Impact Tests for High Pressure Gas Safety Regulations

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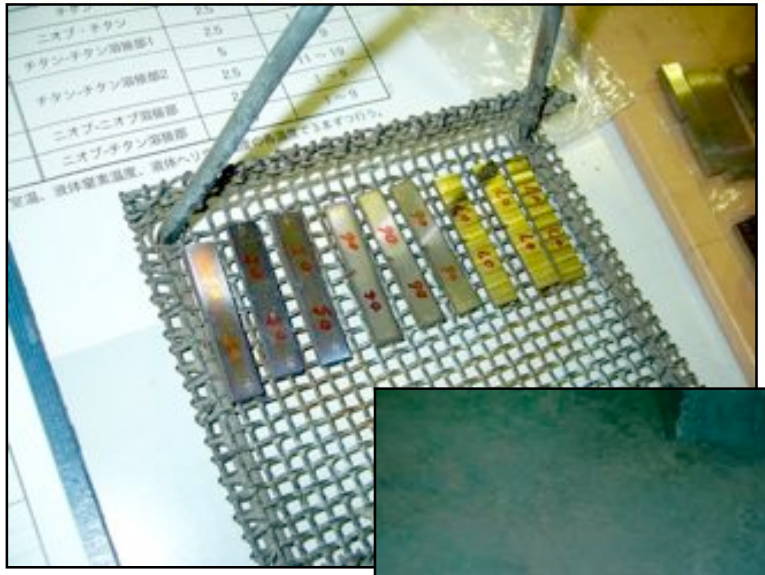
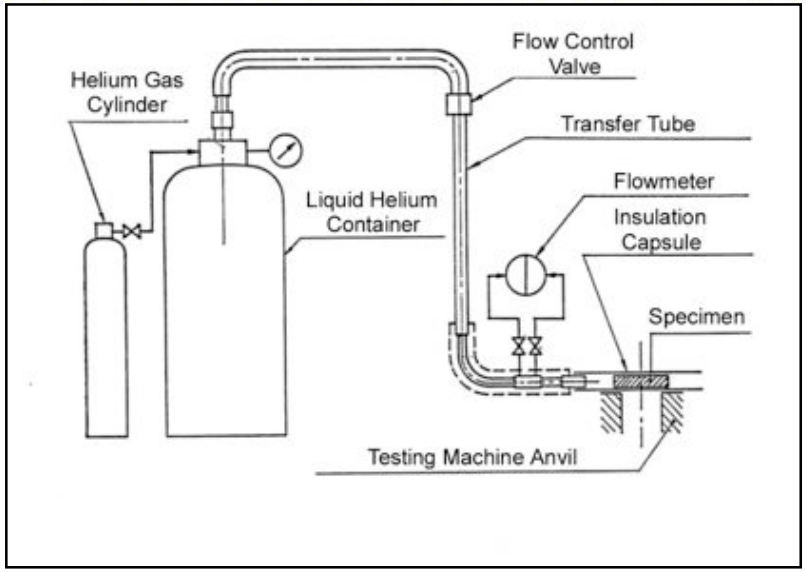
Charpy Impact Test

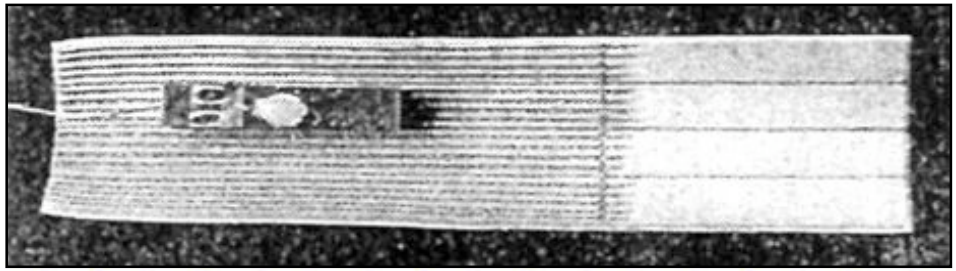
- Acquired data
  - **Absorbed energy for standard size samples**
  - **Charpy impact value for sub-size samples**
- Test temperatures
  - **Room temperature (300 K)**
  - **Liquid nitrogen temperature (77 K)**
  - **Liquid helium temperature (4.2 K)**
- Three (3) samples at least at each test temperature

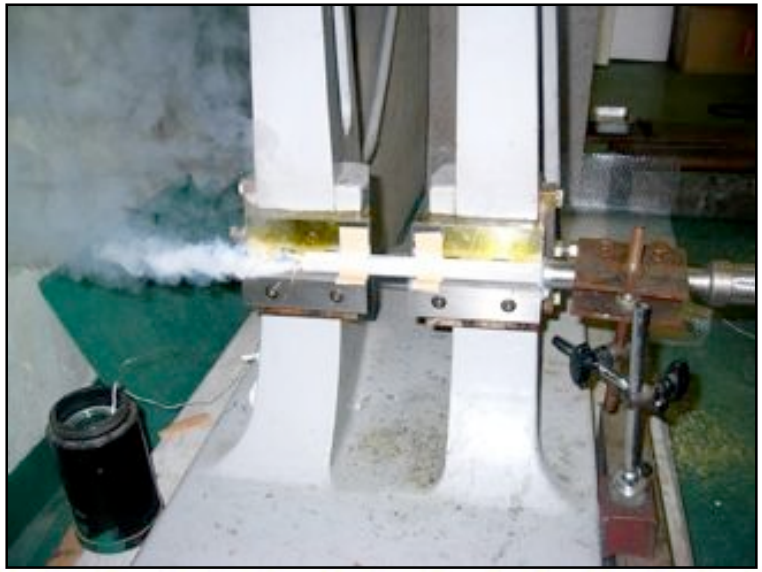
Tests at RT & LN_2 Temp.



Tests at LHe Temperature







Tested Materials

1. Nb
2. Ti
3. NbTi alloy
4. Nb-Nb joint (EBW)
5. Nb-Ti joint (EBW) - 2 times
6. Ti-Ti joint (TIG welding)
   - 2 companies, 2 widths
7. NbTi-Ti joint (TIG welding)
8. Nb-SS316L joint (HIP) - 2 companies

Annealing

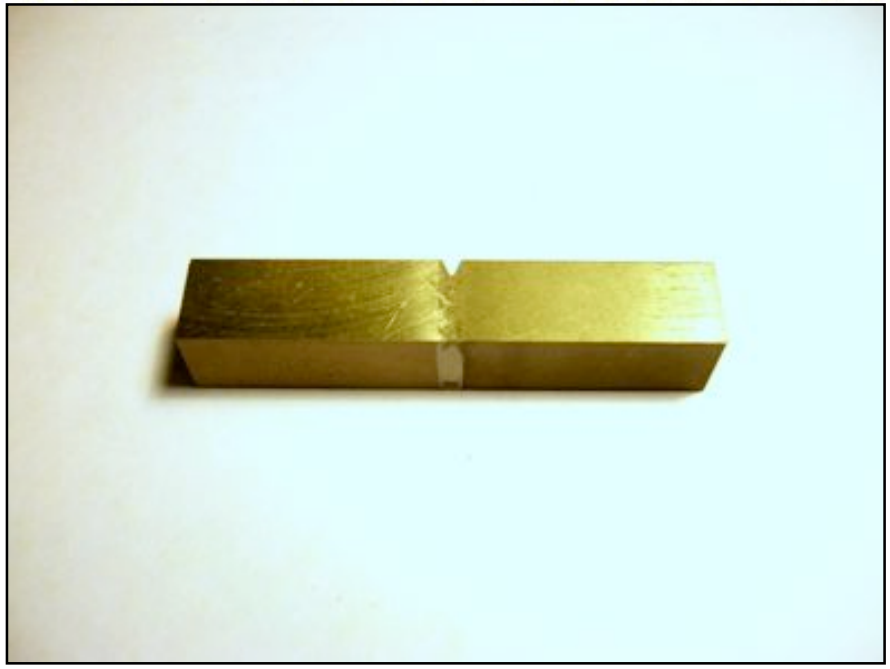
- All samples containing niobium were annealed at 750 °C for 3 hours
  - **Nb**
  - **Nb-Nb joint**
  - **Nb-Ti joint**
  - **Nb-SS316L joint**

Test Samples

- Sample size: JIS Type 4 (with V-notch)
  - **Standard width of samples: 10 mm**
  - **Standard width of notch section: 8 mm**
  - **Standard cross section: 0.8 cm^2**
- Subsize widths:
  - **2.5 mm**
  - **5 mm**
  - **7.5 mm**

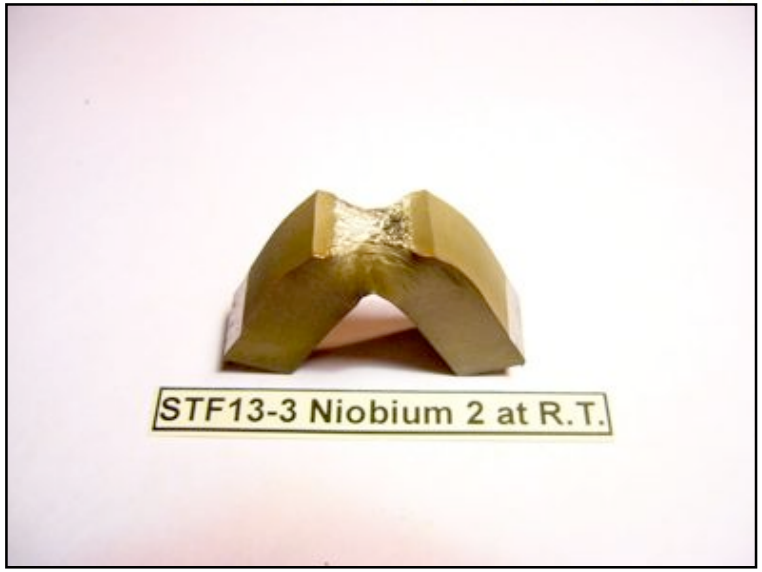
- See comparison of measured data of Ti-Ti joints

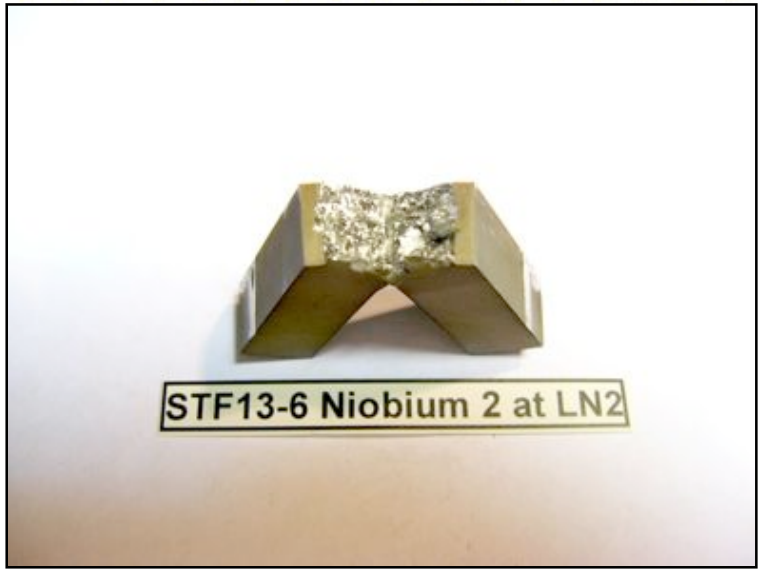
Notes

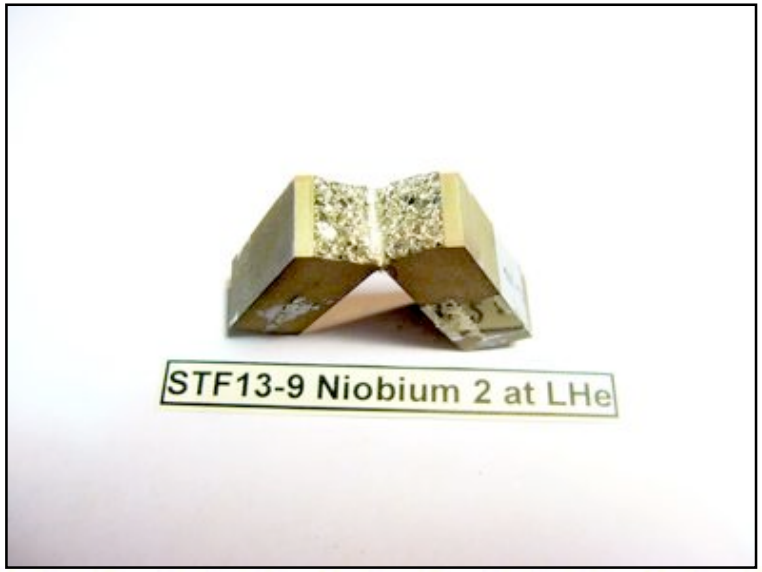


1. Ti-Ti joint samples welded by a company has pits at welded zone (both tensile test samples and impact test samples).
2. Nb-Ti joint samples had been notched at Nb part, not at the interface of two metals. Samples properly notched at the interface are also tested.

