Different Material Transition and He Vessel

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Contents

Different material transition

- Introduction
- R&D at KEK
- Development plan

He vessel specification

- What items should be specified?
- What data should be prepared in order to pass the high pressure gas regulation ?

Transition

Introduction

- **Why different material transition is required ?**

  Present base line design:

  He-vessel and 2 K LHe supply pipe : Ti

  connection between Ti and SUS pipes : flange

  - Reduce cost
  - Increase the reliability of leak tightness

- **Where can we place the transition ?**

  Various solution can be considered:

  - In the end plates of He vessel
  - Between He vessel and 2 K He supply line
  - In the 2 K LHe supply line

  Any solution has advantages and disadvantages.

  --> Better solution should be selected based on the real experiences.

KEK has been pushing forward the development through the STF construction.

R&D on different material transition at KEK

Two kinds of transitions had been developed for the STF-0.5 cryomodule.

- transition for piping
- transition for end plate between cavity and He vessel

1) R&D on Ti/SUS316L transition for piping

Two bonding methods were examined:

(1) friction welding method

- optimization of welding condition

(2) HIP (Hot Isostatic Pressing) method

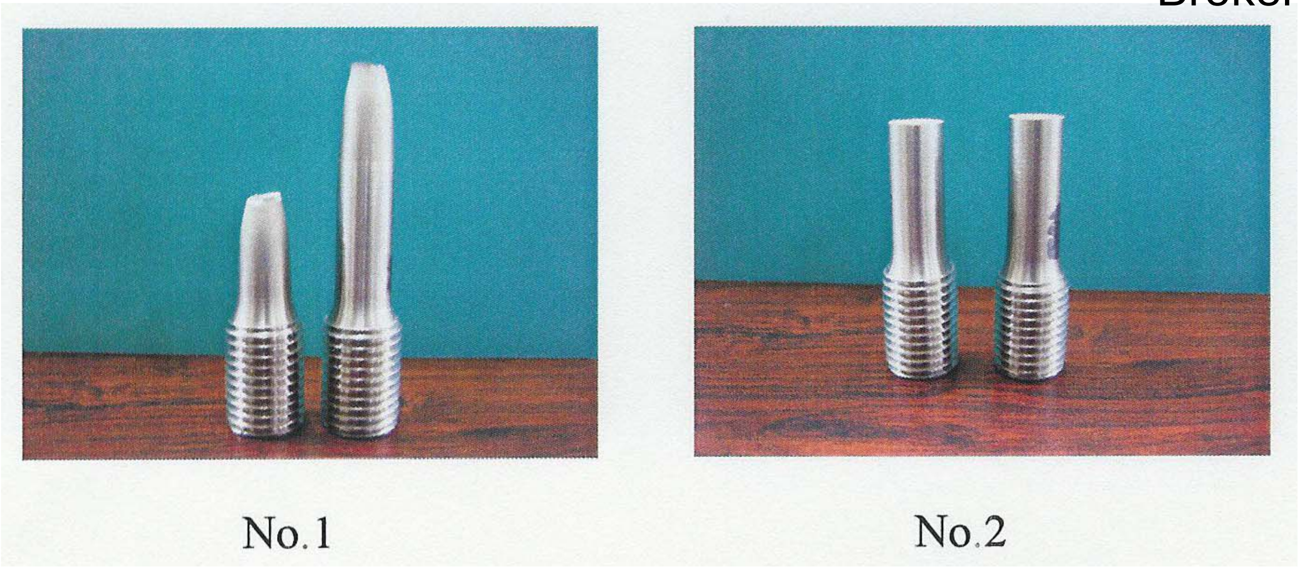
- choice of insert metal
- optimum HIP condition

Tensile strength tests at 300 K and 80 K and

Charpy impact strength tests at 300 K and 80 K were performed

Sample of friction welded transition
and broken samples after the tensile test

Broken HIP samples



Most of the samples were broken in the boundary of the transition.
Fabrication condition was not fully surveyed in both methods.

