2 shows classifications related to the manufacturing of EMM.

EMM shall satisfy the requirements of ESP/ESPN because it uses the cooling water supplied from Tokamak Cooling Water System. The ESPN category is N3 Category 0. Reference [3] provides the justification of the categorization.

“RCC-MRx 2012” is the manufacturing standards to be applied to EMM. The RCC-MRx equipment class is N3.

Table 2 Classification of CBRR

Quality class	QC1
Vacuum class	VAC-1A
RCC-MRx equipment class	N3 _{RX}
ESPN class	N3 _{ESPN} Cat.0

5.2. Qualification test items

Table 3 shows the items of Qualification test to be carried out. The details of each qualification is explained in the following subsections.

Table 3 List of factory qualification test

No.	Components	Purpose of the qualification	Section
(1)	Connecting Rod	— Establishment of welding procedure — Establishment of inspection plan	5.2.1
(2)	Baseplate	— Establishment of the brazing procedure — Evaluation of outgas rate — Evaluation of cooling capability	5.2.2
(3)	Mirror Assembly	— Establishment of HIP procedure — Evaluation of outgas rate	5.2.3

5.2.1. Qualification of Manufacturing Connecting Rod

(1) Testing outline

The manufacturer will make a mockup of the connecting rod by using the same manufacturing process applied to the products. Then, the manufacturer will test the welding joint and the outgas rate.

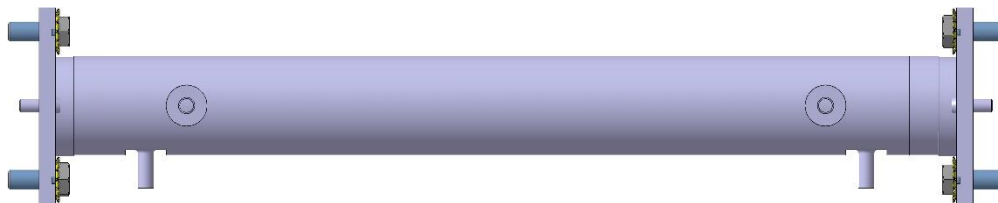


Figure 4. Connecting Rod

(2) Important documents

- i. Technical specification of EMM [2]
- ii. IVH [6], IVH Annexes and IVH appendixes.
- iii. RCC-MRx (TOME 2 “MATERIALS”, TOME 4 “WELDING”)

(3) Testing procedure

The testing sample shall be manufactured complying with the manufacturing work plan that will be approved by ITER Organization before starting qualification test program. The manufacturing work plan will specify the following processes:

- A. Dimensions
- B. Material specifications
- C. Machining tools and cutting oil
- D. Welding procedure
- E. Welding inspection procedure (visual inspection, penetrant testing, radiographic testing, ultrasonic testing, pressure test, helium leak test, transverse tensile test, impact test, metallographic examination, and hardness test)
- F. Visual and dimensional inspection procedure
- G. Cleaning procedure
- H. Test procedure of outgassing rate

Regarding these procedures, the requirements described in the technical specification of EMM [2] shall be complied with.

(4) Evaluation criteria

The evaluation criteria of the qualification are the same as the specification applied to the product [2].

5.2.2. Qualification of Manufacturing Baseplate

(1) Testing outline

The manufacturer will make a mockup of the baseplate by using the same manufacturing process applied to the products. Then, the manufacturer will test the welding joint, the brazing joint and the outgas rate.