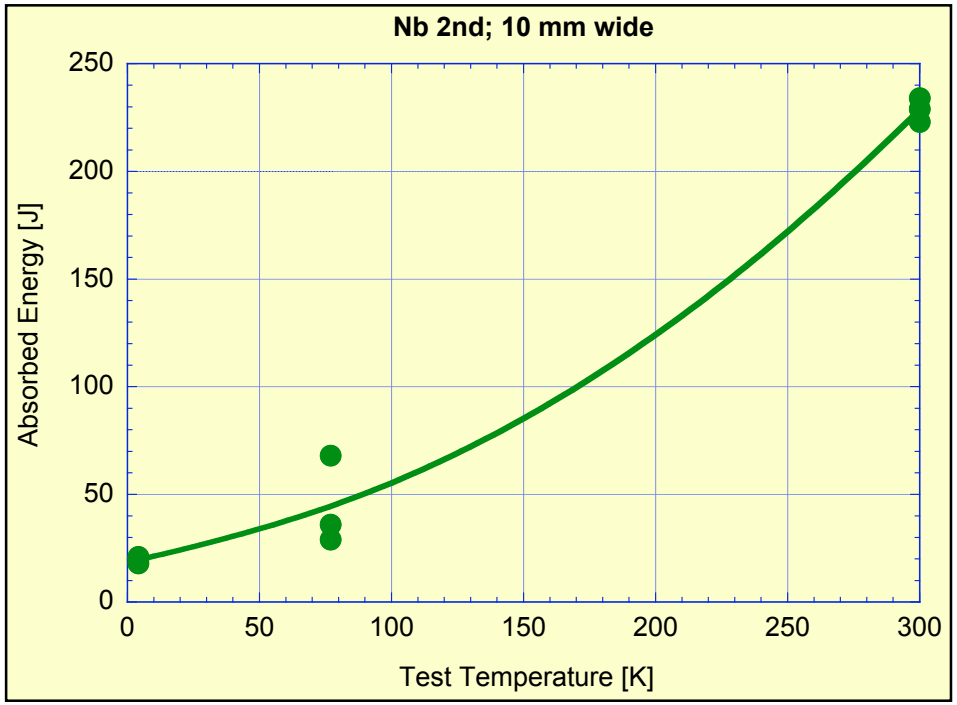
Nb (1)

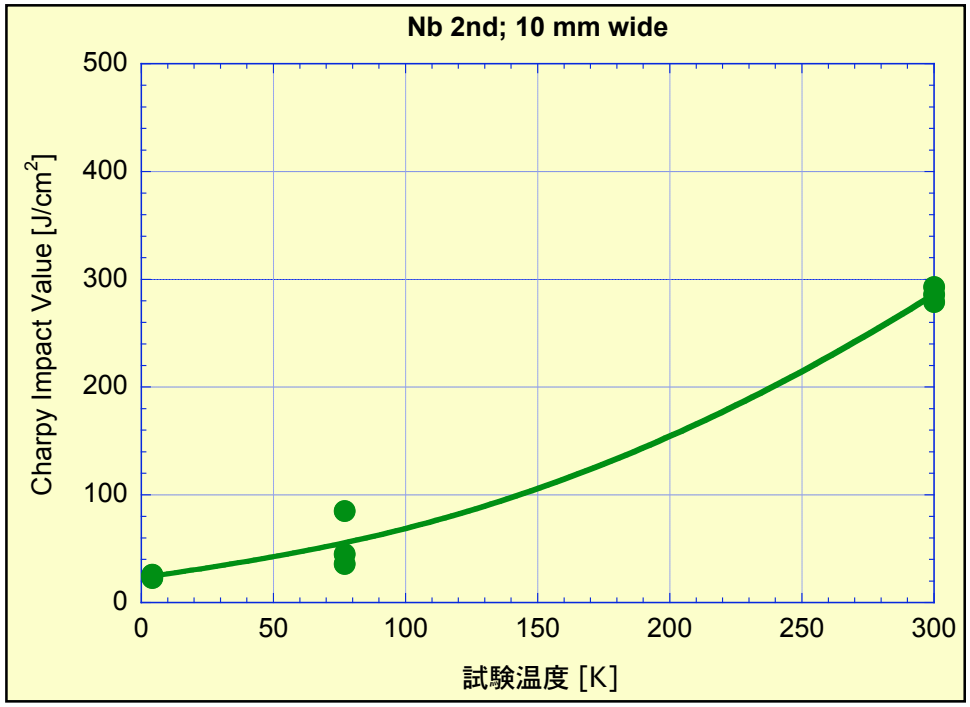

STF13-3 Niobium 2 at R.T.


STF13-6 Niobium 2 at LN2


STF13-9 Niobium 2 at LHe

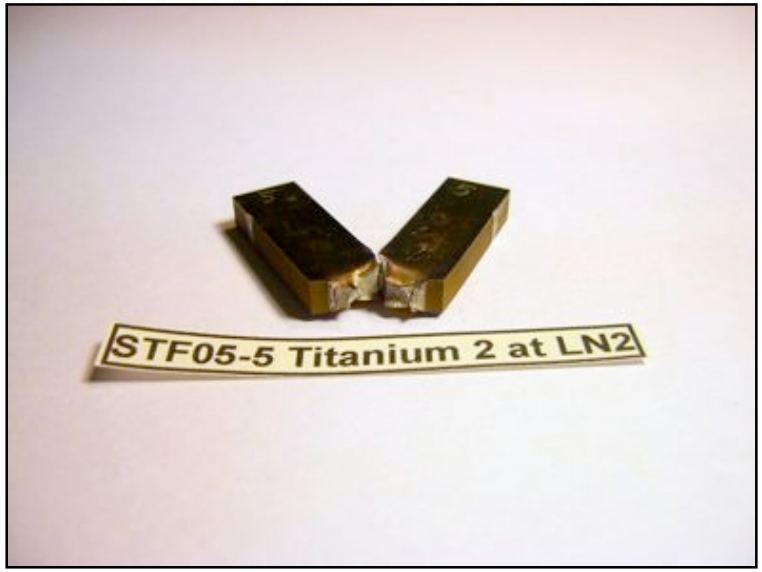
Nb (2)

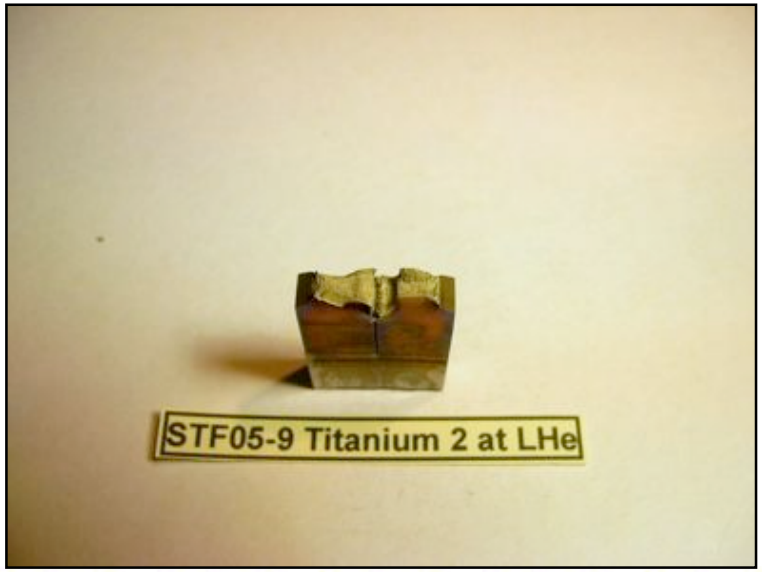

Nb 2nd; 10 mm wide
Absorbed Energy [J]
Test Temperature [K]
0
50
100
150
200
250
300


Nb 2nd; 10 mm wide
Charpy Impact Value [J/cm2]
試験温度 [K]
0
100
200
300
400
500
50
150
250

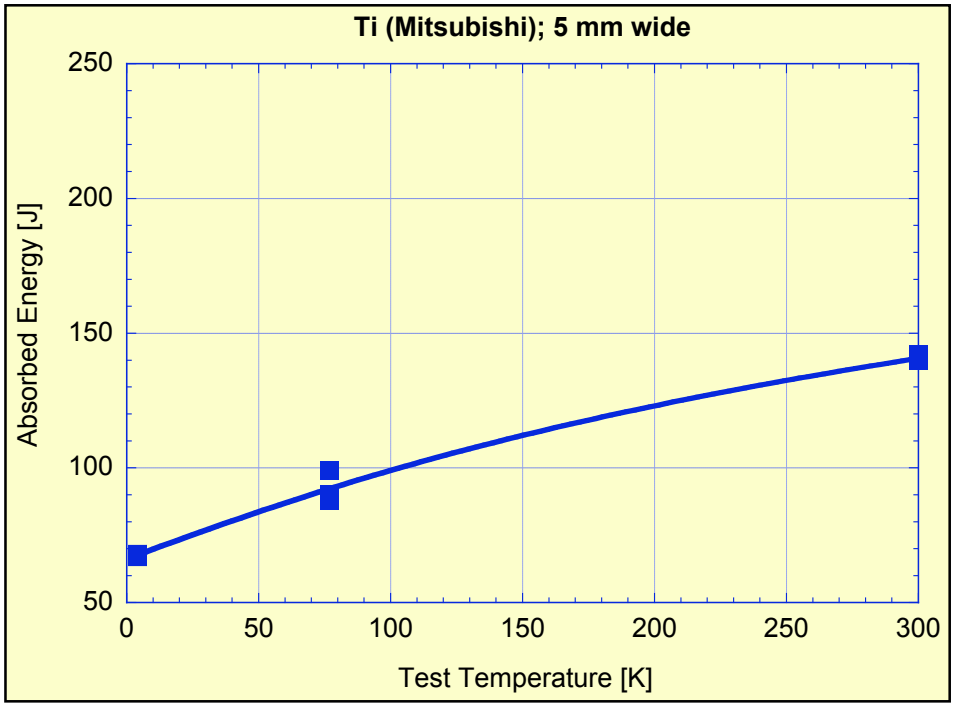
Ti (1)

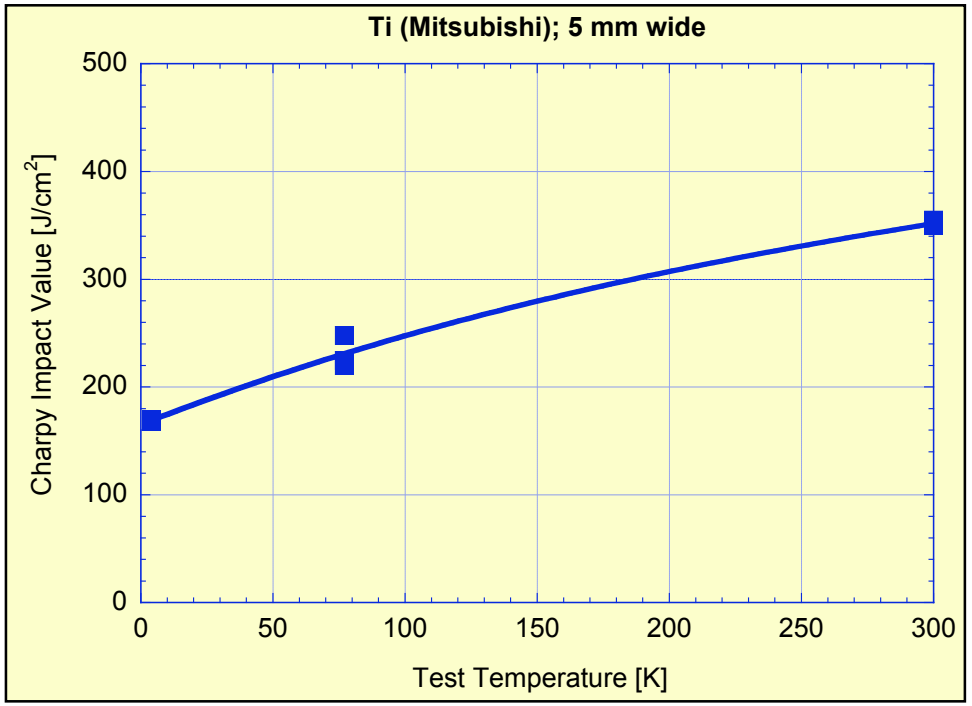

STF05-2 Titanium 2 at R.T.