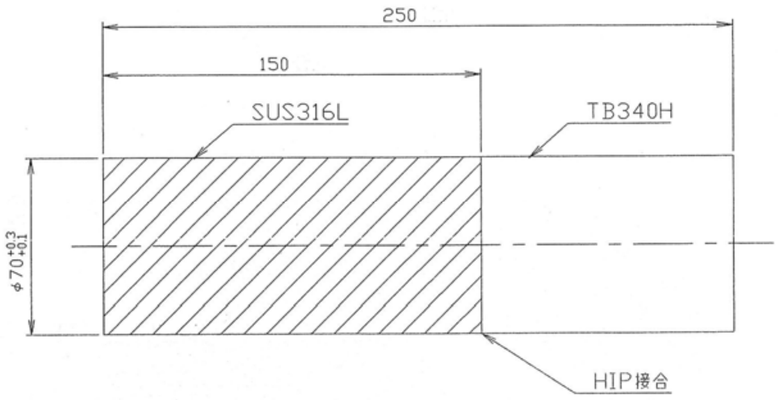
Test results of the samples

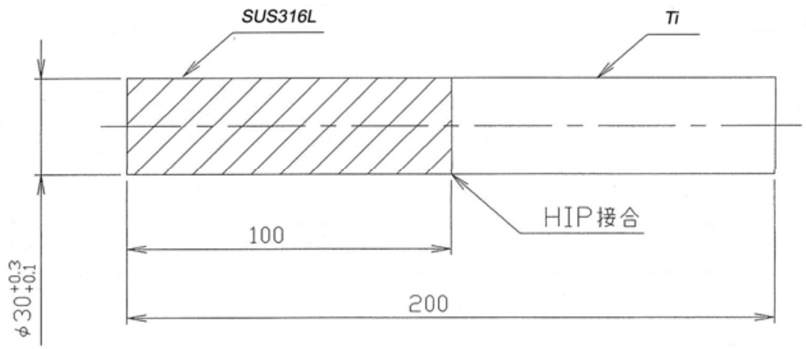
	Tensile strength @ 300K (MPa)	Tensile strength @ 80K (MPa)	Charpy strength @ 300K(J/cm2)	Charpy strength @ 80K(J/cm2)
HIP sample	> 480	>700	~ 10	~ 5
Friction welding sample	> 400	> 500	~ 4	~ 2
Ti rod	~ 490	~ 900	~ 29	~ 32

- By reducing the temperature, the tensile strengths become higher but the Charpy strengths become lower.
- The Charpy strengths of these samples are extremely low compared to that of Ti.
- The Charpy strength of HIP sample is almost 1/6 of Ti, although the tensile strength are almost equal.

Though the Charpy strength of the transition was rather low, the tensile strength was relatively high. And in the real operation a large impact force doesn’t seem to work on it, thus we decided to use the HIP transition in the STF cryomodule carefully.

• Fabrication of HIP transitions for STF cryomodule



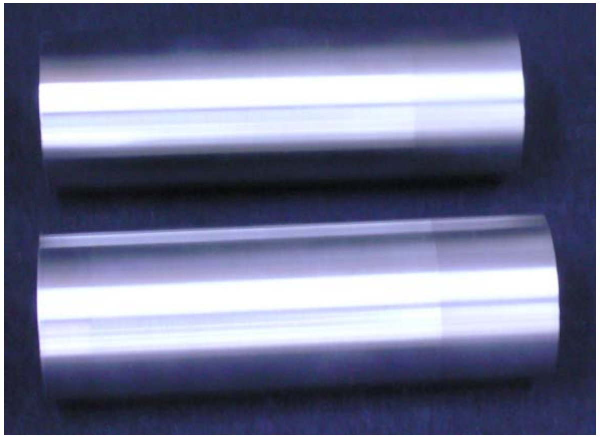


70 mm dia. x 7 rods

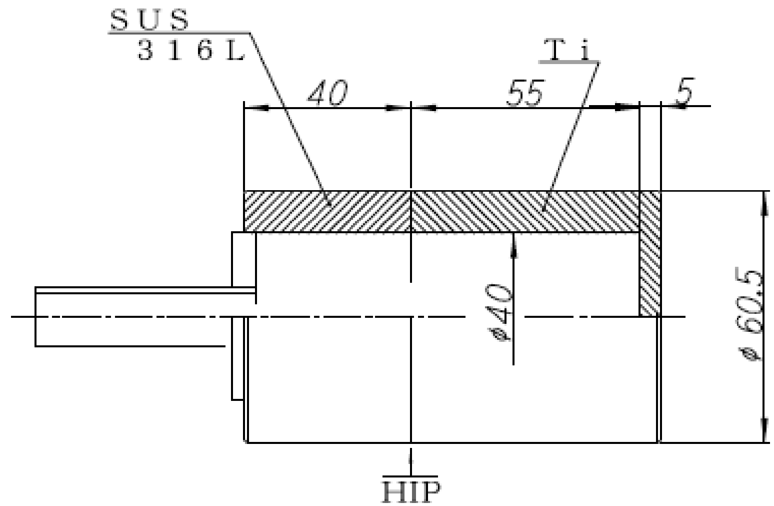
30 mm dia. x 7 rods

Mechanical test samples were made from one rod and tensile test and Charpy test were performed.