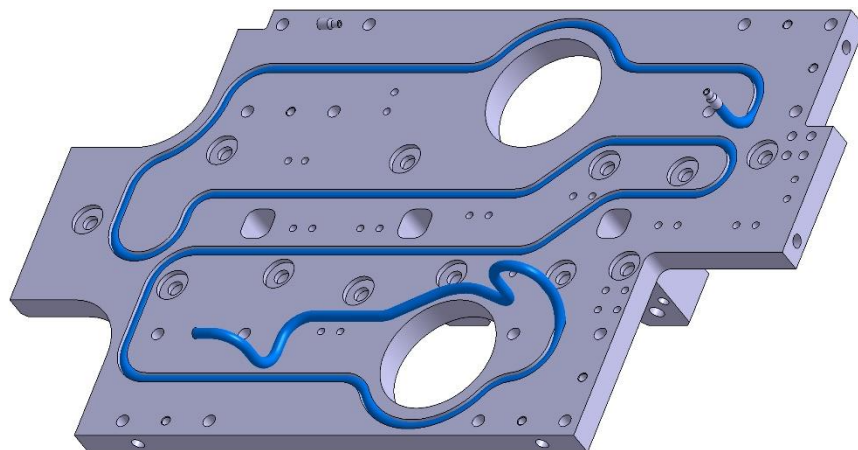


Figure 5. Baseplate

(5) Important documents

- i. Technical specification of EMM [2]
- ii. IVH [6], IVH Annexes and IVH appendixes.
- iii. RCC-MRx (TOME 2 “MATERIALS”, TOME 4 “WELDING”, RF 7300 “BRAZED ASSEMBLIES”)

(2) Testing procedure

The testing sample shall be manufactured complying with the manufacturing work plan that will be approved by ITER Organization before starting qualification test program. The manufacturing work plan will specify the following processes:

- A. Dimensions
- B. Material specifications
- C. Machining tools and cutting oil
- D. Welding procedure
- E. Welding inspection procedure (visual inspection, penetrant testing, radiographic testing, ultrasonic testing, pressure test, helium leak test, transverse tensile test, impact test, metallographic examination, and hardness test)
- F. Brazing procedure
- G. Brazing inspection procedure (visual inspection and thermal response test)
- H. Visual and dimensional inspection procedure
- I. Cleaning procedure
- J. Test procedure of outgassing rate

Regarding these procedures, the requirements described in the technical specification of EMM [2] shall be complied with.

(3) Evaluation criteria

The evaluation criteria of the qualification are the same as the specification applied to the product [2].

5.2.3. Qualification of Manufacturing Mirror Assembly

(1) Testing outline

The manufacturer will make a mockup of the mirror assembly by using the same manufacturing process applied to the products. Then, the manufacturer will test the HIP joint and the outgas rate.

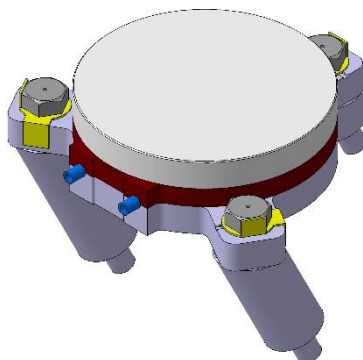


Figure 6. Mirror assembly

(6) Important documents

- i. Technical specification of EMM [2]
- ii. IVH [6], IVH Annexes and IVH appendixes.
- iii. RCC-MRx (TOME 2 “MATERIALS”)

(2) Testing procedure

The testing sample shall be manufactured complying with the manufacturing work plan that will be approved by ITER Organization before starting qualification test program. The manufacturing work plan will specify the following processes:

- A. Dimensions
- B. Material specifications
- C. Machining tools and cutting oils
- D. HIP procedure
- E. HIP inspection procedure (destructive examination)
- F. Visual and dimensional inspection procedure
- G. Cleaning procedure
- H. Test procedure of outgassing rate

Regarding these procedures, the requirements described in the technical specification of EMM [2] shall be complied with.

In order to inspect the HIP joint, destructive examination is necessary. Thus, the two mockups of the HIP joint are necessary. One is used for the destructive examination, and the other is used for the test of the outgassing rate.

(3) Evaluation criteria

The evaluation criteria of the qualification are the same as the specification applied to the product [2].

5.2.4. Common Notices to Qualification

This section gives common notices that is applicable to several qualification described in Table 3.

- When measuring the outgassing rate, a high precision gas measuring device will be used, and the principle of the device shall be a dynamic flow method (see Reference [5]).
- This document was prepared for FDR, and cutting oils and cleaning fluids are not determined yet at this moment. The cutting oils and cleaning fluids will be specified by a contractor who will be determined after tendering the manufacturing of PoPola EMM. If the contractor would specify a special fluid, the acceptance for use of the fluid will be checked by ITER Vacuum responsible officer in accordance with IVH.
- RCC-MRx RS3231.2 requires the destructive tests. The manufacturer can make the destructive tests by using welded coupons or can make the destructive tests by using the mockups that are made for Sections 5.2.1 and 5.2.2.