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Improvement in Cavity Fabrication Technology and Cost Reduction Methods

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H. Hara, H. Hitomi, K. Kanaoka, T. Yanagisawa

MHI Japan

Contents

1-1 SRF activities at MHI

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‘86~ Tristan Cavity 36sets

1-1 SRF activities at MHI

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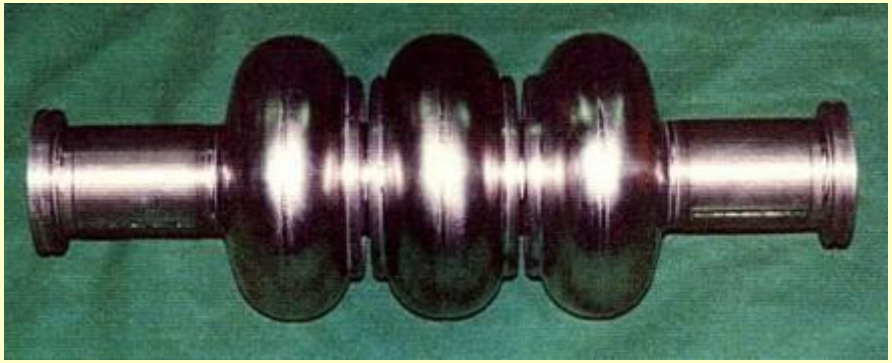

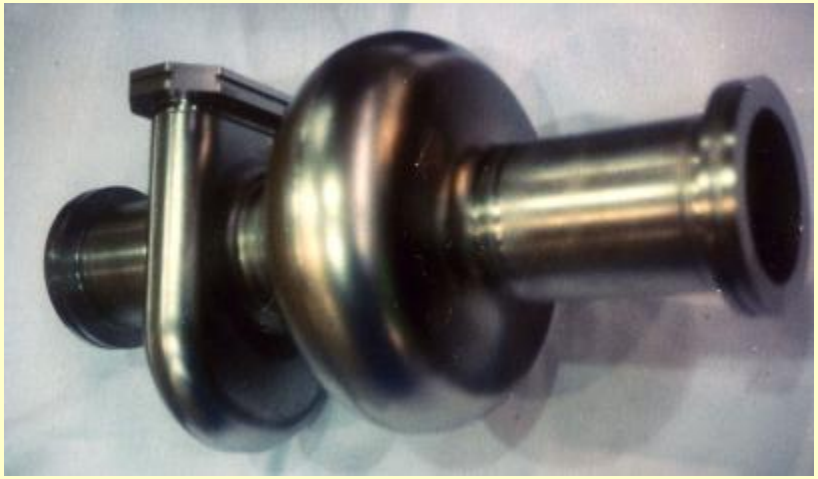

’90~ L-band Cavity

1-1 SRF activities at MHI

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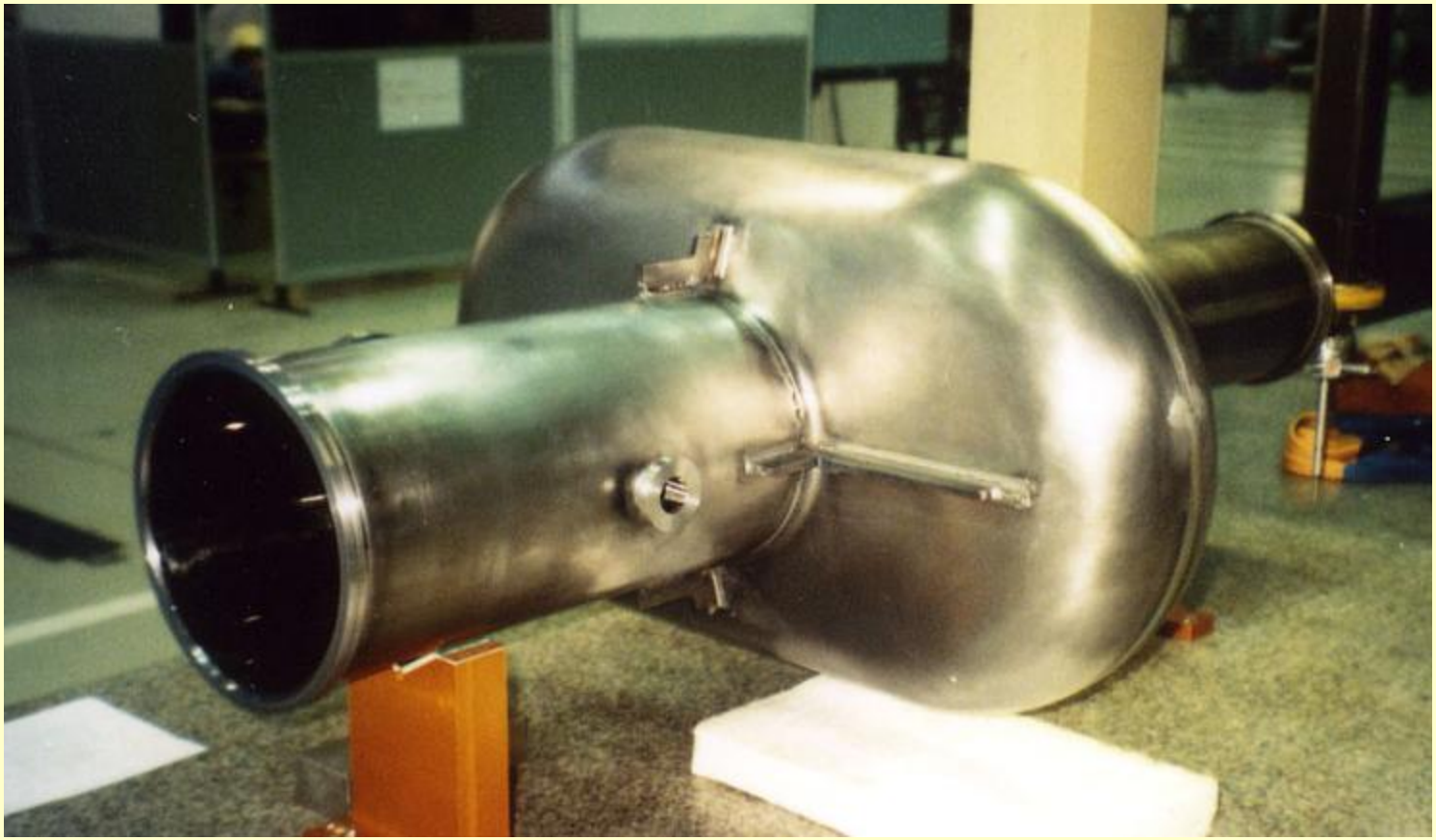

’02~ Crab Cavity 2 sets

1-1 SRF activities at MHI

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Courtesy of KEK

’06~ ERL Cavity 9 sets

1-1 SRF activities at MHI

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’05~ STF Cavity 22 sets

1-2 Activities for improvement of cavity performance

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In case of KEK STF cavities

Phase	Cavity No.	Thickness of thinning	Shape of groove	Bead condition	Frequency of chemical polishing	Management of cleanness	High pressure gas safety law
1.0	#1-4	2.5 mm	Butt	Bumpy	Only after thinning	Air duster	–
1.5	#5-6 #7-9	2.0 mm		Smoother	Each step (just before EBW)	Clean area	–
	#10-11		Step	Flatter			–
2.0	#12-22			More stable		Air top gun	Adapted