STF05-5 Titanium 2 at LN2

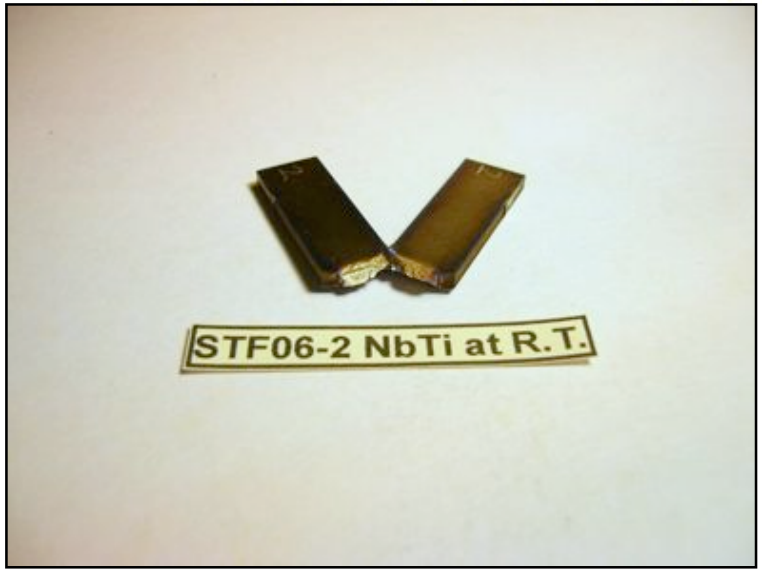

STF05-9 Titanium 2 at LHe

Ti (2)

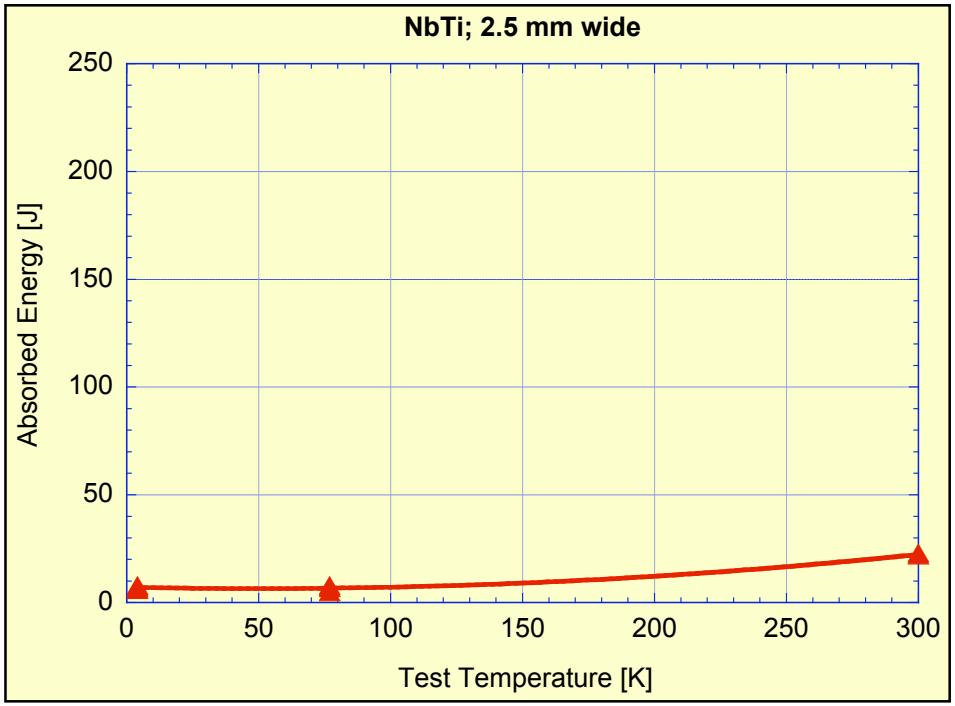

Ti (Mitsubishi); 5 mm wide
Absorbed Energy [J]
250
200
150
100
50
0
50
100
150
200
250
300
Test Temperature [K]

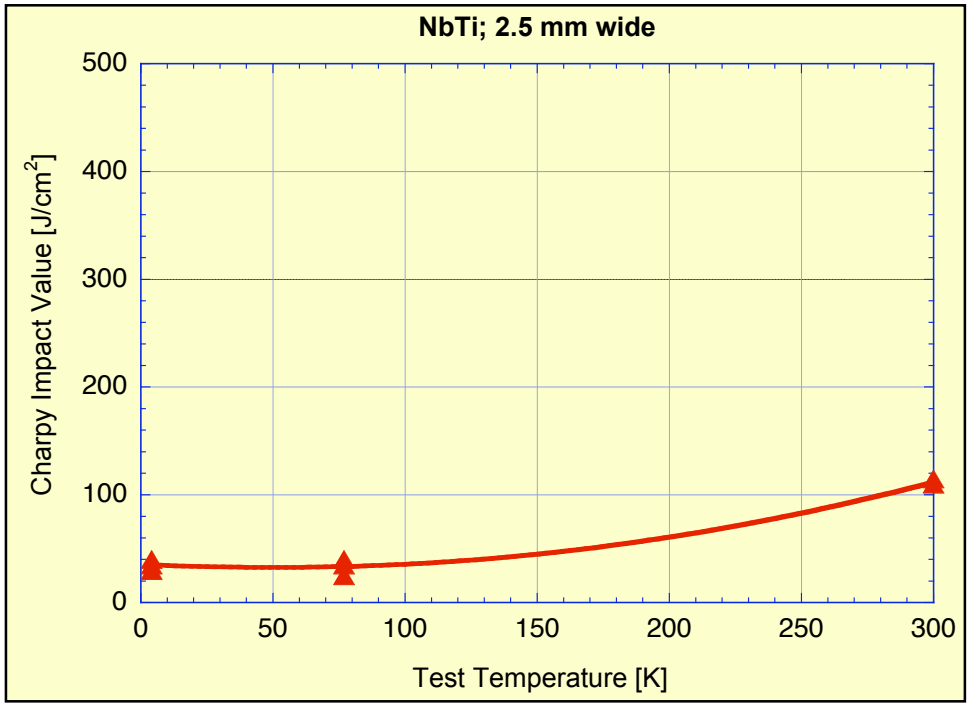

Ti (Mitsubishi); 5 mm wide
Charpy Impact Value [J/cm2]
500
400
300
200
100
0
0
50
100
150
200
250
300
Test Temperature [K]

NbTi (1)

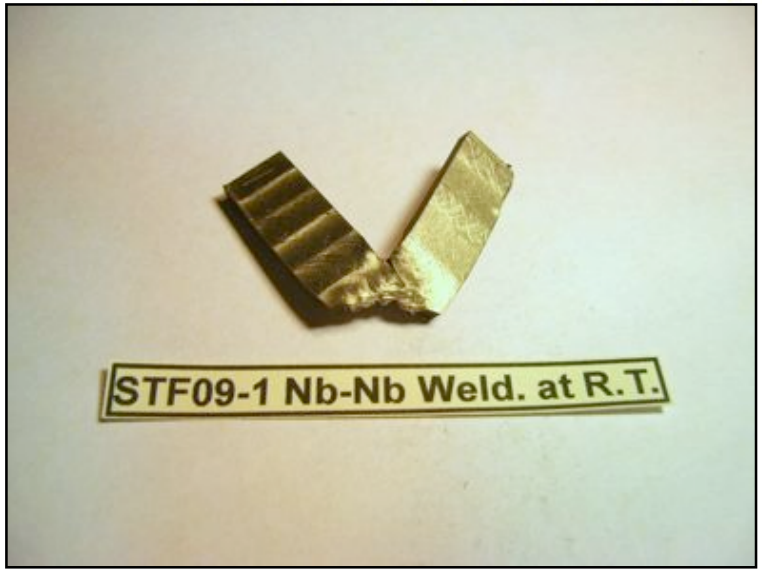


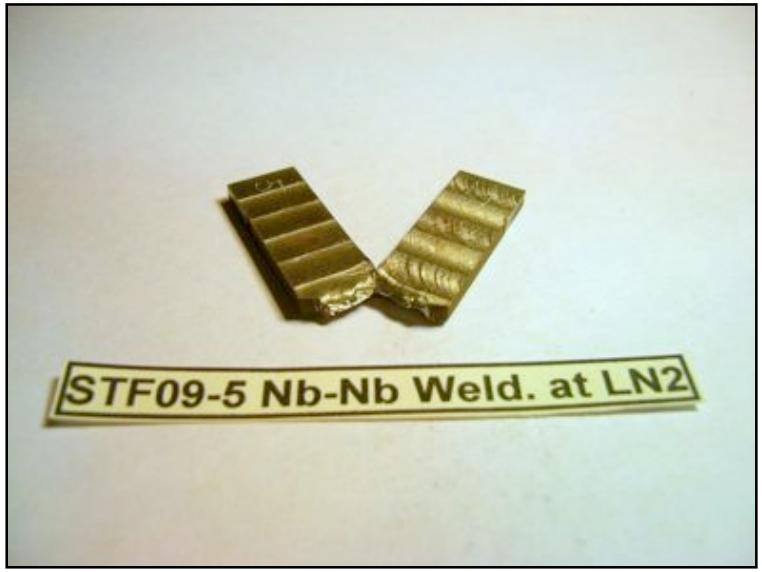
NbTi (2)


NbTi; 2.5 mm wide
Absorbed Energy [J]
250
200
150
100
50
0
0
50
100
150
200
250
300
Test Temperature [K]


NbTi; 2.5 mm wide
Charpy Impact Value [J/cm²]
500
400
300
200
100
0
0
50
100
150
200
250
300
Test Temperature [K]

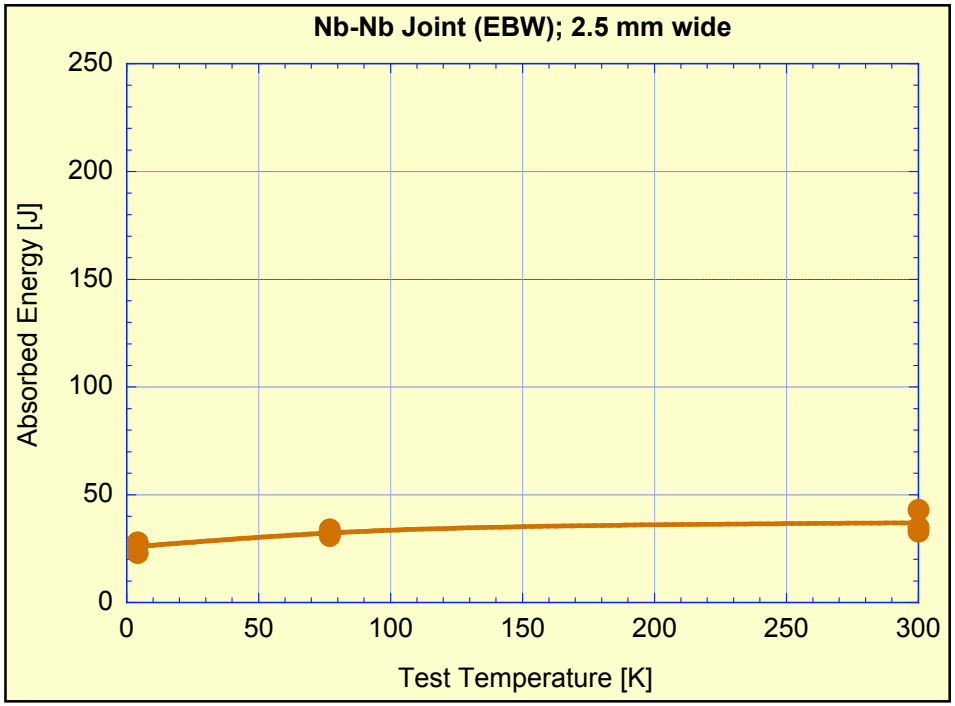
Nb-Nb Joint (1)

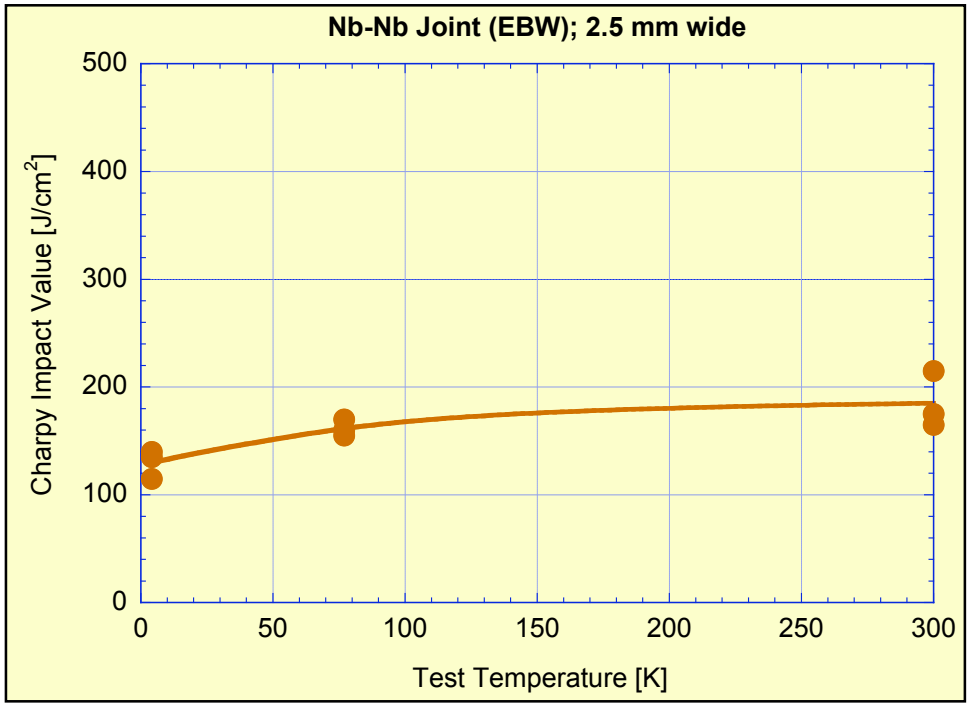

STF09-1 Nb-Nb Weld. at R.T.