And it was confirmed that the strengths were almost the same as those of the previous small samples.



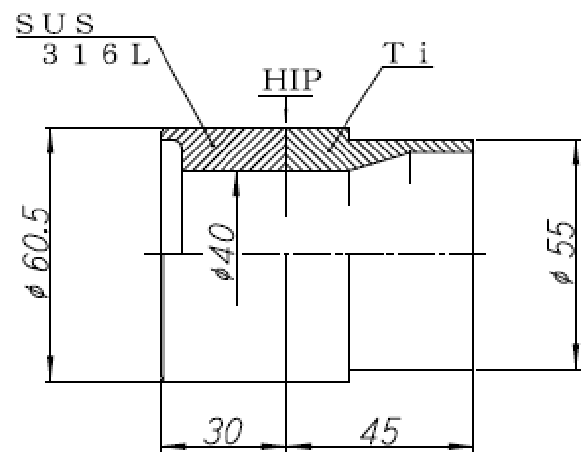
The transition rods were machined to a pipe-shape.



All pipe-shaped transitions were leak tested at RT, 4.2 K and 2 K.

No He-leak in all test conditions

leak rate sensitivity < 1 x 10^{-10} Pa.m^3/s



The final machining was performed and the transition pieces were welded to the pipe.

Final shape of the transition

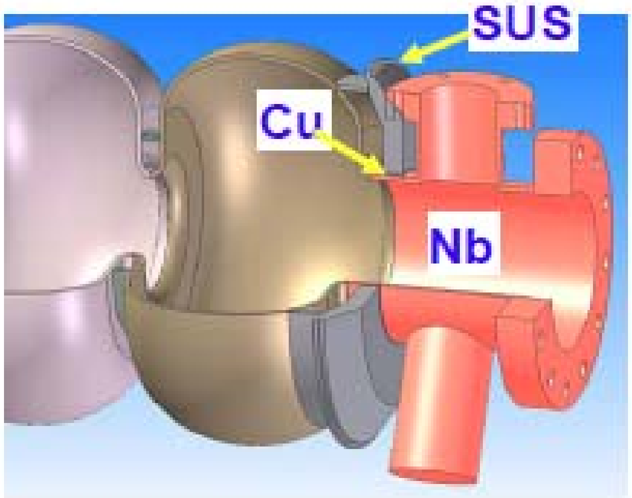
rather large thickness was taken for the transition part (~10 mm), since the bonding method was a butt joint.

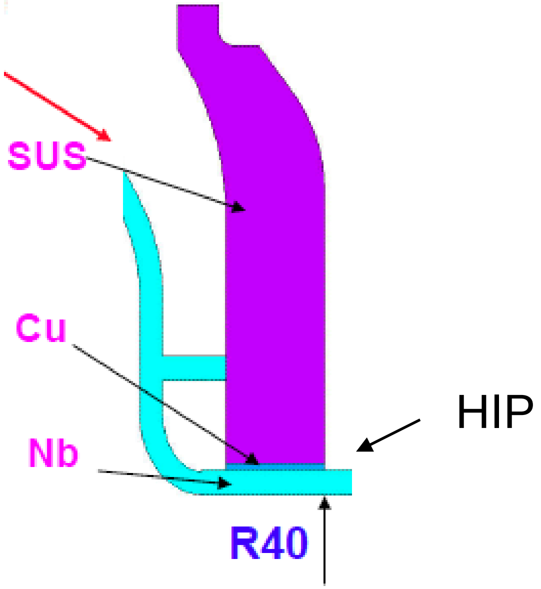
- Two transitions(60 mm dia. and 30 mm dia.) were installed into STF-0.5.
- The cryomodule was cooled down to 2 K and the cavity test had been performed without any troubles in these transitions.
- We confirmed that HIP transition of this type was able to use in cryomodule.

However, we think that the improvement of Charpy strength is necessary in order to use it in the full size cryomodule, which should follow the high pressure gas regulation.

2) Development of Nb-SUS transition between cavity and He-vessel

This development has been advanced by KEK LL-cavity group and the transition was adopted for the end of the LL-cavity.