1-3 Recent result of vertical test for STF Cavity

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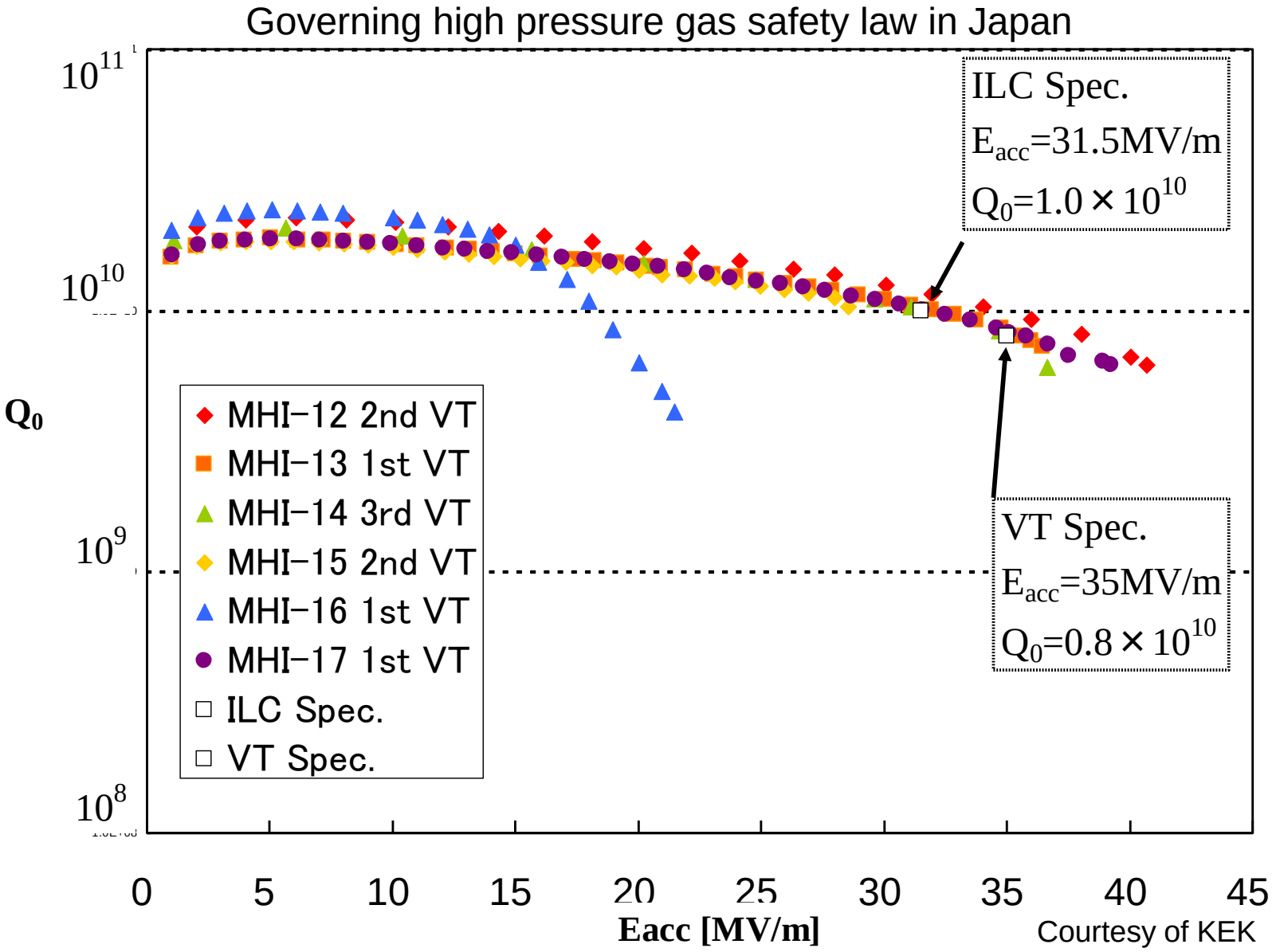

Courtesy of KEK

1-3 Recent result of vertical test for STF Cavity

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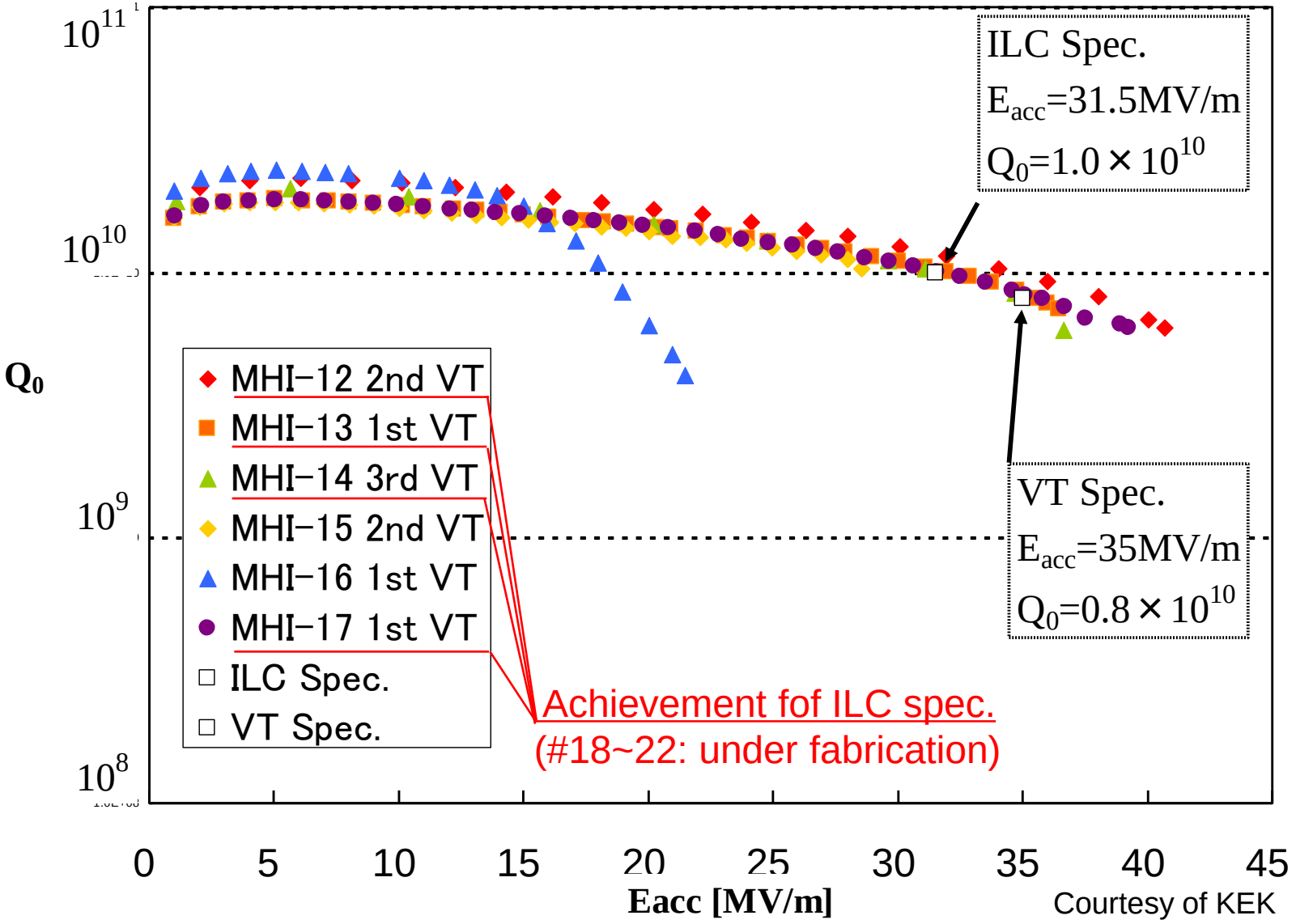
Governing high pressure gas safety law in Japan



Courtesy of KEK

Contents

2. Improvement in cavity fabrication method for cost reduction

General principles about cost reduction for mass-production:

1. Reducing number of parts Cavity have more than 50 parts
2. Automation or outsourcing
3. Batch process
4. Reducing process time
   - Change of fabrication procedure
   - Using special jig and machine
   - Optimization of machine time and factory layout

2. Improvement in cavity fabrication method for cost reduction

List of our proposed fabrication methods

Applied to Production cavities
- To simplify inner conductor of HOM coupler design
- Seamless beam-pipe (deep-drawing)

Applied to R&D cavities
- Using LBW instead of EBW for stiffener and flange
- Automatic finishing for inner surface of cell
- Seamless dumbbell

Under development
- Using brazing instead of EBW for stiffener and flange

Proposal
- Combination of pick-up port and flange
- Combination of base-plate and beam tube