STF09-5 Nb-Nb Weld. at LN2

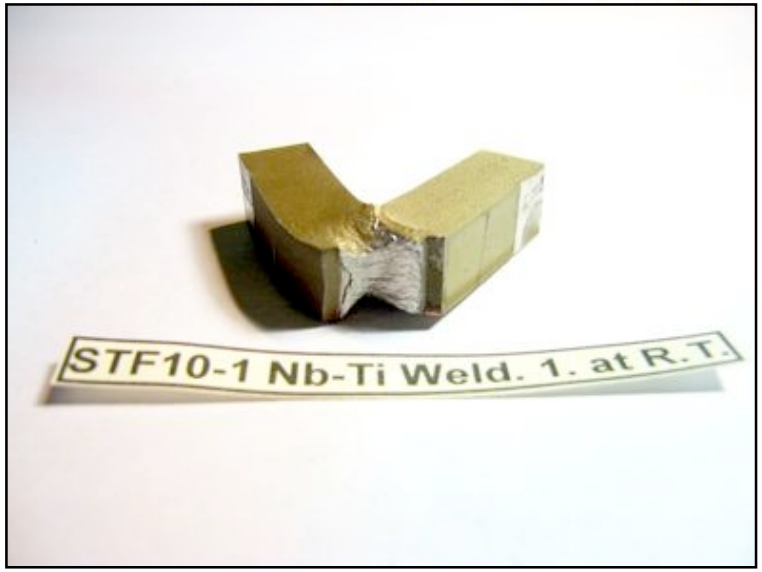

STF09-8 Nb-Nb Weld. at LHe

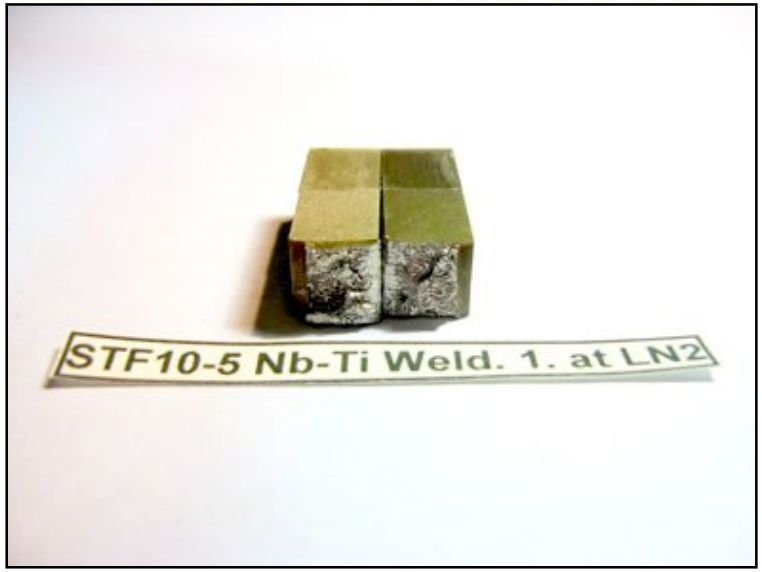
Nb-Nb Joint (2)

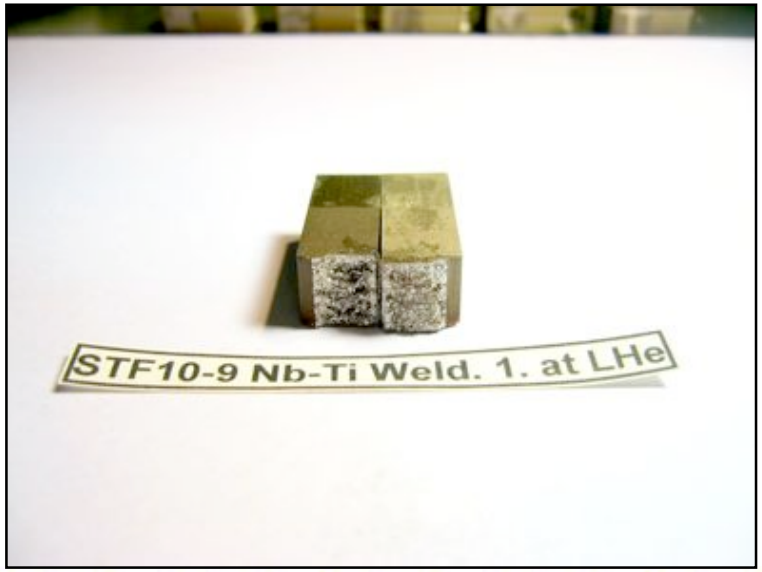

Nb-Nb Joint (EBW); 2.5 mm wide
Absorbed Energy [J]
0
50
100
150
200
250
0
50
100
150
200
250
300
Test Temperature [K]


Nb-Nb Joint (EBW); 2.5 mm wide
Charpy Impact Value [J/cm2]
0
100
200
300
400
500
0
50
100
150
200
250
300
Test Temperature [K]

Nb-Ti Joint (1)

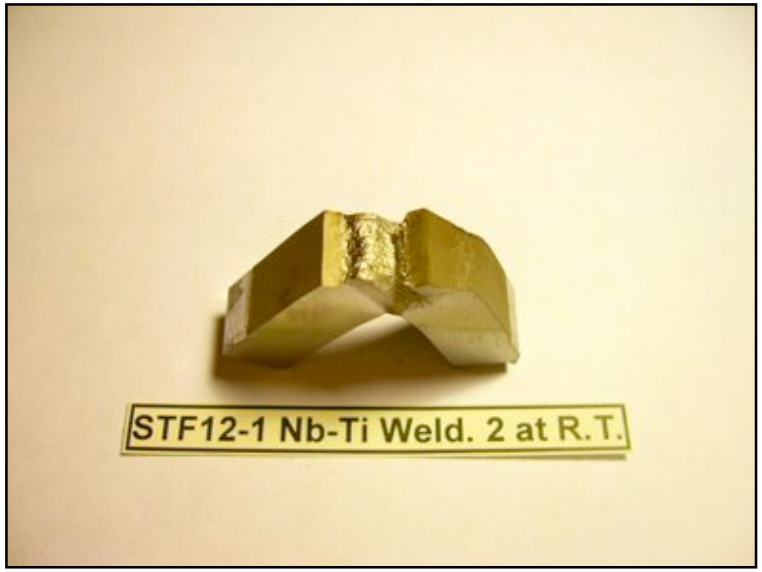

STF10-1 Nb-Ti Weld. 1. at R.T.


STF10-5 Nb-Ti Weld. 1. at LN2


STF10-9 Nb-Ti Weld. 1. at LHe


STF10-9 Nb-Ti Weld. 1. at LHe

Nb-Ti Joint (2)


STF12-1 Nb-Ti Weld. 2 at R.T.

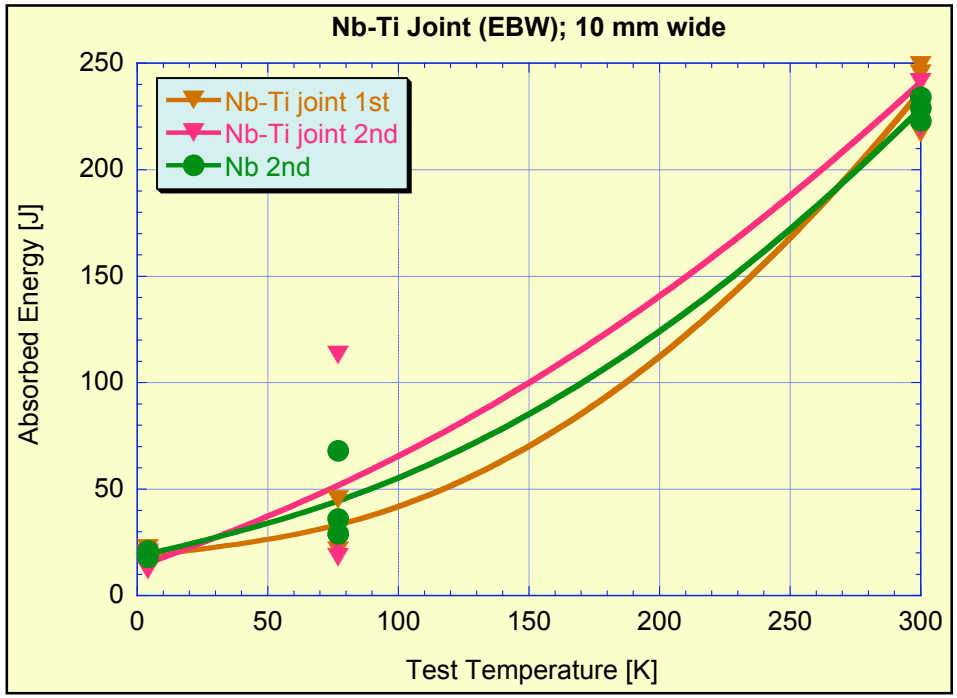

STF12-3 Nb-Ti Weld. 2 at R.T.

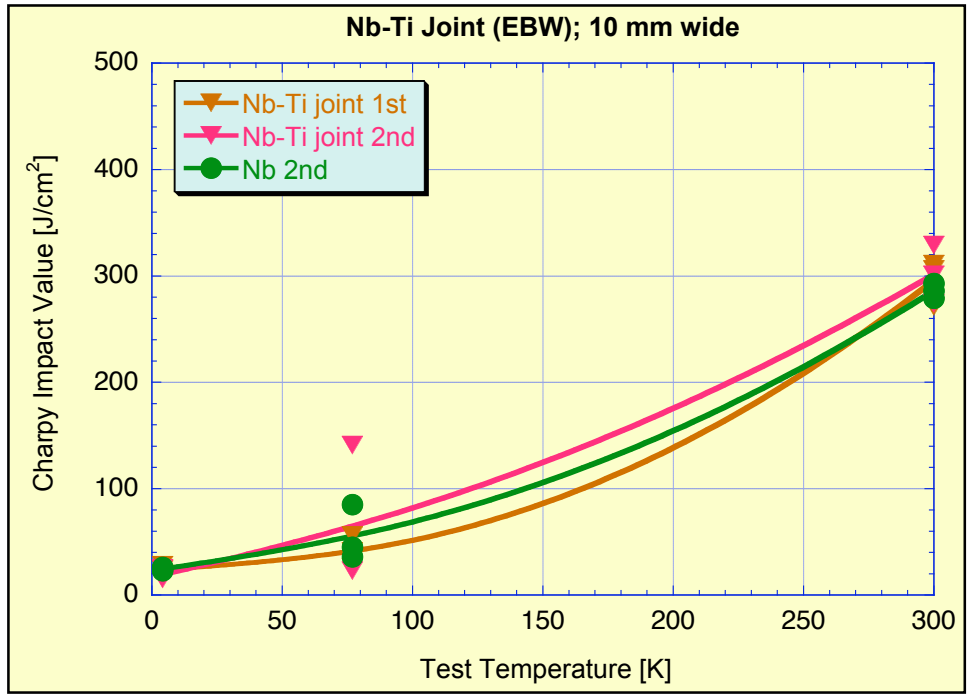

STF12-5 Nb-Ti Weld. 2 at LN2


STF12-6 Nb-Ti Weld. 2 at LN2

Nb-Ti Joint (3)

Nb-Ti Joint (4)