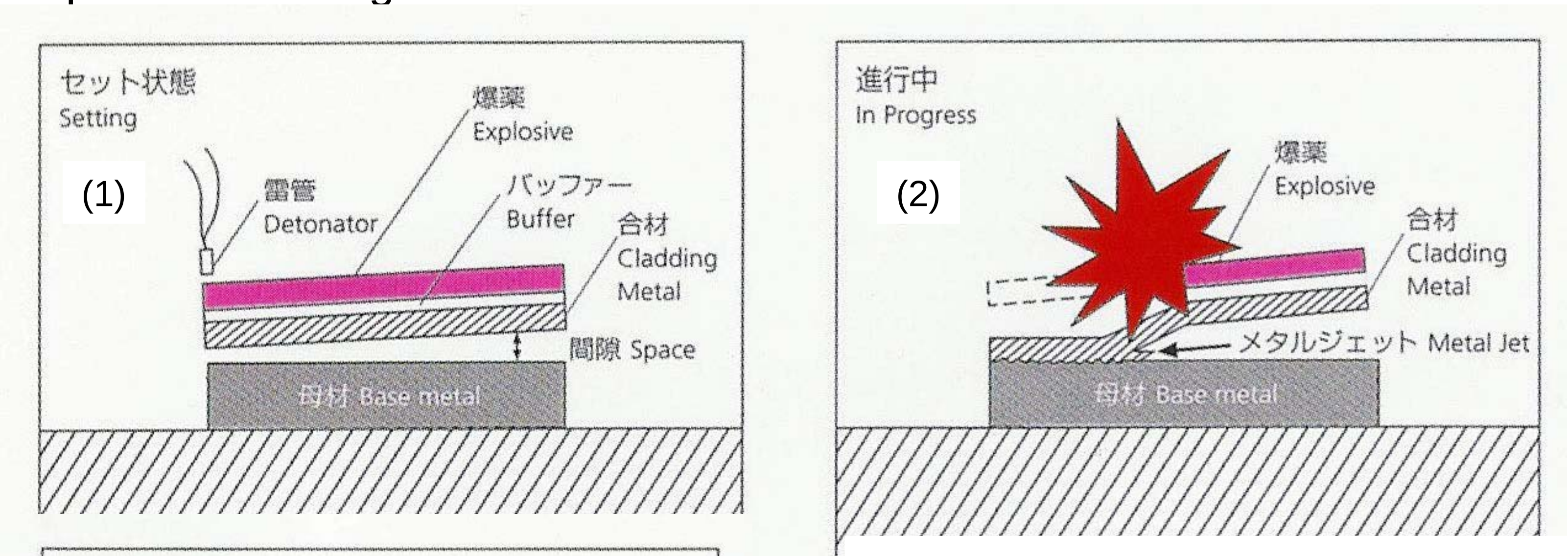


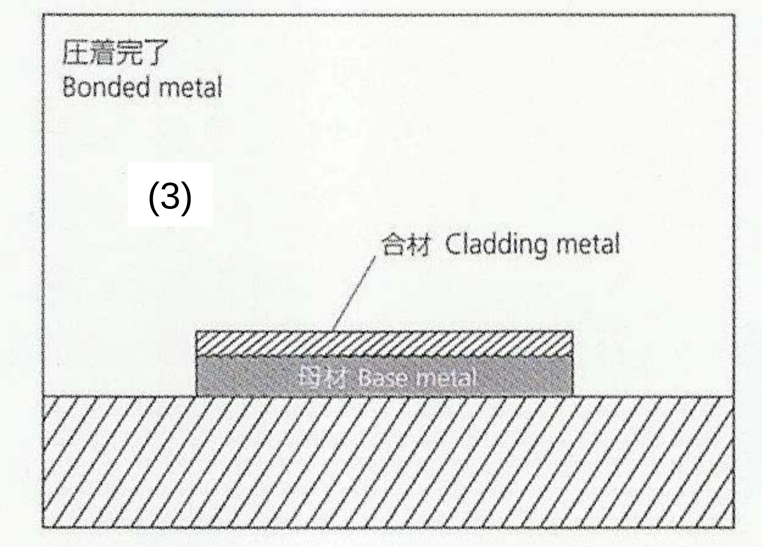
- Small ring sample (flange shape) was made and leak tightness test was performed at 2 K. Then real size transitions were fabricated.
- A LL-cavity with two transitions was installed into the STF-0.5 cryomodule.
- The cool down test to 4 K has been successfully done without any trouble.
- The 2 K test will be performed soon.