2-1 Fabrication of MHI-A cavity

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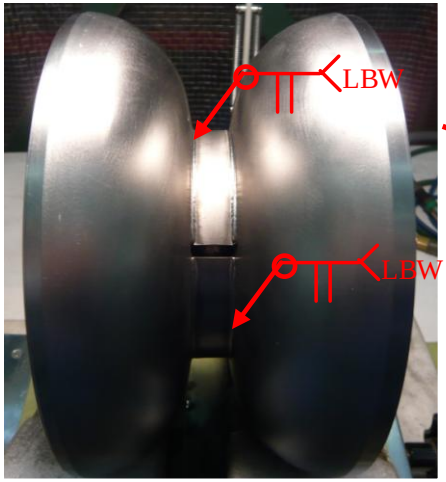
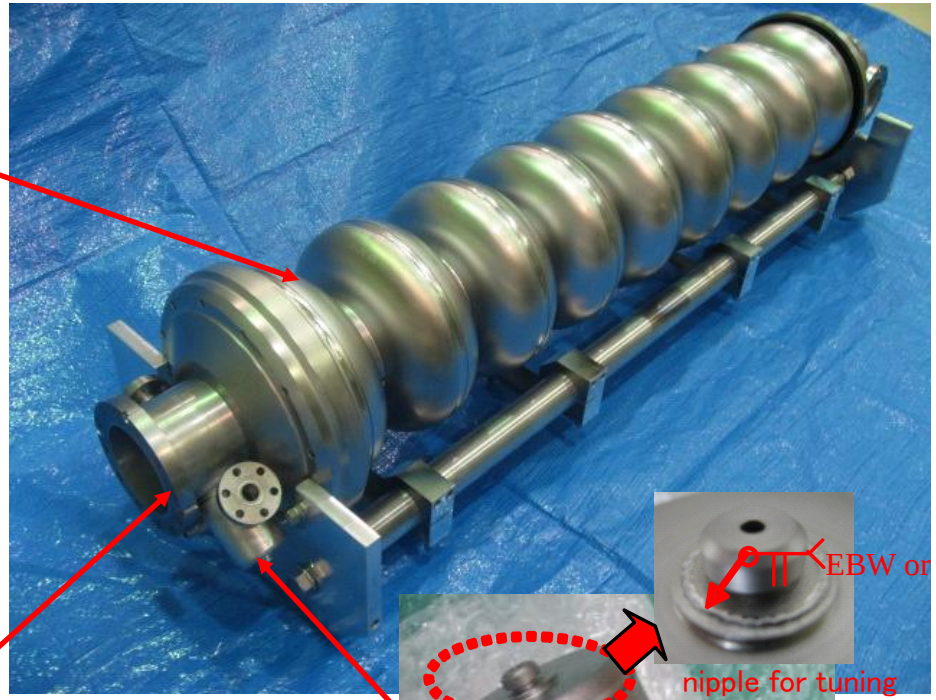
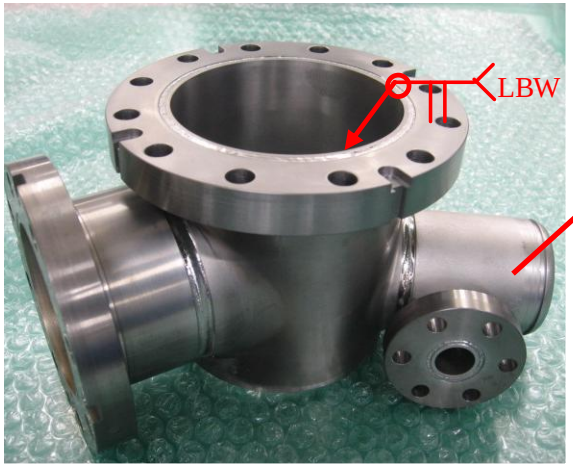
MHI-A was fabricated in order to establish new methods such as
- Deep drawing for HOM cup
- LBW for stiffener ring and flanges of beam tube







2-1 Deep drawing for HOM coupler (MHI-A)

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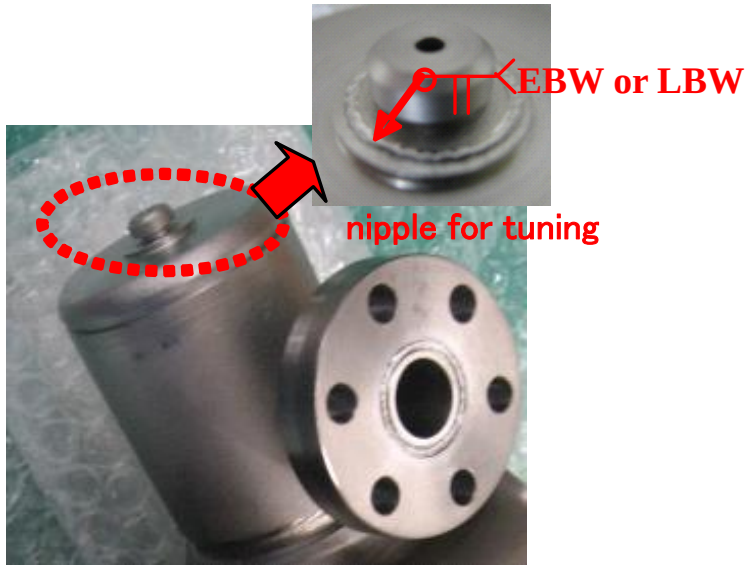
- Machining was used at the top of cup and the welding groove
- A nipple to tune a notch frequency was fixed by welding
- No finishing for Inner surface

We expect ▲30% cost reduction from prior method.

Nb disk φ130-3t

Forming

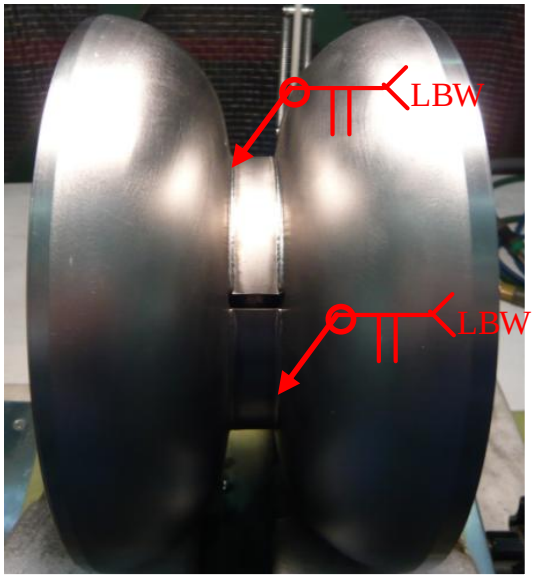
Machining



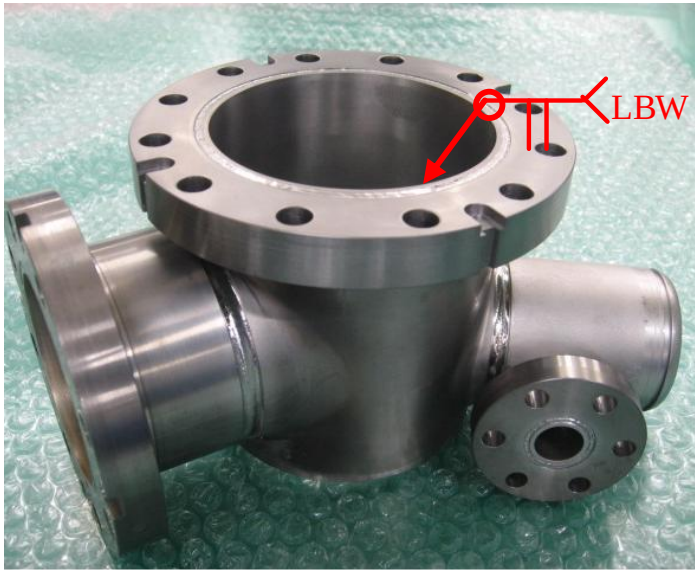
EBW for nipple, port and inner conductor

2-1 LBW for stiffener rings and flanges (MHI-A)

- Cooling time is shorter than EBW.
- Vacuum condition is not required.
  - **argon gas atmosphere**
  - **oxygen content controlled**
- LBW bead was equivalent to EBW bead