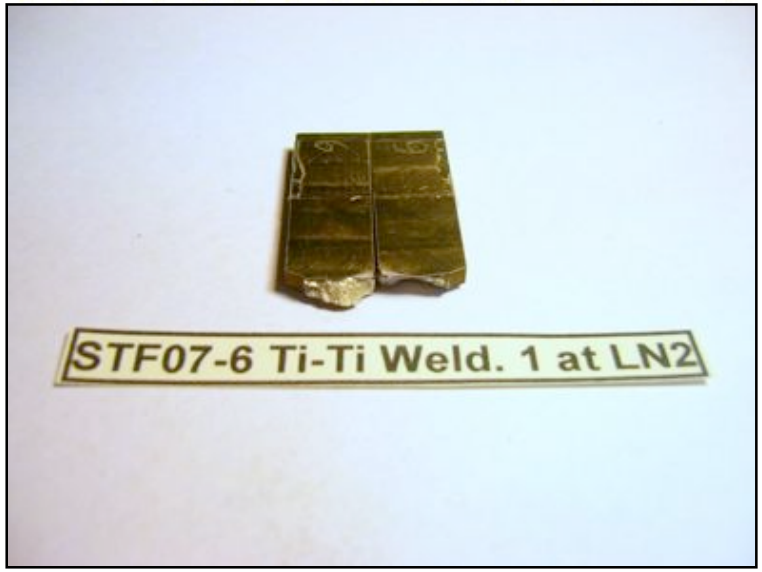


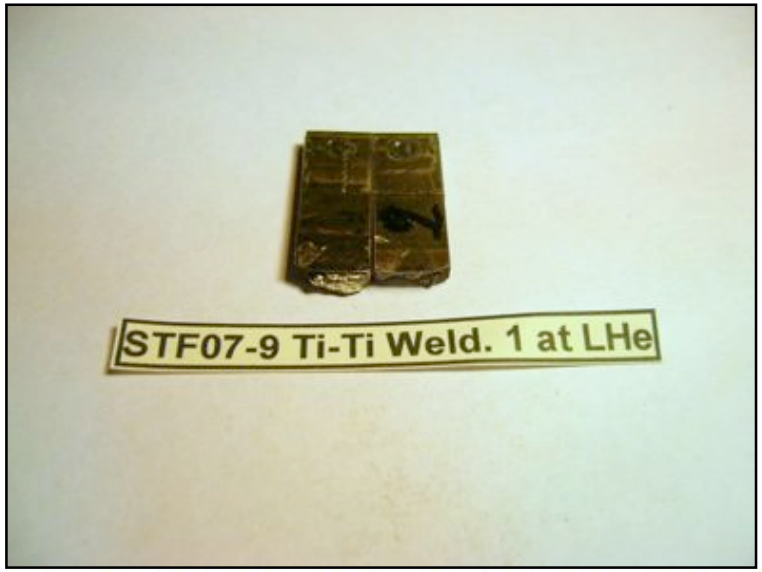


- First Nb-Ti samples show almost same results of Nb ones, since their notches located in Nb part.
- Second Nb-Ti results are not so different from those of firtst ones.

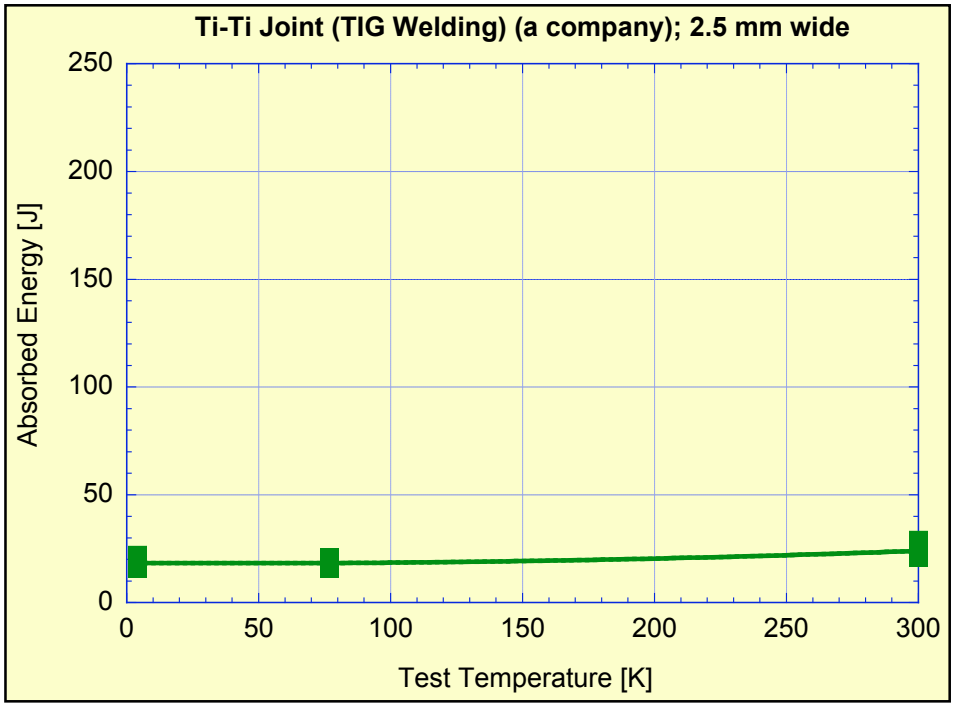
Ti-Ti Joint (1)

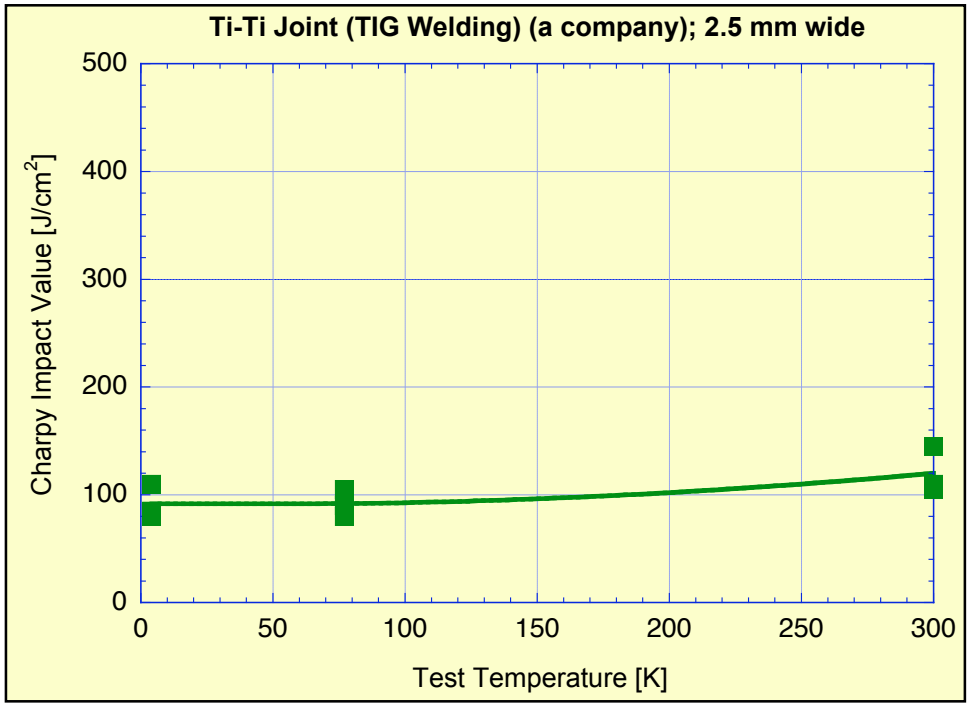

STF07-1 Ti-Ti Weld. 1 at R.T.


STF07-6 Ti-Ti Weld. 1 at LN2


STF07-9 Ti-Ti Weld. 1 at LHe

Ti-Ti Joint (2)


Ti-Ti Joint (TIG Welding) (a company); 2.5 mm wide
Absorbed Energy [J]
250
200
150
100
50
0
0
50
100
150
200
250
300
Test Temperature [K]


Ti-Ti Joint (TIG Welding) (a company); 2.5 mm wide
Charpy Impact Value [J/cm2]
500
400
300
200
100
0
0
50
100
150
200
250
300
Test Temperature [K]

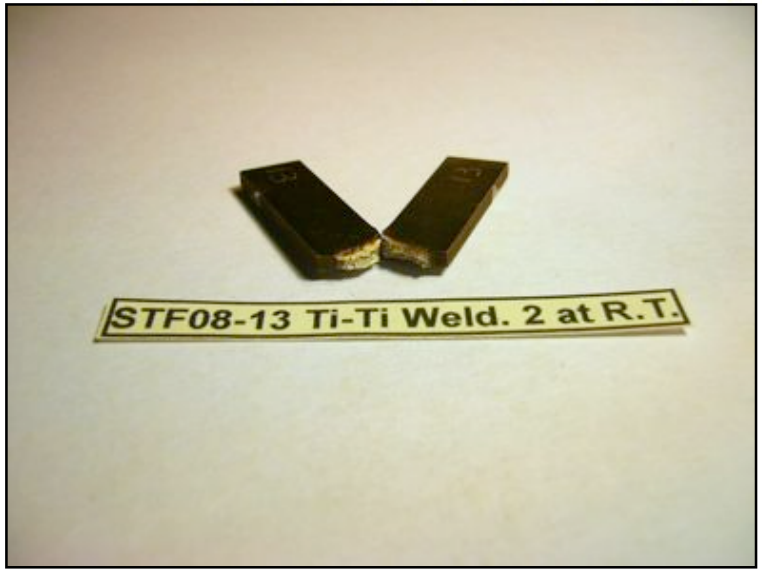
Ti-Ti Joint (3)

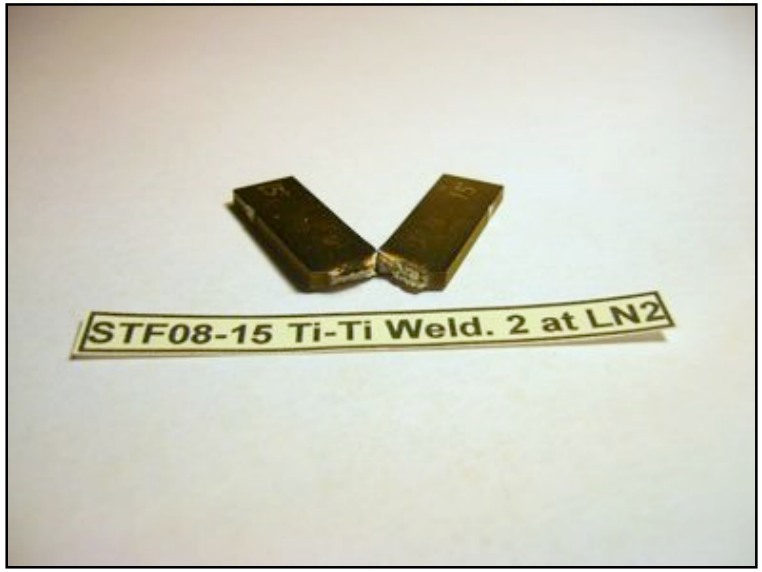

STF08-2 Ti-Ti Weld. 2 at R.T.

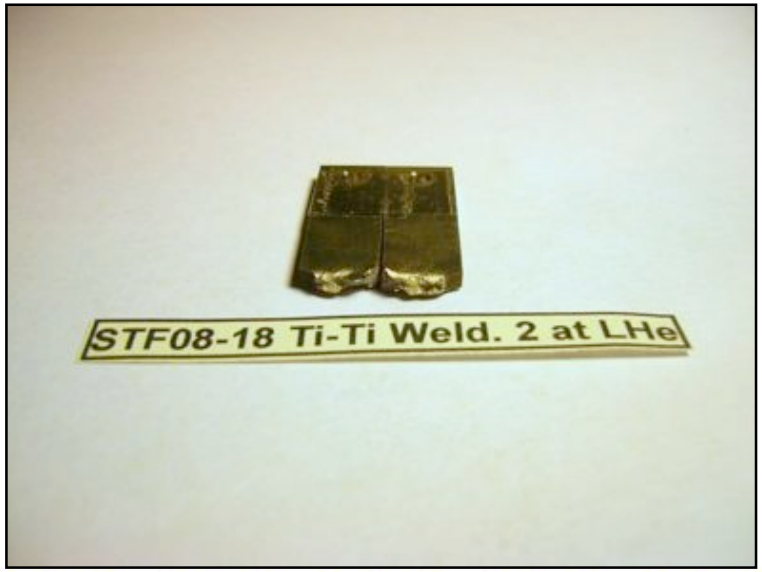

STF08-4 Ti-Ti Weld. 2 at LN2


STF08-7 Ti-Ti Weld. 2 at LHe

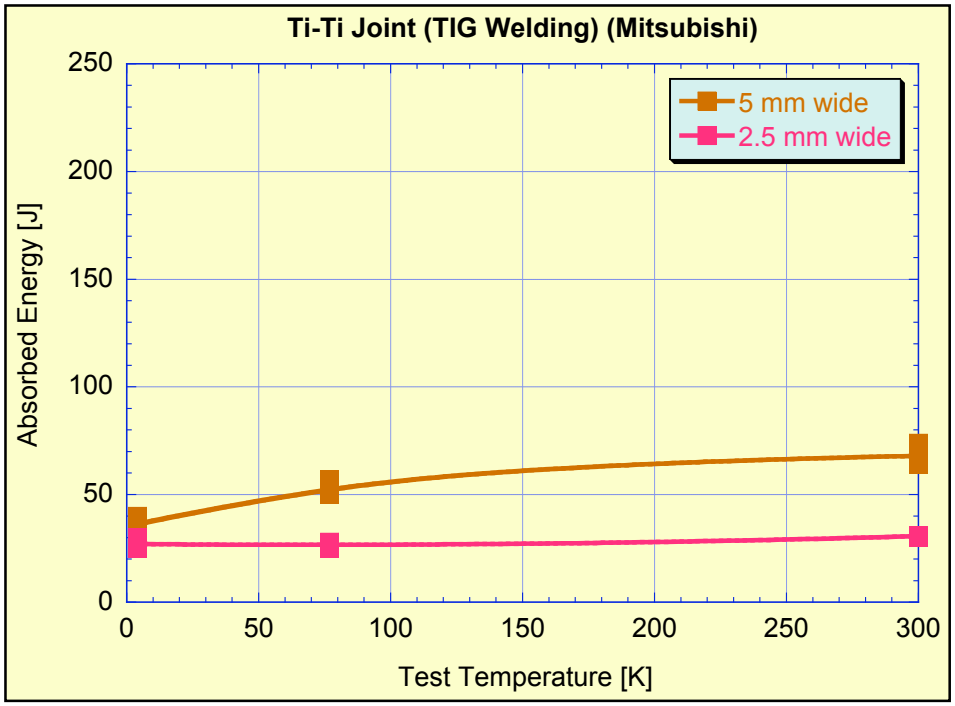
Ti-Ti Joint (4)