R&D after the STF-phase 0.5

- **Trial of new technology to obtain higher Charpy strength**

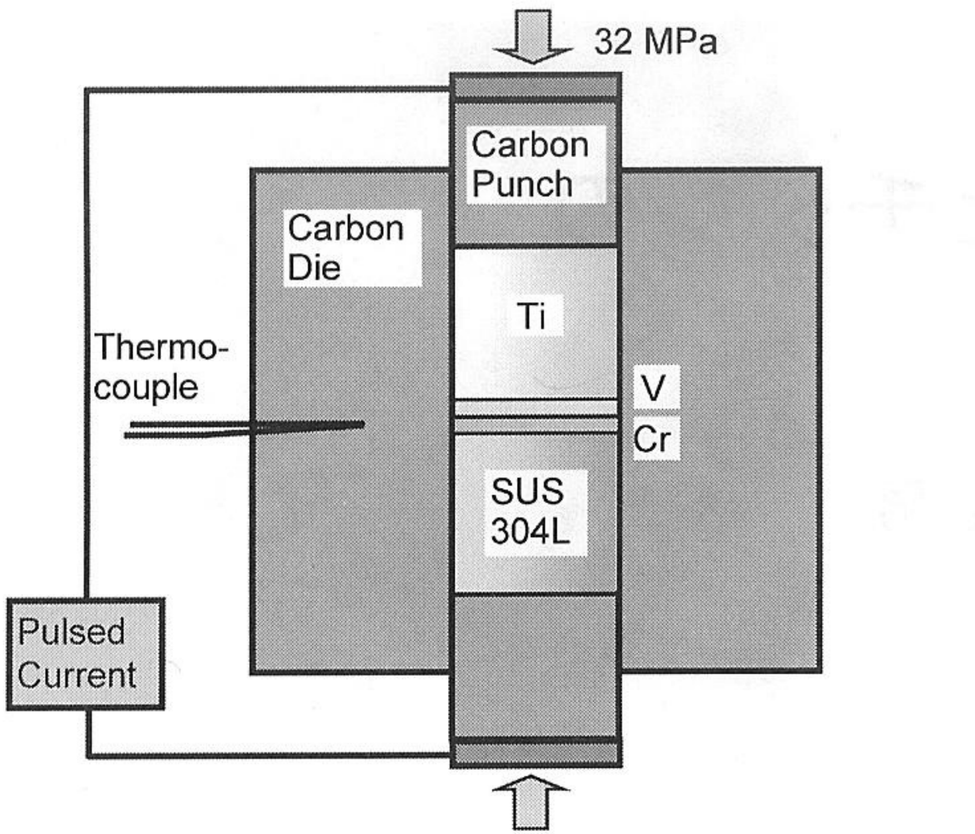
1) Explosion bonding





Once the explosives are detonated, the cladding metal is pressed onto the base metal at extremely high speed, fluidizing the collision front of both metals.

2) Pulsed current hot pressing: insert metal (Cr+V or Cu+V)



Mechanical strength of the samples made by new technology

	Tensile strength @300K (MPa)	Tensile strength @80K (MPa)	Charpy strength @300K(J/cm2)	Charpy strength @80K(J/cm2)
HIP	> 480	>700	~ 10	~ 5
Explosion bonding	(>> 400)		~ 30	~ 25
Pulsed current			~8 (Cu+V) ~ 1.8 (Cr+V)	~ 8 (Cu +V) ~ 1.9(Cr+V)

- Explosion bonding is a very promising method.
- The Charpy strength of this method is much higher than that of other methods.

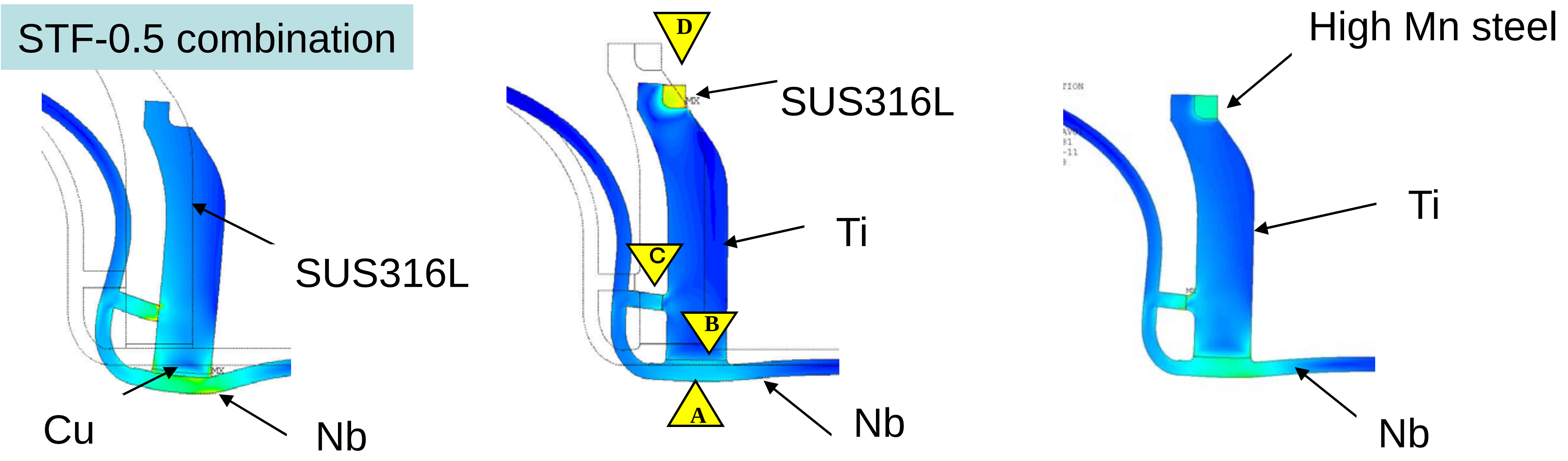
  However, the present method uses an insert material of Ni (2mm).