For dumbbell stiffener rings



For beam tube flanges

2-1 1st VT Result of MHI-A cavity

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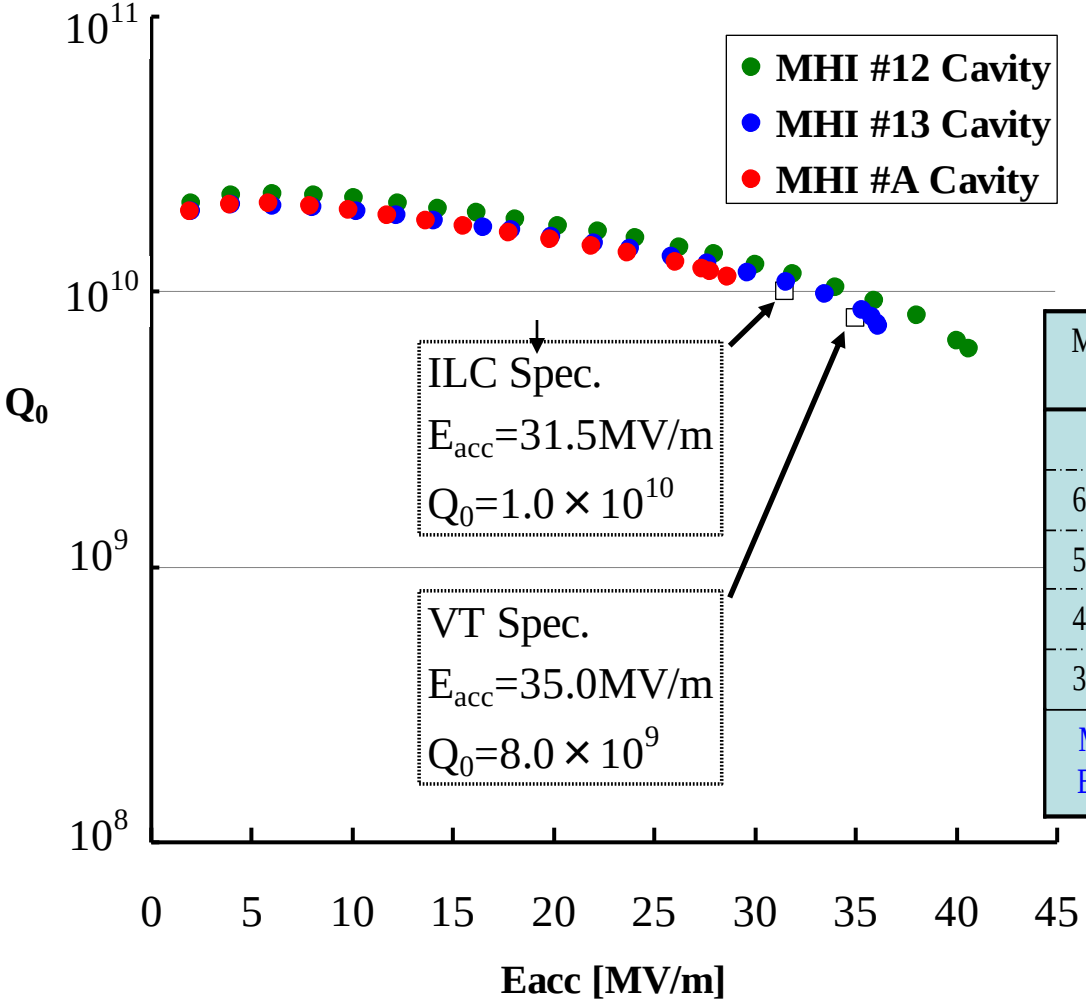
- The MHI-A cavity achieved 29.5 MV/m without problem at LBW points and HOM coupler.
- We found these new techniques can be available for future cavities.



Mode	Achieved Eacc [MV/m] 1&9 cell	2&8 cell	3&7 cell	4&6 cell	5 cell	Course of Eacc Limit
π	29.05	29.05	29.05	29.05	29.05	Heating @ 8 cell
6/9 π	>39.91	0	>39.91	>39.91	0	Input Power Limit
5/9 π	32.42	22.05	38.26	6.48	41.17	Heating @ 5 cell
4/9 π	21.34	27.96	12.16	30.94	0	Heating @ 8 cell
3/9 π	14.76	29.52	14.76	14.76	29.52	Heating @ 8 cell
Max Eacc	>39.91	29.52	>39.91	>39.91	41.17	No Heating @ LBW points

Courtesy of KEK

Contents

2-2 Seamless dumbbell 2 cell cavity (MHI-B)

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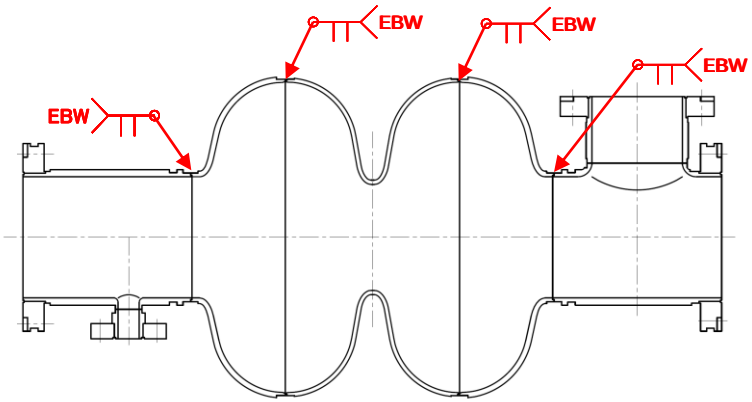
Target :
Inspecting a performance of seamless dumbbell.



Under fabrication

Seamless dumbbell

This cavity is developed by JLab, KEK, and MHI.

End cell

Beam tube

Feature
- No welding seam on iris and longitudinal line.
- Finishing for inner surface of dumbbell is auto buffing.
- Easy to inspect inner surface
- Easy to handle the forming die

2-2 Forming technique for seamless dumbbell

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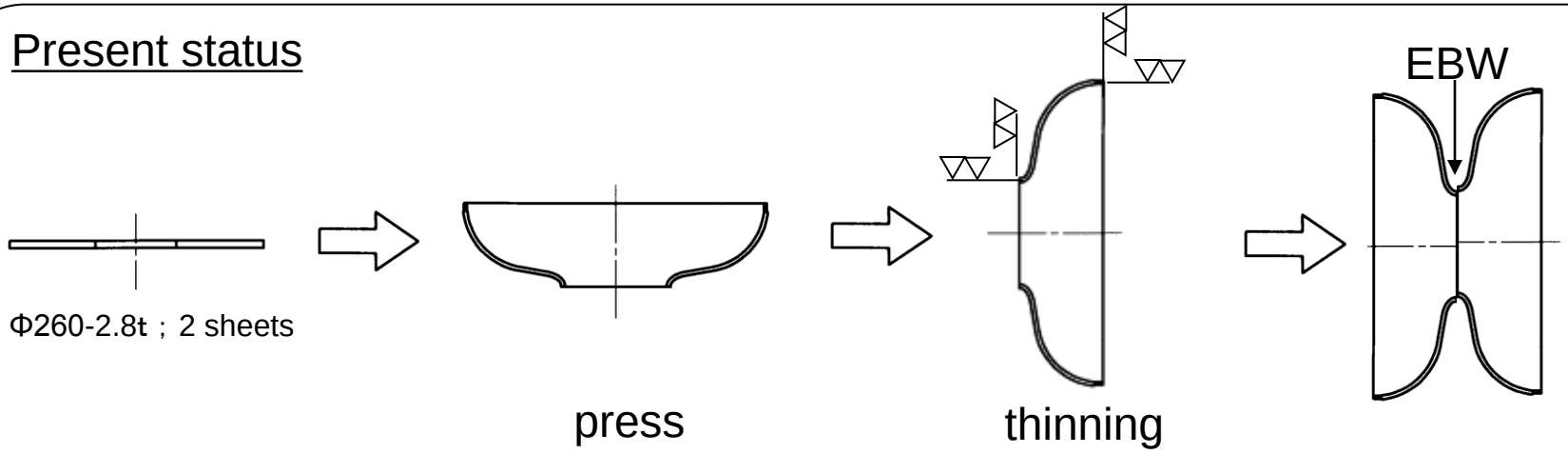
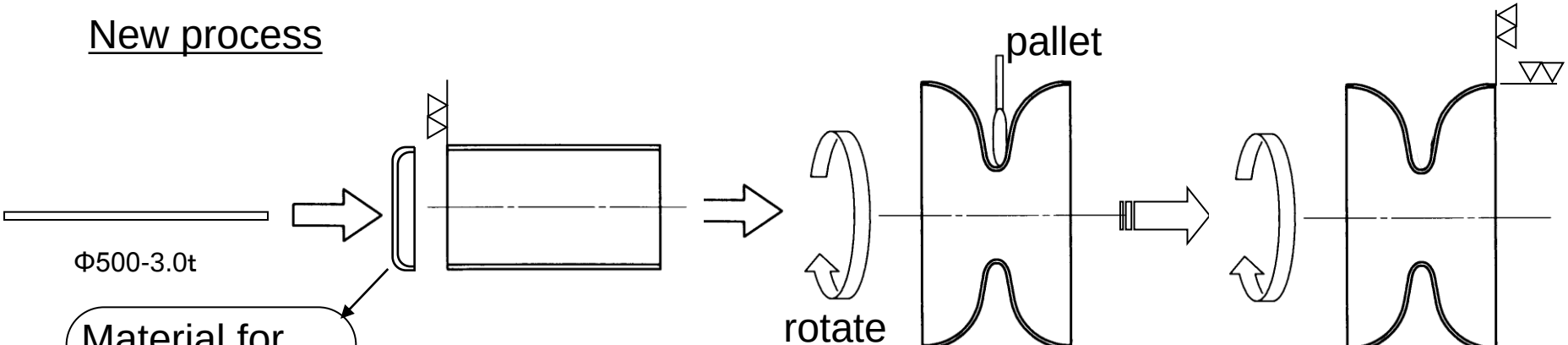
Present status



New process



Material for
- Input port
- HOM coupler
- Stiffener ring

We expect ▲50% cost reduction from prior method.