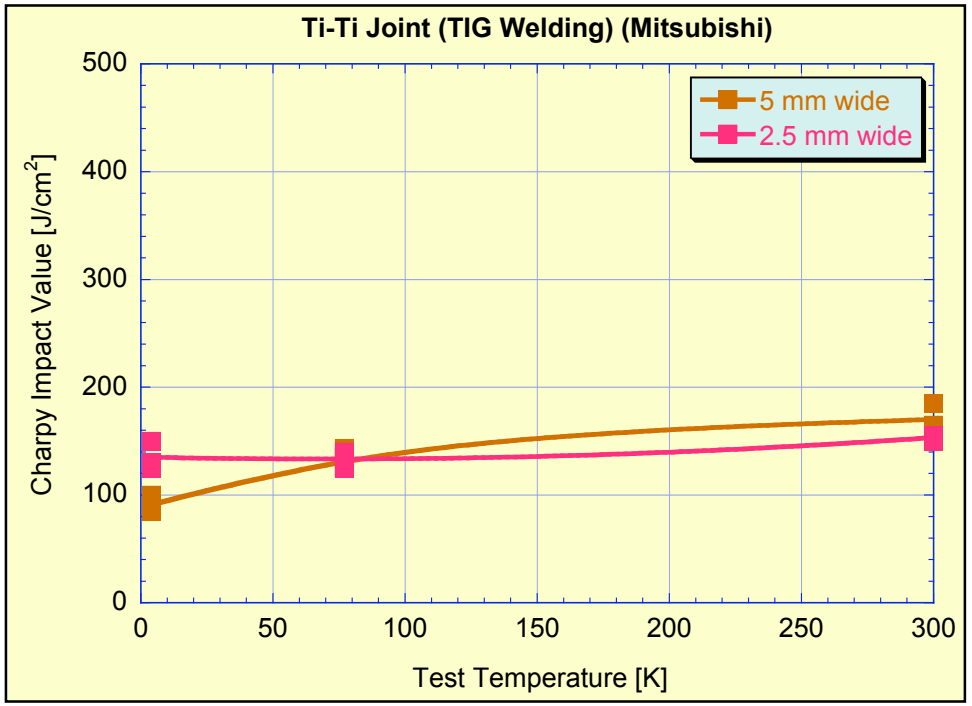

STF08-13 Ti-Ti Weld. 2 at R.T.


STF08-15 Ti-Ti Weld. 2 at LN2


STF08-18 Ti-Ti Weld. 2 at LHe

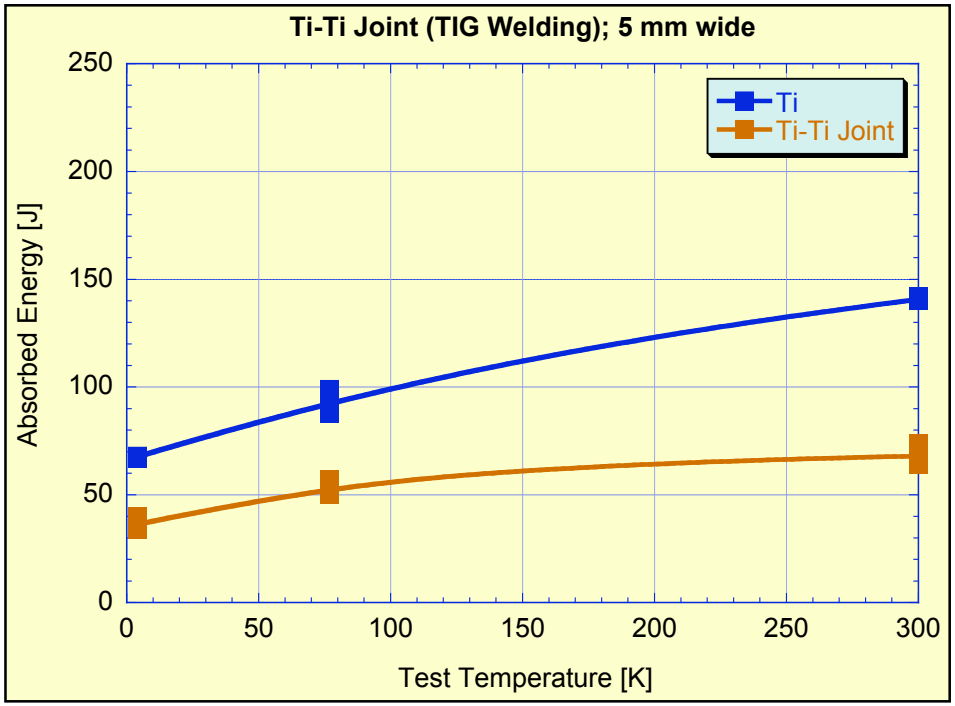
Ti-Ti Joint (5)

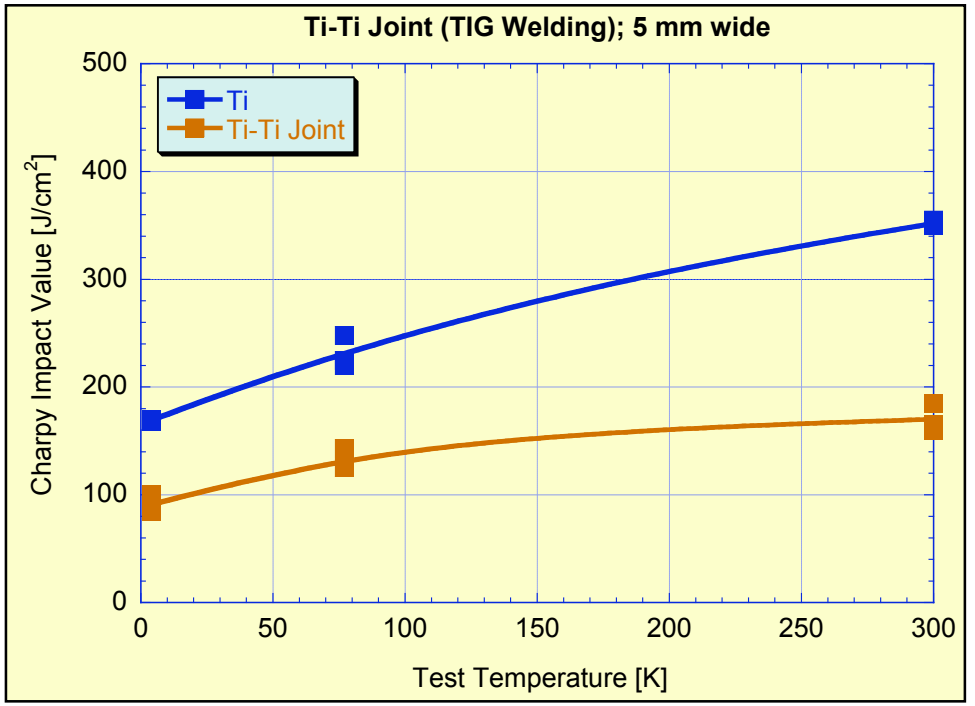




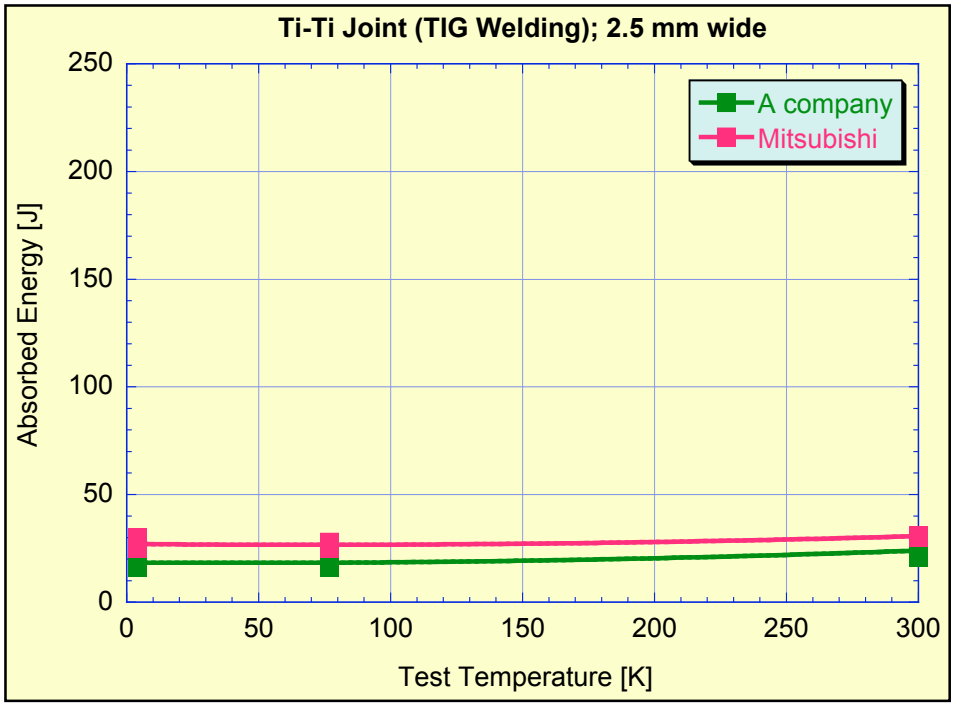
- It is not fair to compare data of different width samples

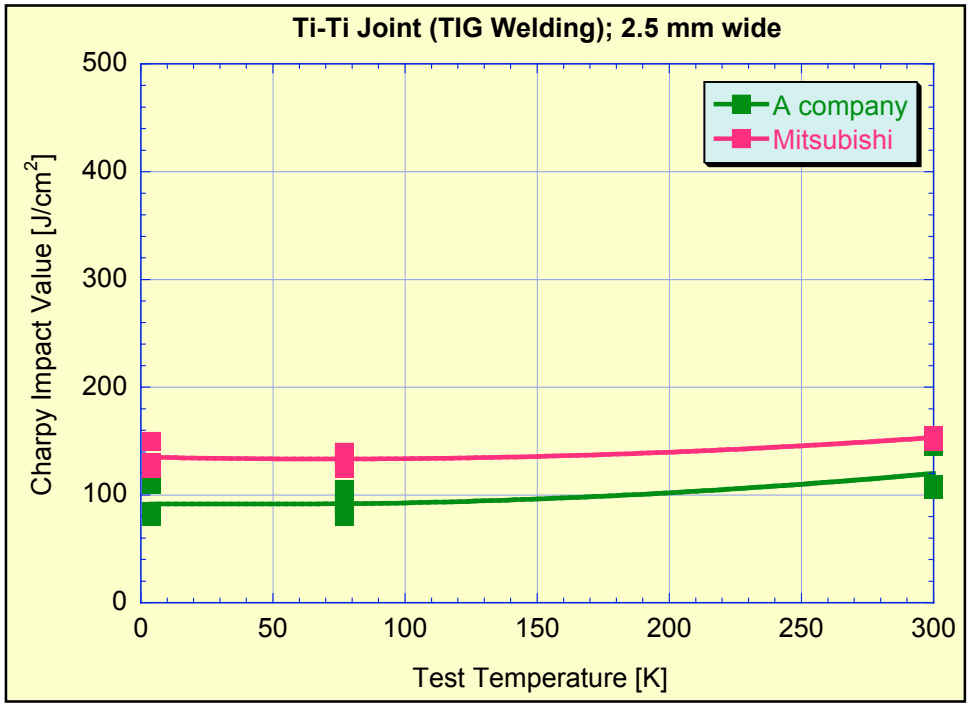
Ti-Ti Joint (6)


Ti-Ti Joint (TIG Welding); 5 mm wide
Absorbed Energy [J]
Test Temperature [K]
Ti
Ti-Ti Joint
0
50
100
150
200
250
300


Ti-Ti Joint (TIG Welding); 5 mm wide
Charpy Impact Value [J/cm²]
Test Temperature [K]
Ti
Ti-Ti Joint
0
100
200
300
400
500
50
150
250