- **R&D of the end plate with different material transition**

More complicated: big diameter

Thermal and mechanical analysis has been performed

By LL Cavity Group



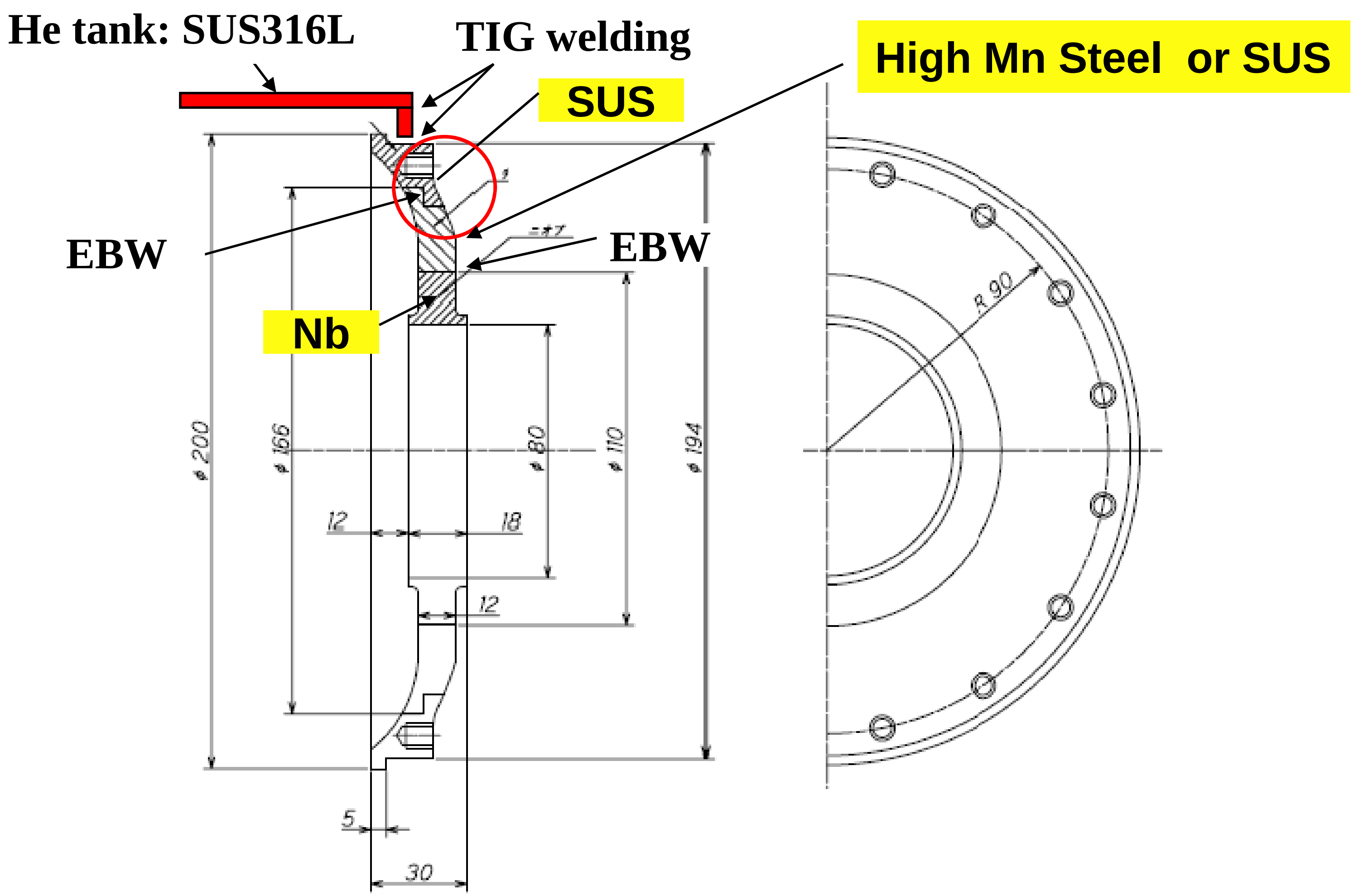
(1) Nb/Cu/SUS316L (2) Nb/Ti+SUS316L (3) Nb/Ti+High Mn steel