2-2 Details of seamless dumbbell

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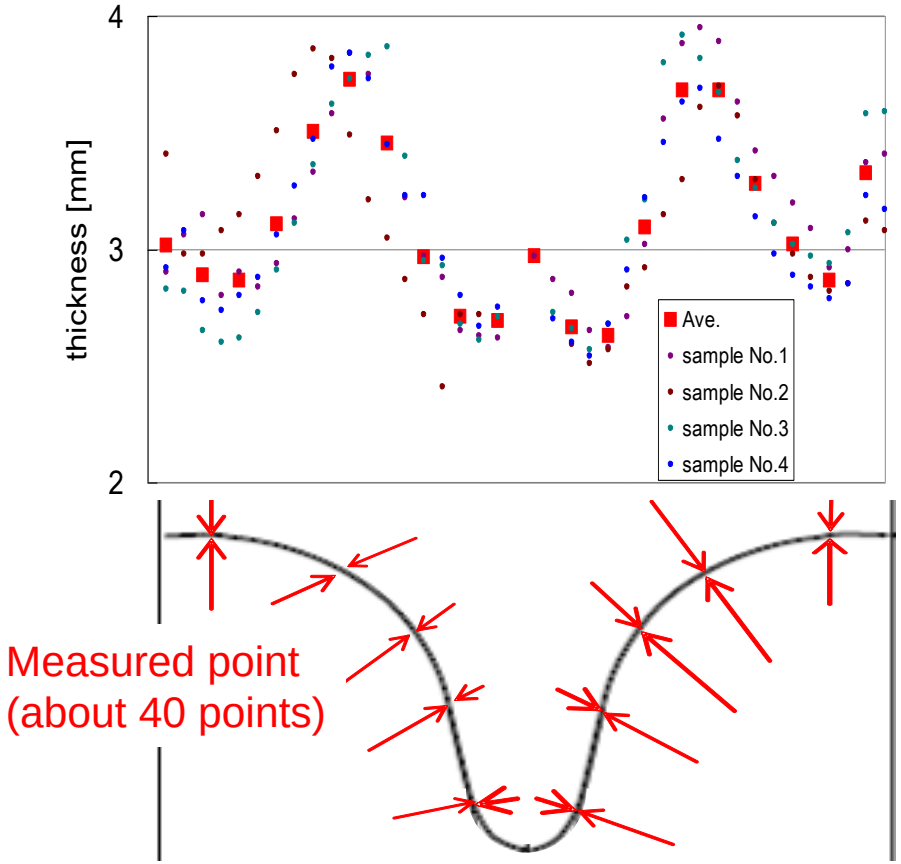
- Seamless pipe was produced by deep drawing(t = 2.87 - 3.05 mm)
- Inside shapes deviation from design was less than 0.5 mm
- It is possible to improve cell shape and deviation of thickness by changing die shape or forming condition.



Deviation of thickness

Reported in EPAC08

Forming pipe made by **spinning**

rough

Recent condition

smoother

Forming pipe made by **deep drawing**

Quality of inner surface

2-2 Auto finishing for inner surface

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- It takes much time for finishing by human hand.
- Finishing should be done automatically with a robotic finisher.
- We are developing auto buffing and carrying out basic test.

Present status

Auto buffing test; case of seamless dumbbell

Ra≒80 before

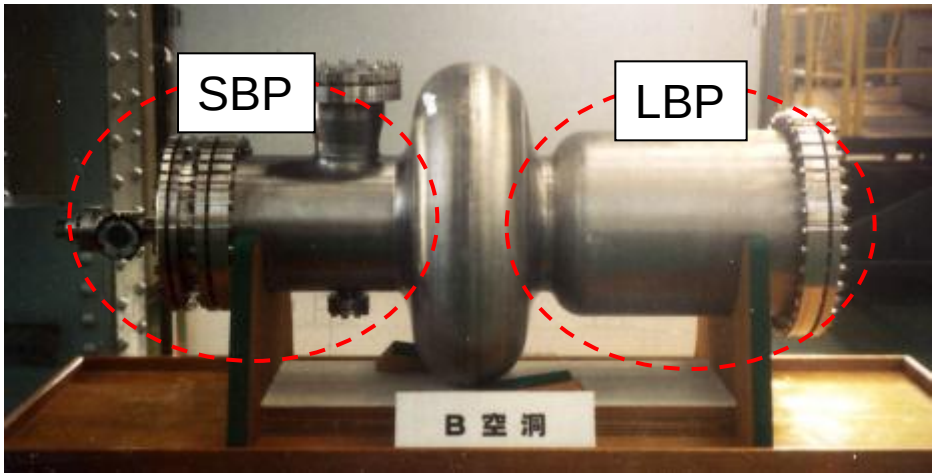
We expect ▲80% cost reduction from prior method.

after Ra≒2

MHI-B cavity will be assembled in August and tested at JLab.

Contents

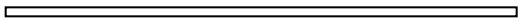
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology



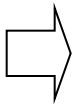
508MHz 1cell Cavity (For KEKB R&B：Prior process)

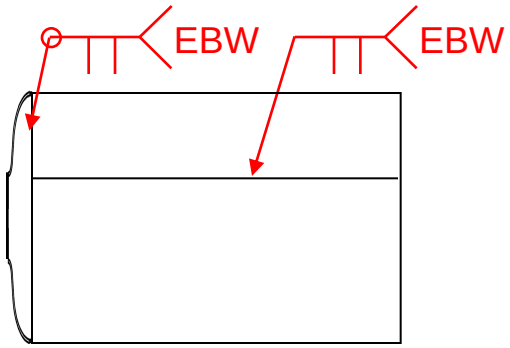
Prior process

LBP



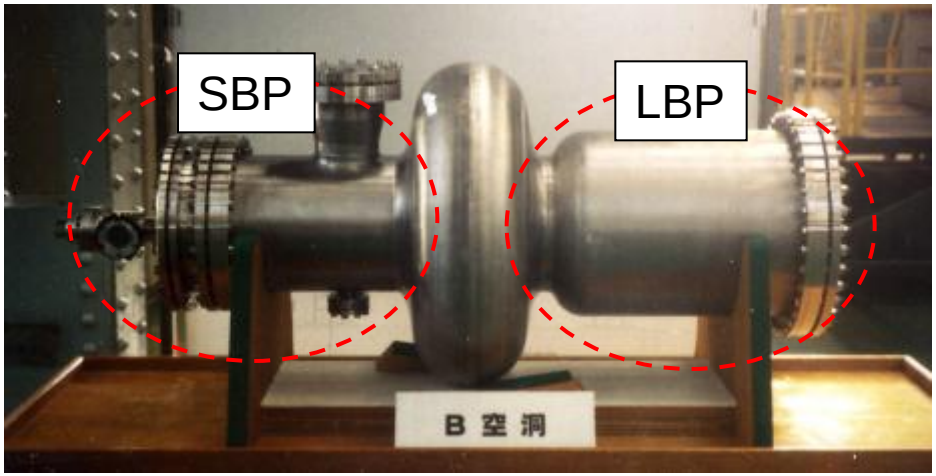
t3.0mm Niobium sheet





Roll forming and EBW

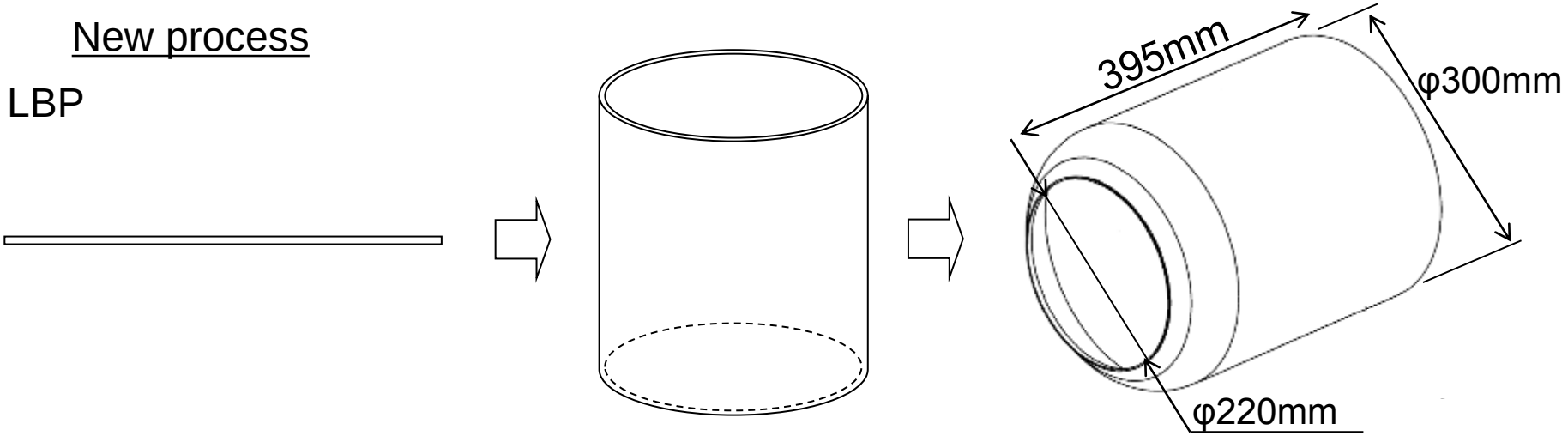
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology