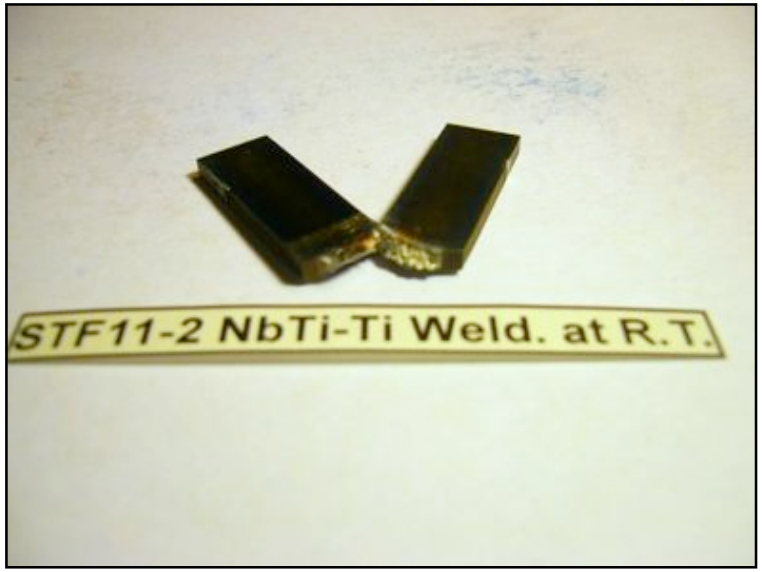
Ti-Ti Joint (7)

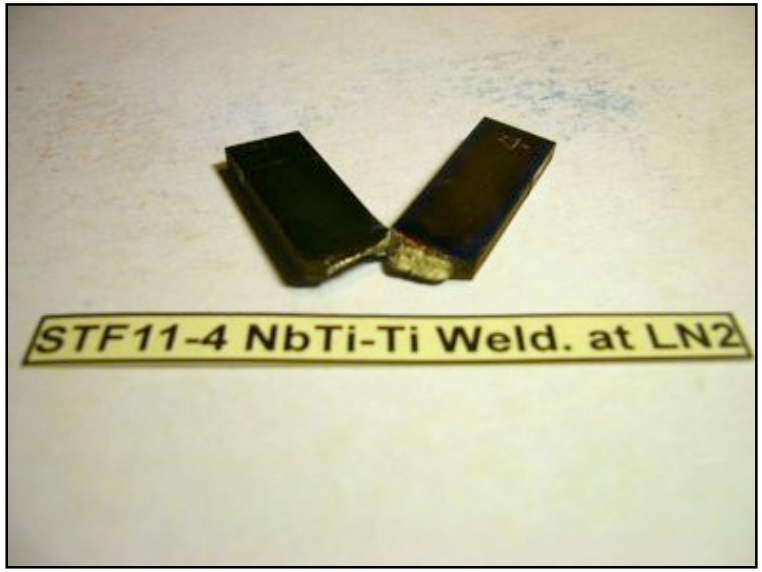




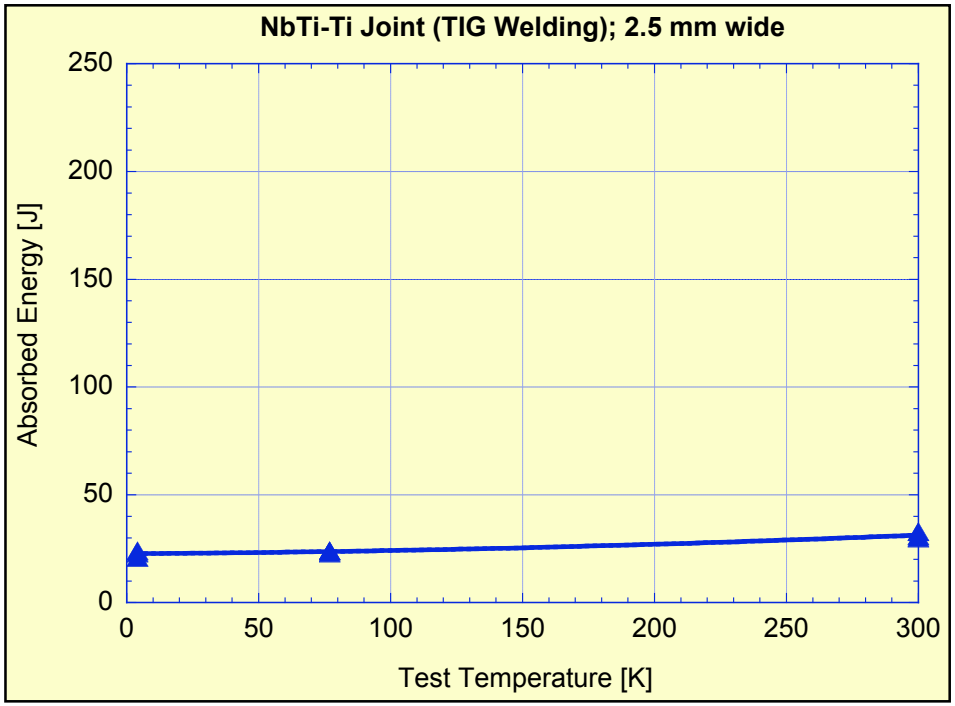
- Data of a company lower than those of Mitsubishi

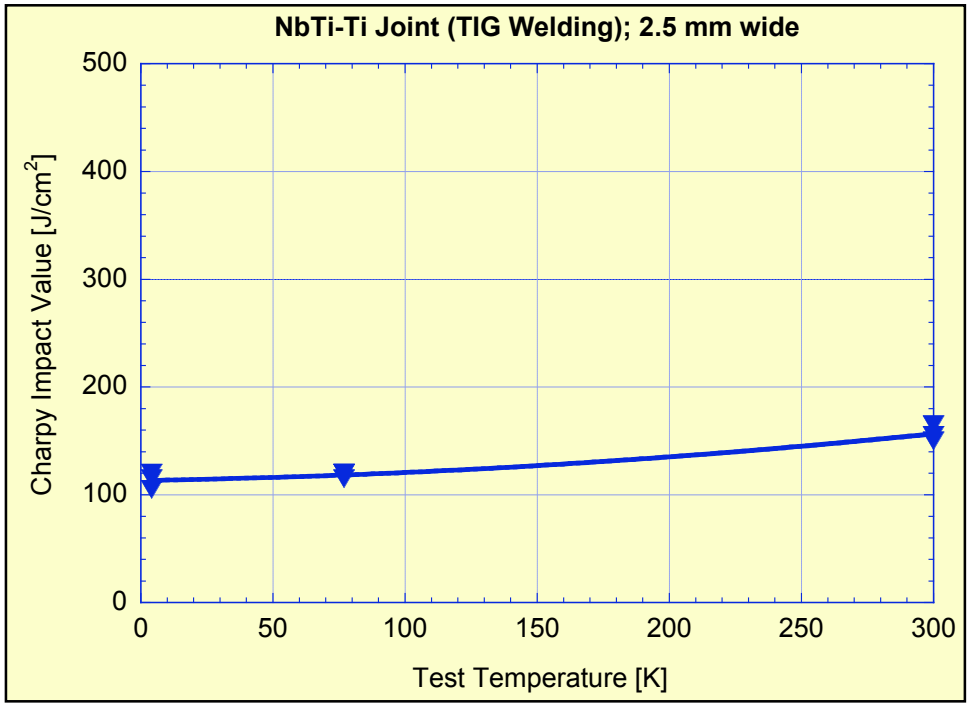
NbTi-Ti Joint (1)



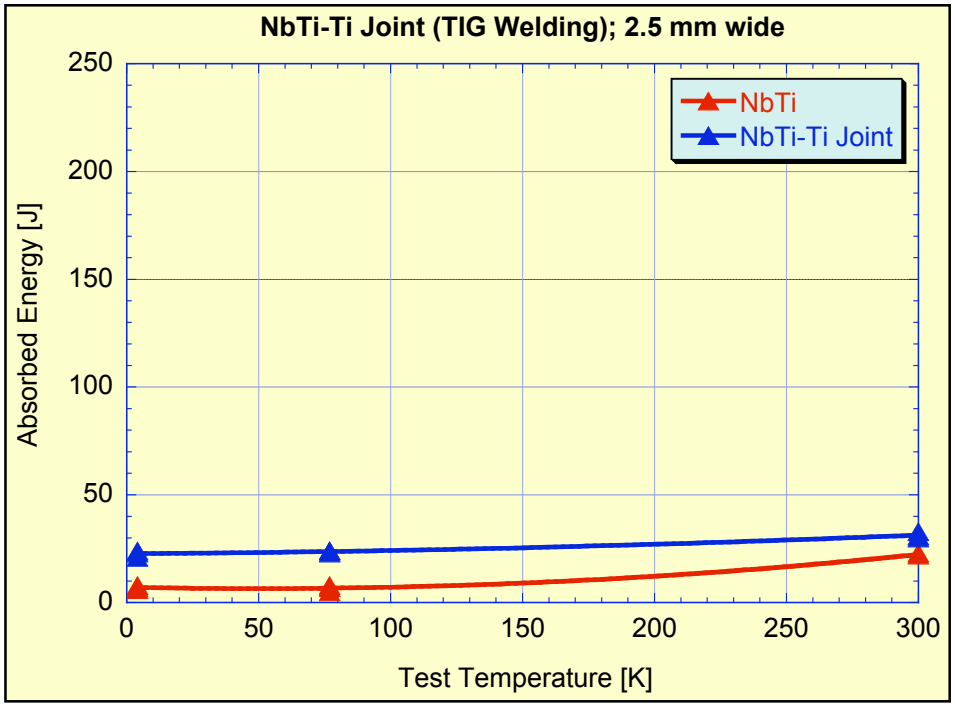


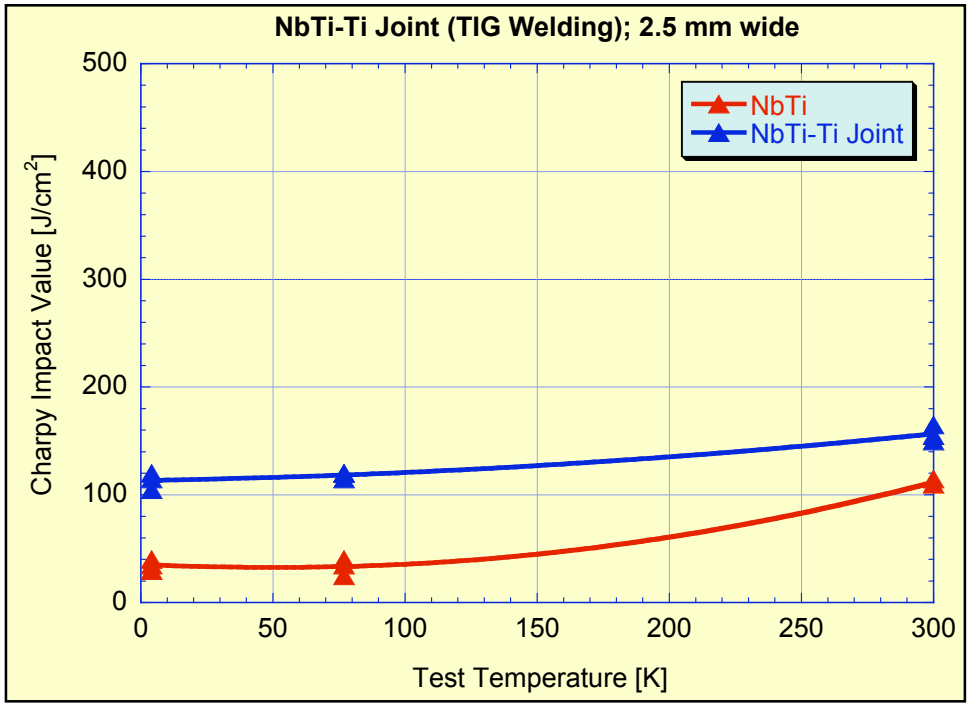
NbTi-Ti Joint (2)





NbTi-Ti Joint (3)





Nb-SS Joint (1)

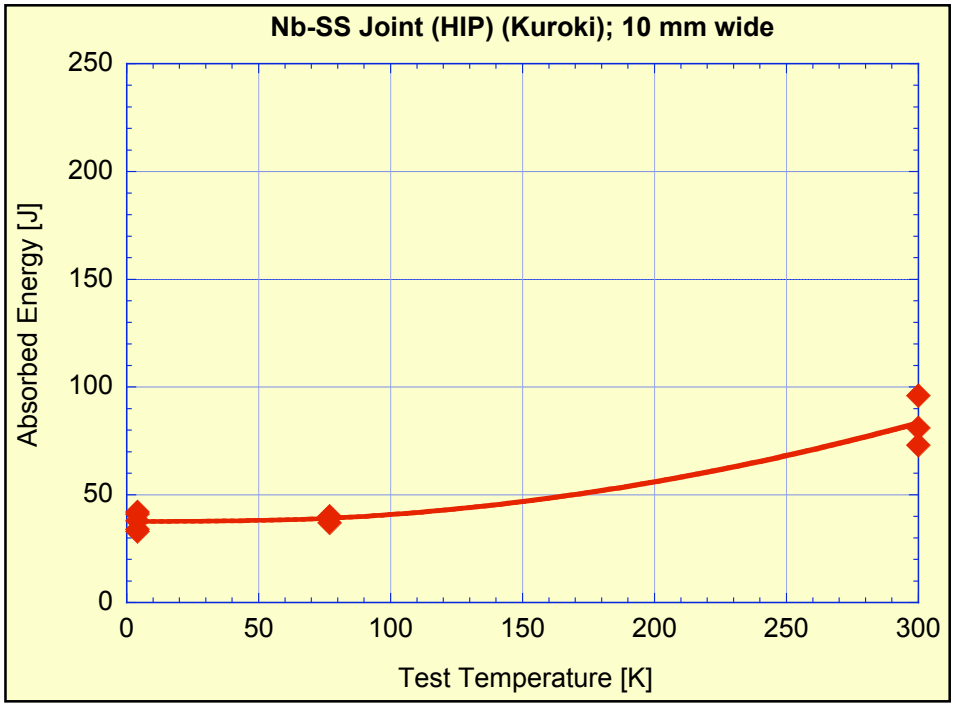

STF03-1 Nb-SS (HIP) 1 at R.T.