Maximum Surface Stress

	A [MPa]	B [MPa]	C [MPa]	D [MPa]
(1) Nb/Cu/SUS316L	250	500	500	
(2) Nb/Ti/SUS316L	100	100	200	470
(3) Nb/Ti/High Mn Steel	100	100	200	80

Nb-SUS end plate design @ KEK

by K. Saito



What should we do next ?
Next R&D plan of the transition

- R&D on pipe-shape transition

  Pursue the explosion bonding (Ti-SUS) with non-magnetic material

  - enough Charpy strength will be obtained in the near future, so, Ti vessel + Ti-SUS transition scheme will become feasible.
  - however, it is not so easy to apply this technique to the end plate. (the present technique is applicable only for plate bonding)

- R&D on Nb-SUS end plate
  - detailed thermal and mechanical analysis will be necessary and close collaboration with cavity group is indispensable.

    reliable data concerning the mechanical strength and thermal contraction are very important.
  - development of bonding technology for Nb and high Mn steel

- Development of test equipment

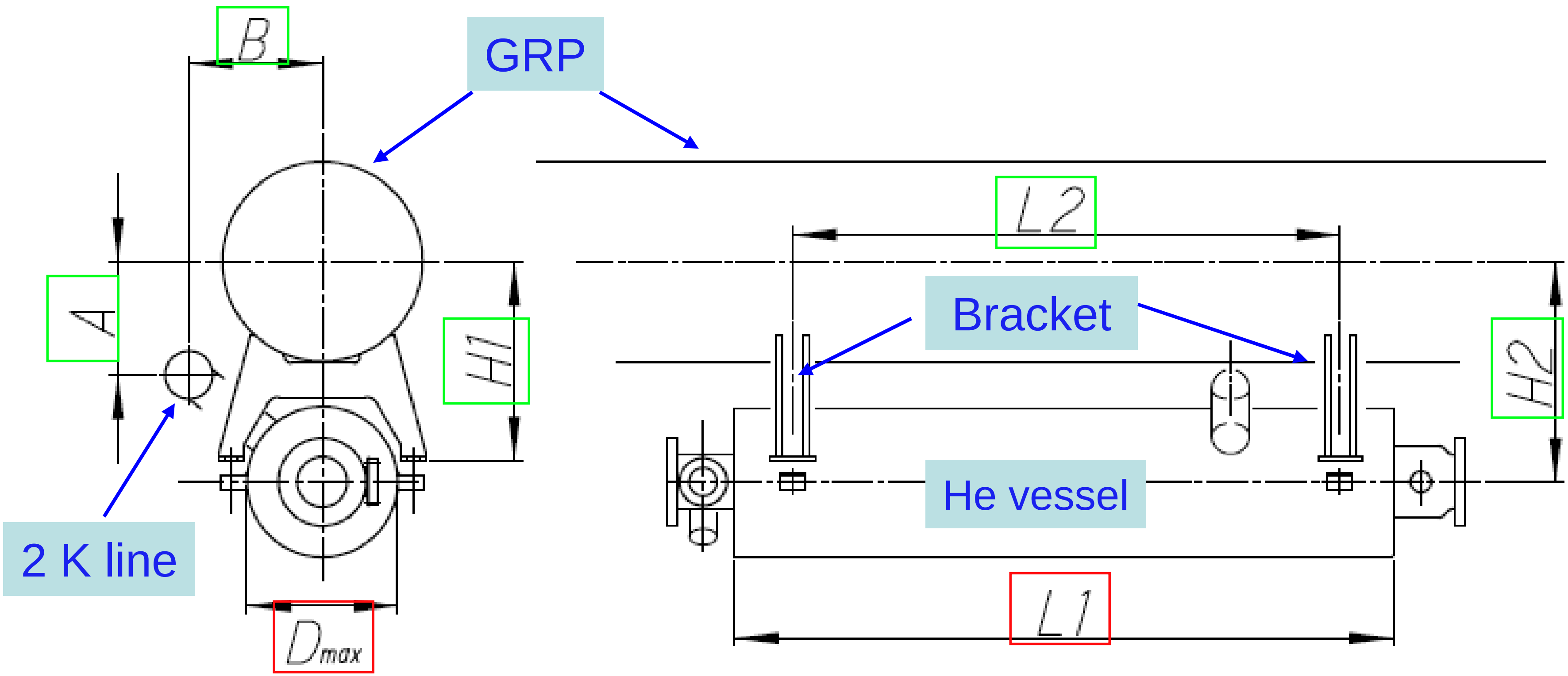
  establishment of evaluation method

He vessel specification

- Specification items should be minimal and room to accept future progress should be left.