508MHz 1cell Cavity (For KEKB R&B：Prior process)

New process

LBP

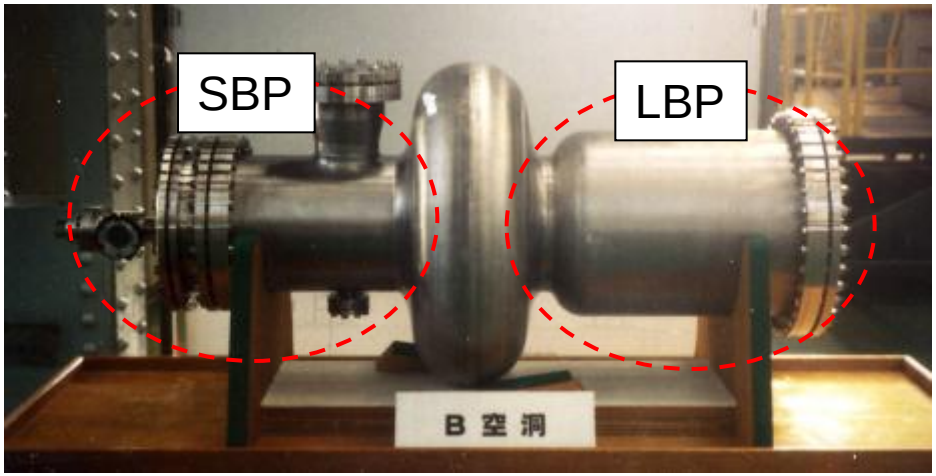


t3.0mm Niobium sheet

Deep drawing

Bulge forming

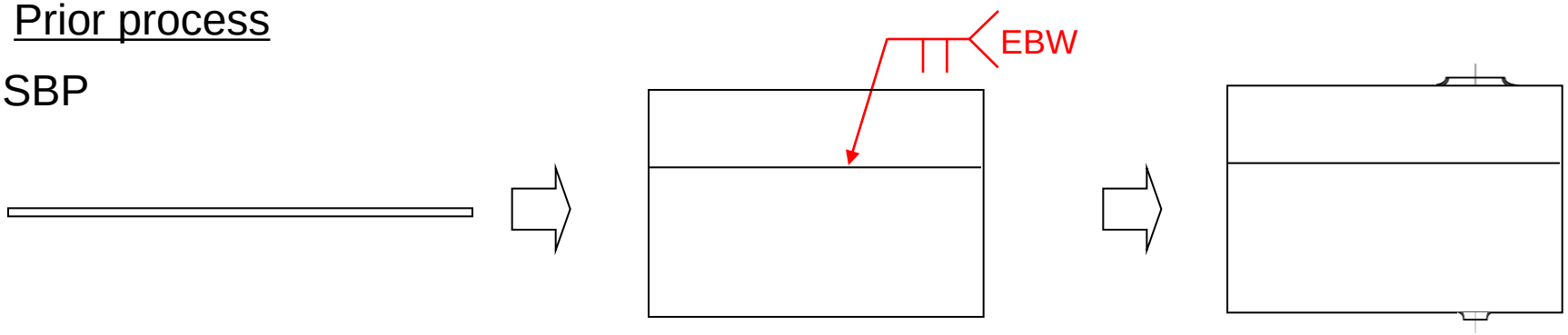
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology



508MHz 1cell Cavity (For KEKB R&B：Prior process)

Prior process

SBP

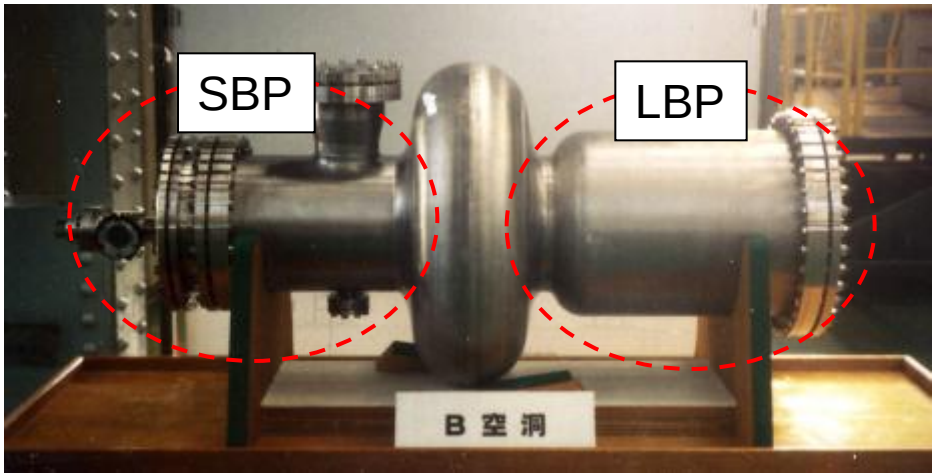


t3.0mm Niobium sheet

Roll forming and EBW

Bulge forming

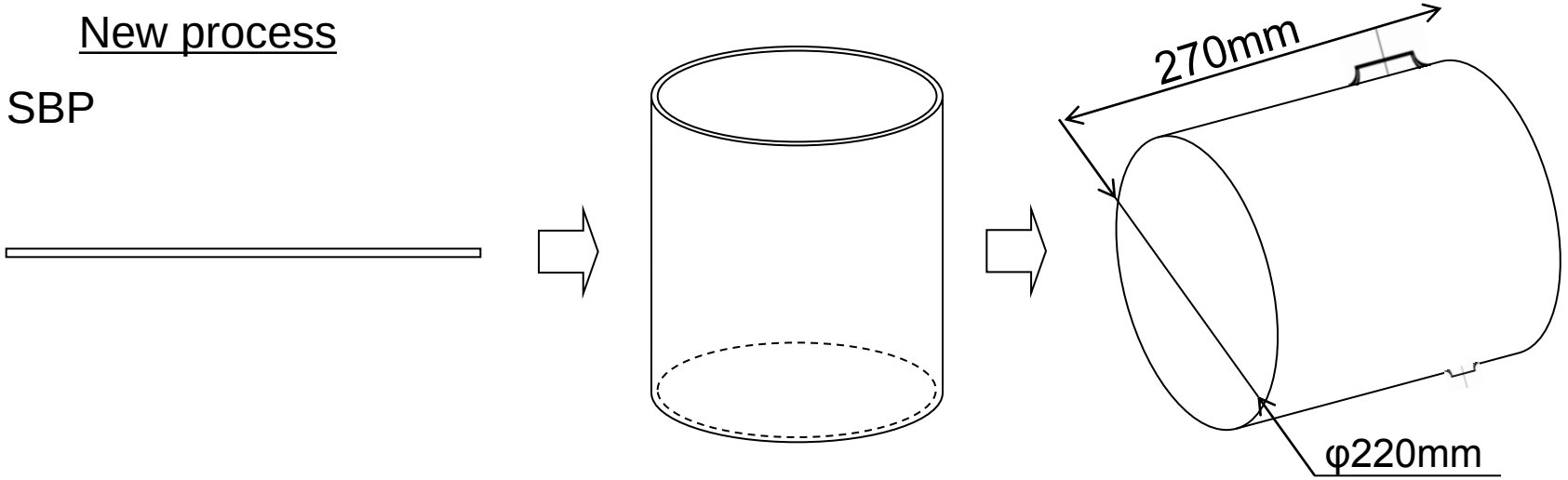
2-3(1) 500MHz SRF cavity for NSRRC using deep drawing technology



508MHz 1cell Cavity (For KEKB R&B：Prior process)

New process

SBP



t3.0mm Niobium sheet　　Deep drawing　　Bulge forming

2-3(2) Brazing Joint for flange and stiffener (for STF Cavity)

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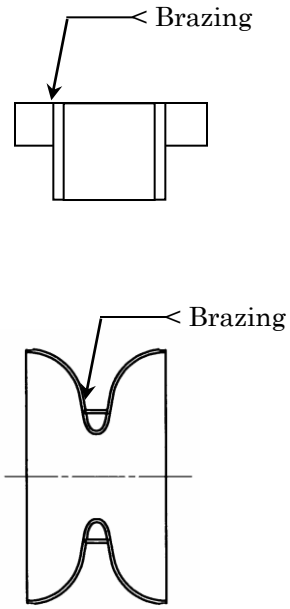
Under development

We did the basic mechanical test result of brazing Nb and Ti joints and Nb and Nb joints

material	Brazing material	Surface treatment	Ave. Shearing strength (N/mm^2)	Break point	Ave. Absorbing Energy Kv_2(J)	Leak test	Remarks
Nb/Ti	A	–	124	Nb	0.58	○	
		○	122	Nb	–	○	
	B	–	45	joint	0.55	○	
		○	40.7	joint	–	–	
	C	–	42.7	joint	0.6	○	
		○	39.2	joint	–	–	
Nb/Nb	A	–	54.6	joint	–	–	
	B	–	120.6	Nb/joint	9.78	–	1sample :22J
	C	–	121.6	Nb/joint	4.05	–	
		○	106.6	joint	–	–	



A; Ti group

B, C; Ag group

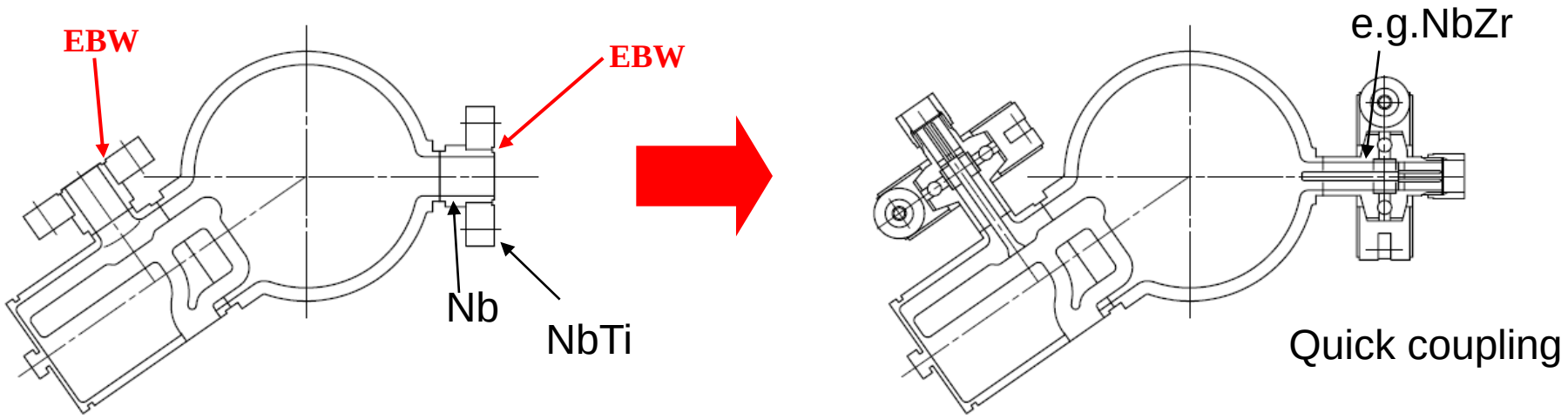
Heat treatment after Brazing: 923K x 3H, 77K x 5 min.
Test temperature: room temperature

- Need some test for brazing condition and cavity performance

2-3（3）Change for material & coupling for flanges (for STF Cavity)

Proposal from MHI

Combination of monitor port and flange



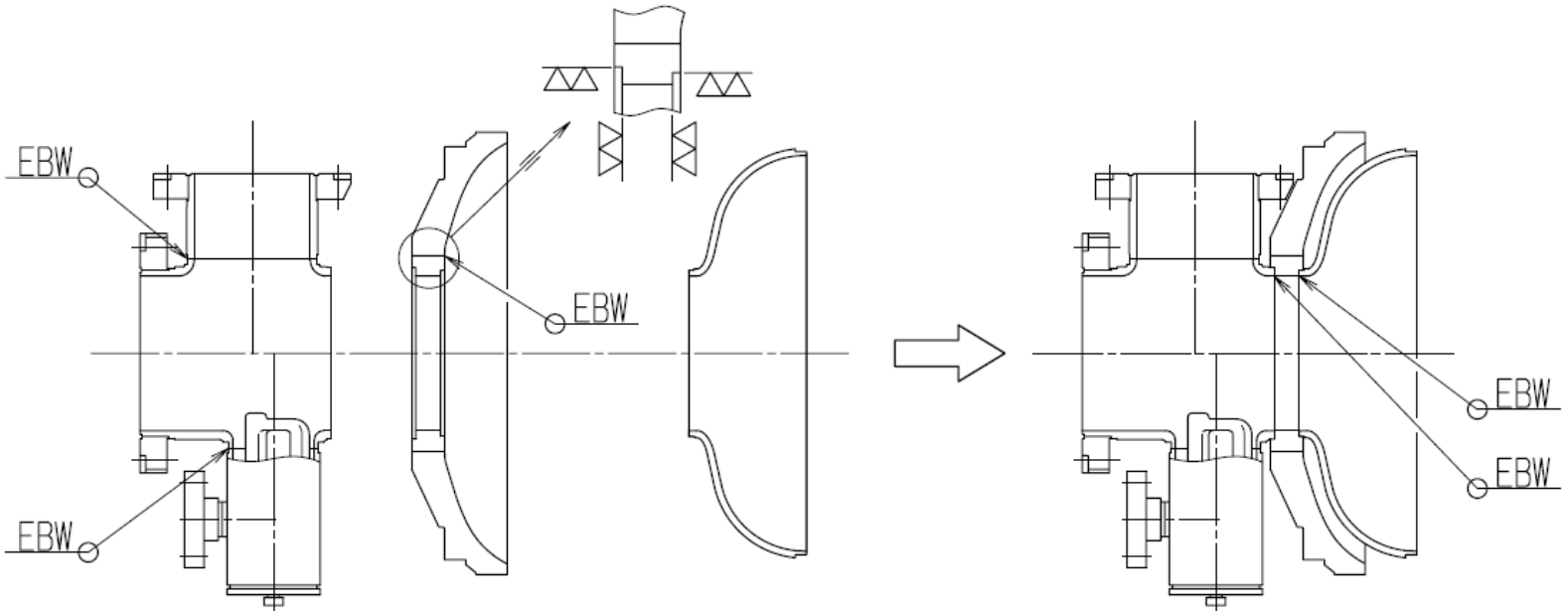
- Can reduce one part
- Can reduce one welding seam
- Need some experiment to EP chemical
- Need some leakage test at 2K

2-3（4） Combination of end group parts (for STF Cavity)