What items should be specified?

- Dimensional spec.
  - Max diameter of He vessel (incl. magnetic shield)
  - Length of He vessel
  - Interface parameters
    - Location and size of the bracket
    - Location and size of cryogenic pipes


B
GRP
A
H1
L2
Bracket
H2
2 K line
He vessel
Dmax
L1

- Material spec.
  - Ti , SUS316L or High Mn steel
- Test
  - High pressure test: P=?
  - He leak check leak rate limit ?

What data should be prepared

in order to pass the high pressure gas regulation ?

need to start discussion

- Mechanical strength data
  - Nb
  - Ti
  - different material transition: Nb-Ti, Ti-SUS or Nb-SUS
- Fatigue test data of bellows: Ti bellows or SUS bellows

Conclusion

- KEK has been developing the different material transitions for piping and end plate of cavity.
  The 1st generation transitions were able to be used in STF-0.5.

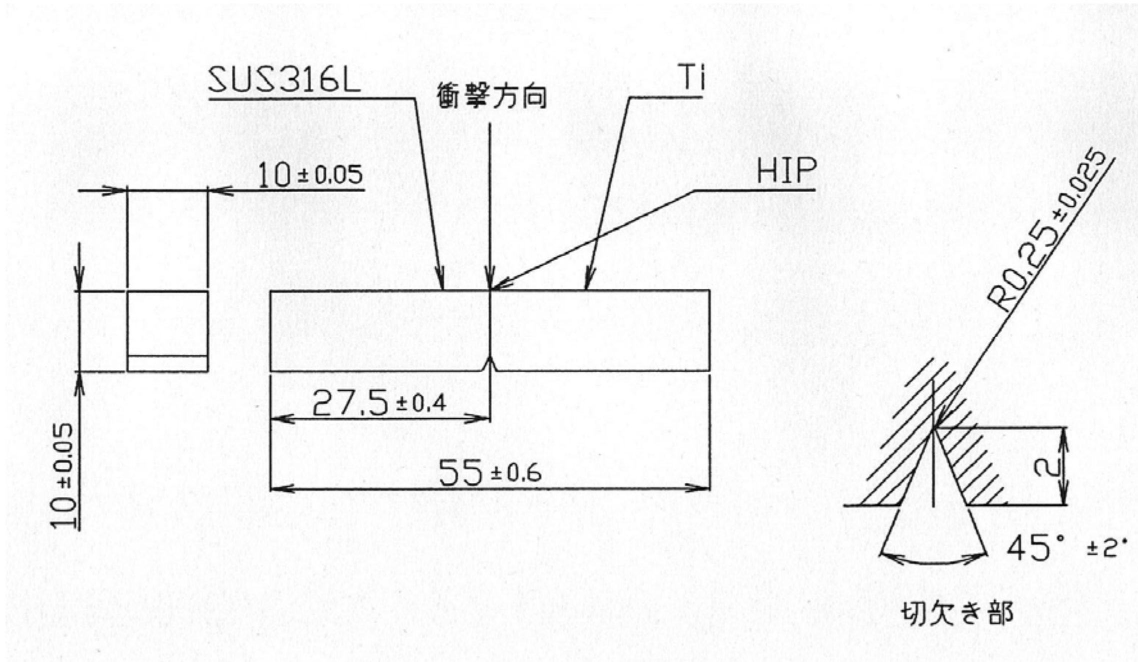
- However, the improvement of Charpy impact strength of the transition would be indispensable to pass the high pressure gas regulation.
  More further development is necessary.

- An example of the specification items concerning He vessel was shown.

Japanese high pressure gas regulation

- Impact strength test

sample size:



Test temp < design temp

Minimum tensile strength (MPa)	Min absorption energy: Ave of 3 samples	Min absorption energy: Min of one sample
σ < 450	18 J (22.5 J/cm2)	14 J (17.5 J/cm2)
450 < < 520	20 (25)	16 (20)
520 < < 660	27 (33.75)	20 (25)
660 < σ	27 (33.75)	27 (33.75)