Proposal from MHI

Reduce for EBW seam by combination of base-plate and beam-tube

Present process

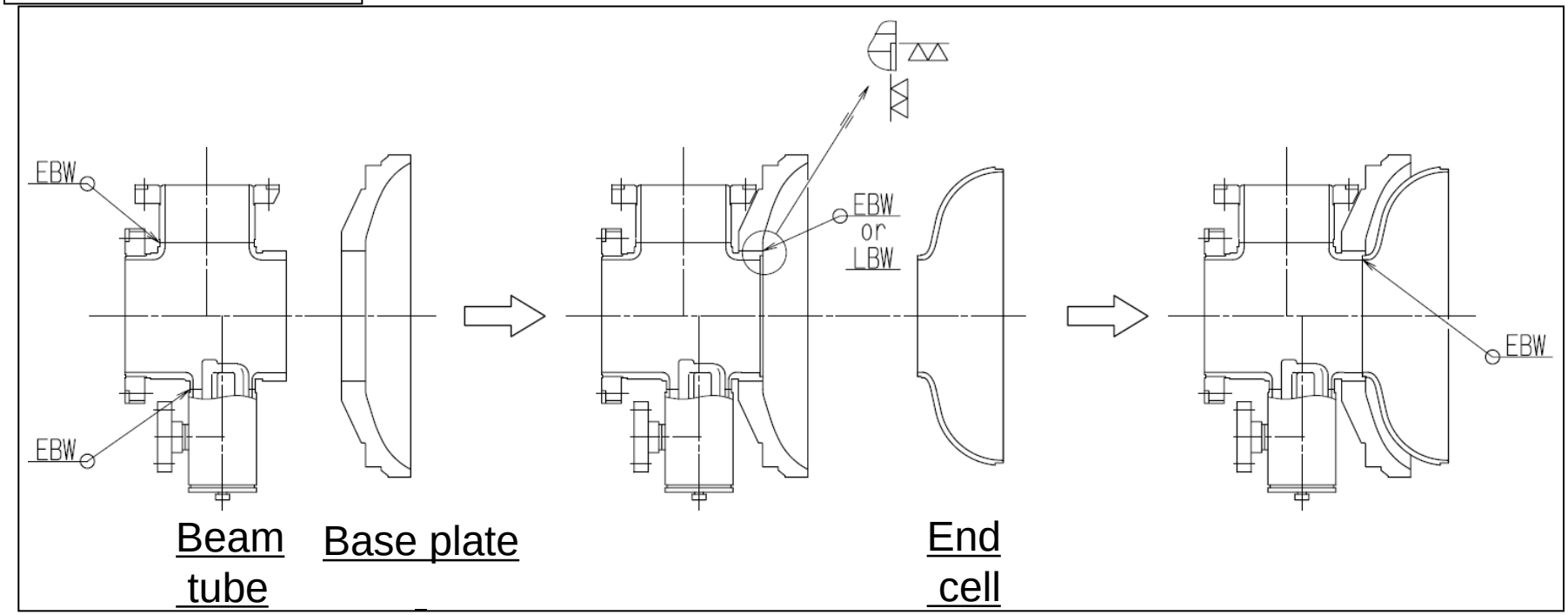


2-3（4） Combination of end group parts (for STF Cavity)

Proposal from MHI

Reduce for EBW seam by combination of base-plate and beam-tube

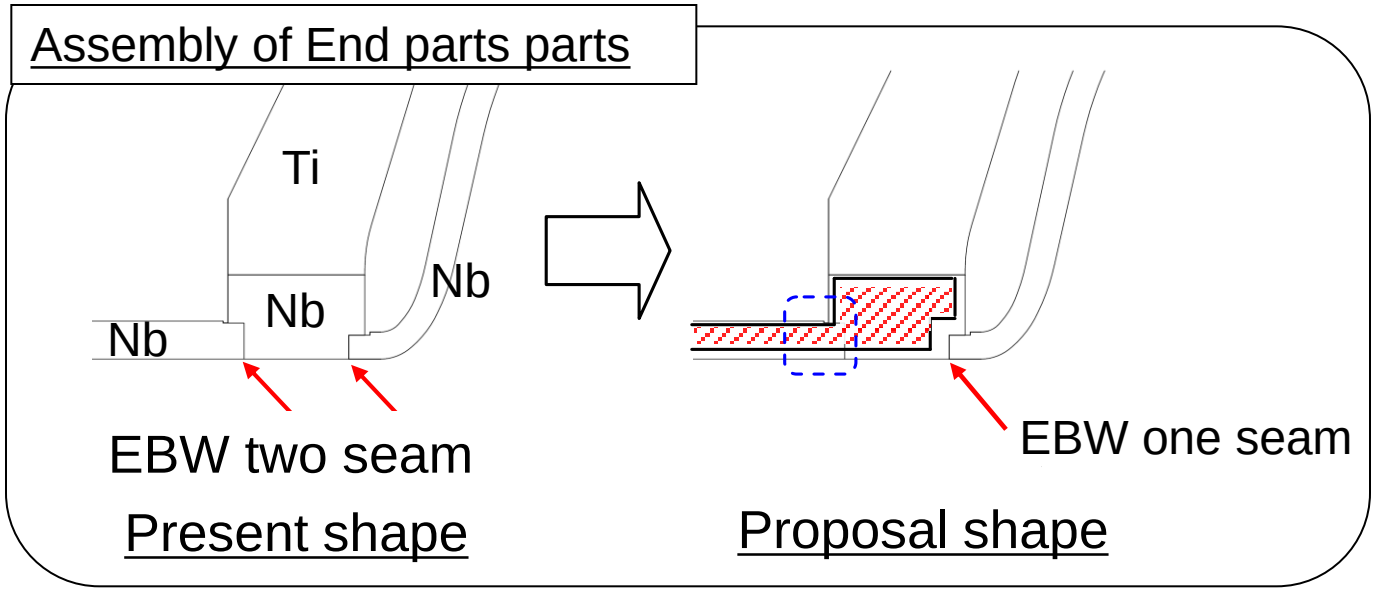
Proposal process



2-3（4） Combination of end group parts (for STF Cavity)

Proposal from MHI

Reduce for EBW seam by combination of base-plate and beam-tube



Contents

3 Current status at MHI factory

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New EBW machine

Beam power : max 10 kW
Accelerating voltage : 80 kV

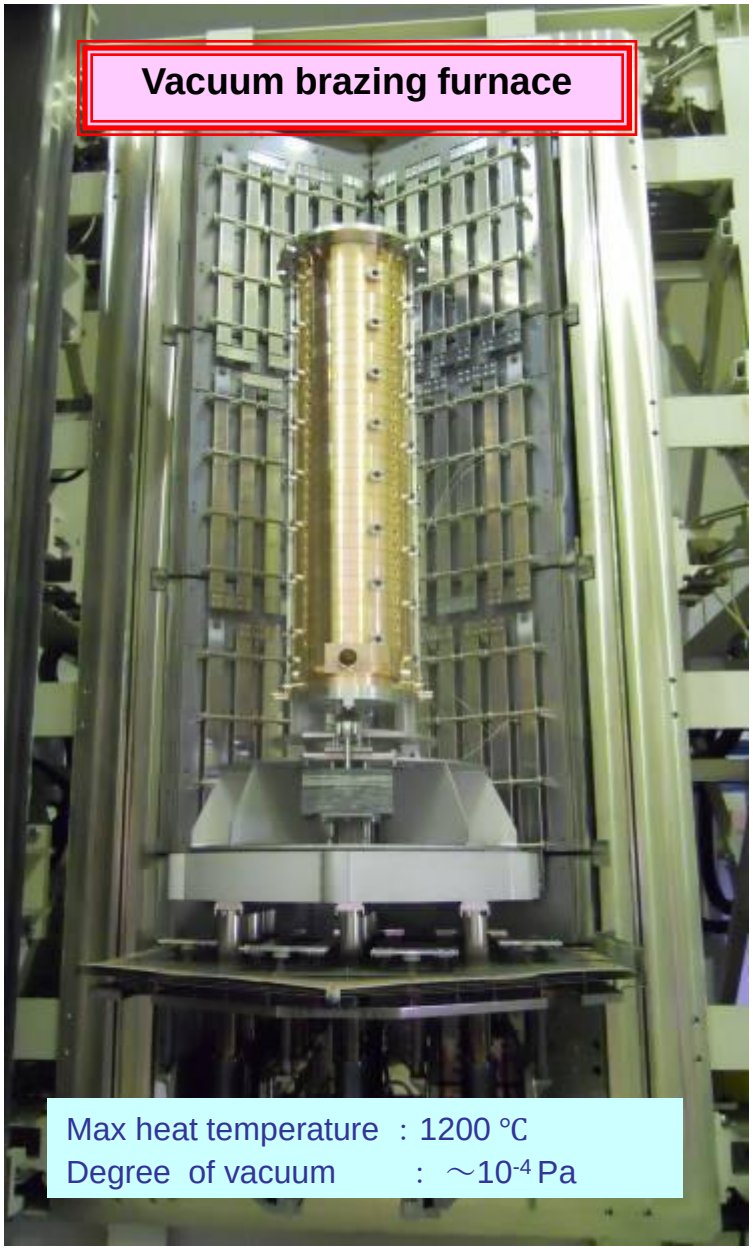
Installed in April 2011

We will develop mass-production method by using new EBW and LBW machine

High power fiber laser welding machine

Generator : 25kW fiber laser system
Head : made by MHI

3 Current status at MHI factory



We will develop mass-production method by using big furnace and clean room

Contents

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4. Summary

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- We have supplied some 1.3GHz SRF cavities for STF and ERL projects at KEK for the last few years. The cavity performance are improving step by step.

- We have proposed some ideas for cost reduction and these method was established step by step. We need to estimate in detail the effect of cost reduction.

- According to MHI-A cavity, we were sure that using LBW joints instead of EBW joints for the parts of little influence to cavity performance was available.

- MHI-B cavity with seamless dumbbell is under fabrication. This cavity is going to be finished on August 2011. After inspection and surface treatment, RF test will be carried out at JLab on this autumn.

Special thanks

Special thanks to

E. Kako, K. Watanabe , S. Noguchi,

T. Shishido, Y. Yamamoto at KEK

for STF activities in this presentation

and

T. Furuya at KEK, C. Wang at NSRRC

for 500 MHz cavity in this presentation.

The END

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Thank you for your attention.