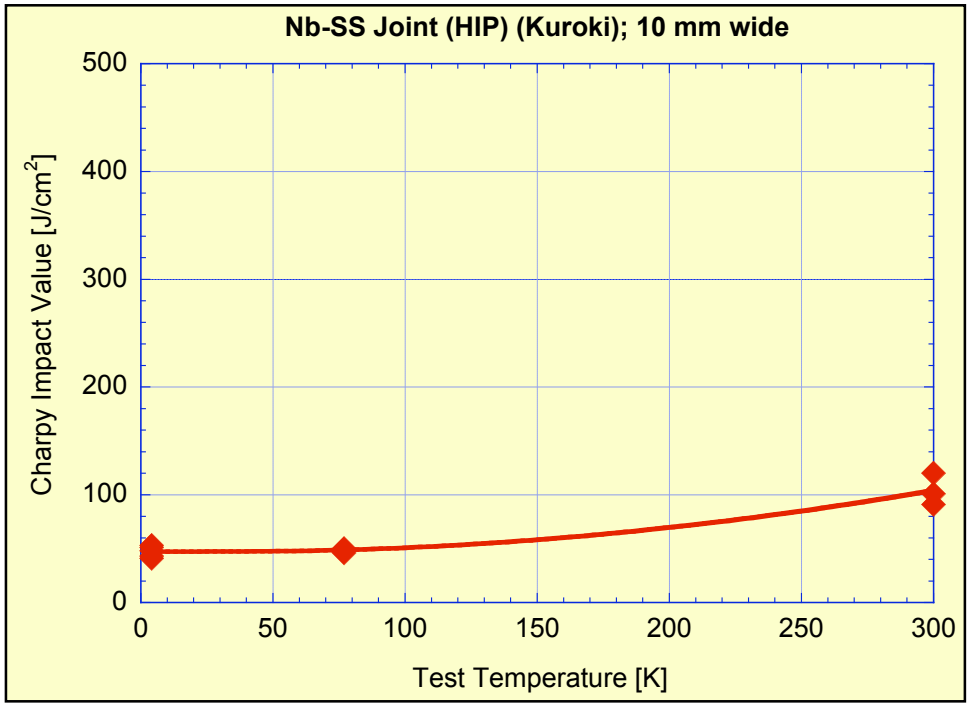

STF03-4 Nb-SS (HIP) 1 at LN2


STF03-8 Nb-SS (HIP) 1 at LHe


STF03-11 Nb-SS (HIP) 1 at LHe

Nb-SS Joint (2)


Nb-SS Joint (HIP) (Kuroki); 10 mm wide
Absorbed Energy [J]
0
50
100
150
200
250
0
50
100
150
200
250
300
Test Temperature [K]


Nb-SS Joint (HIP) (Kuroki); 10 mm wide
Charpy Impact Value [J/cm2]
0
100
200
300
400
500
0
50
100
150
200
250
300
Test Temperature [K]

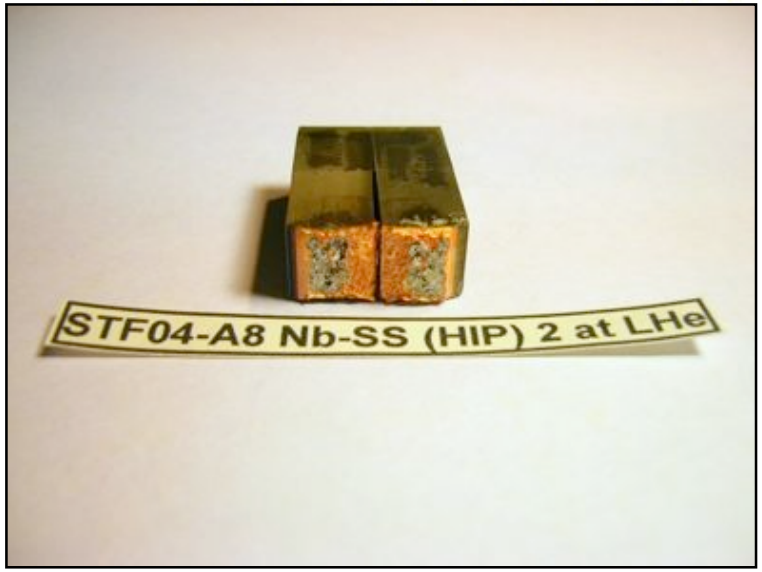
Nb-SS Joint (3)


STF04-A2 Nb-SS (HIP) 2 at R.T.


STF04-A4 Nb-SS (HIP) 2 at LN2


STF04-A8 Nb-SS (HIP) 2 at LHe

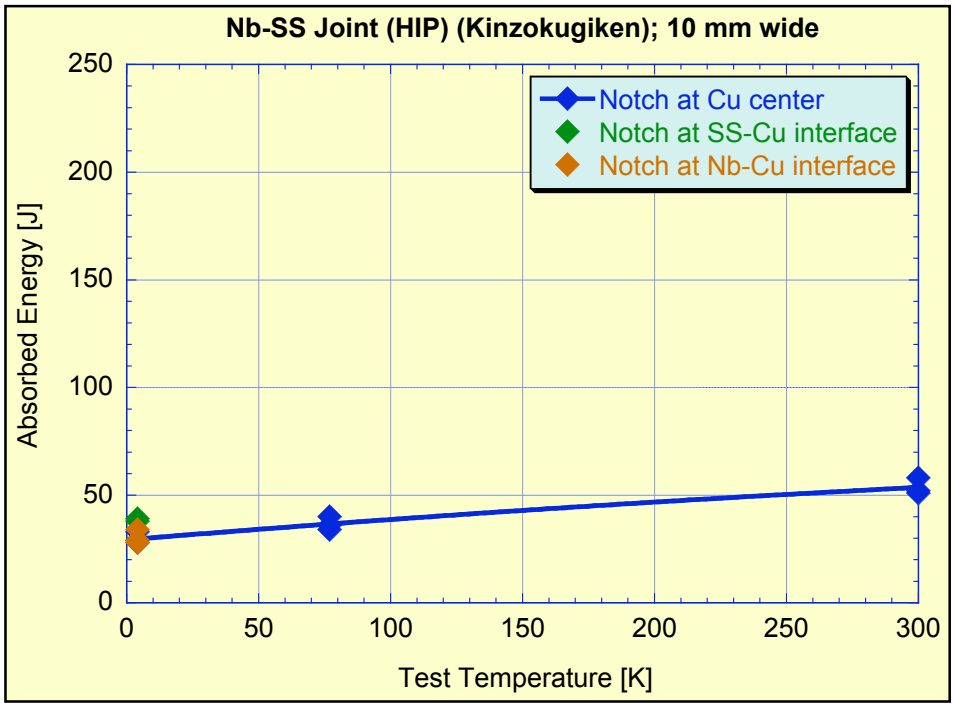
Nb-SS Joint (4)

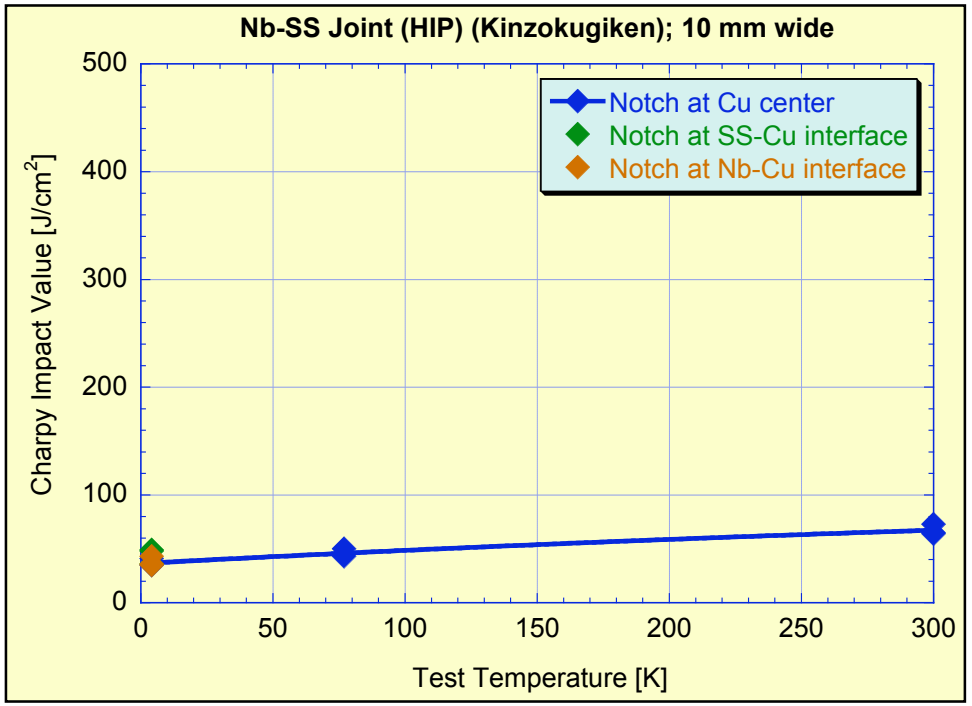

STF04-A8 Nb-SS (HIP) 2 at LHe


STF04-B3 Nb-SS (HIP) 2 at LHe


STF04-C3 Nb-SS (HIP) 2 at LHe

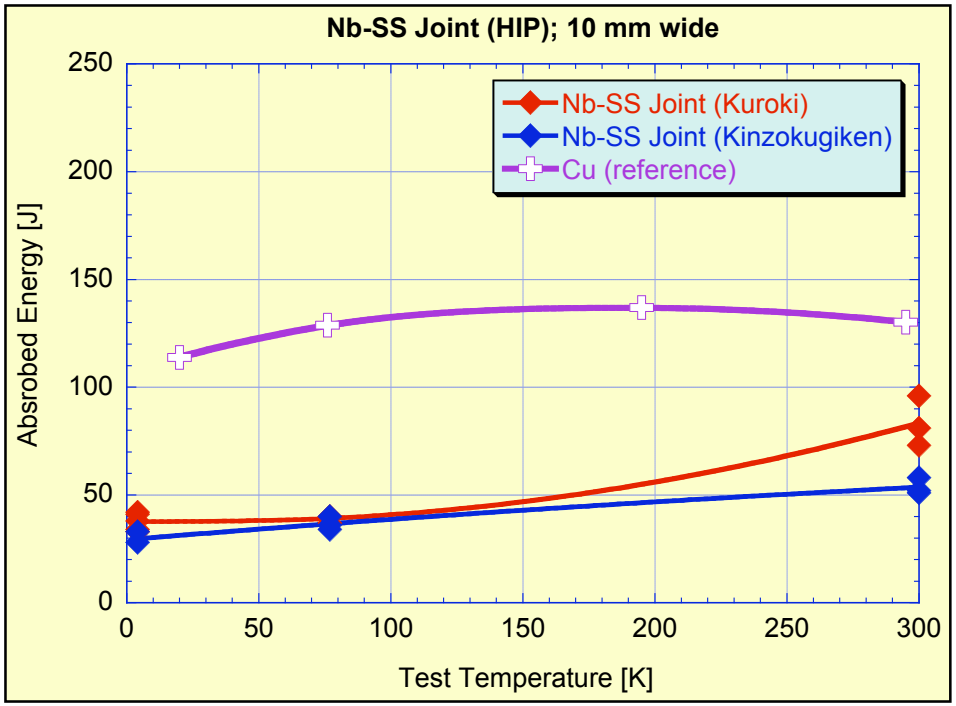
Nb-SS Joint (5)

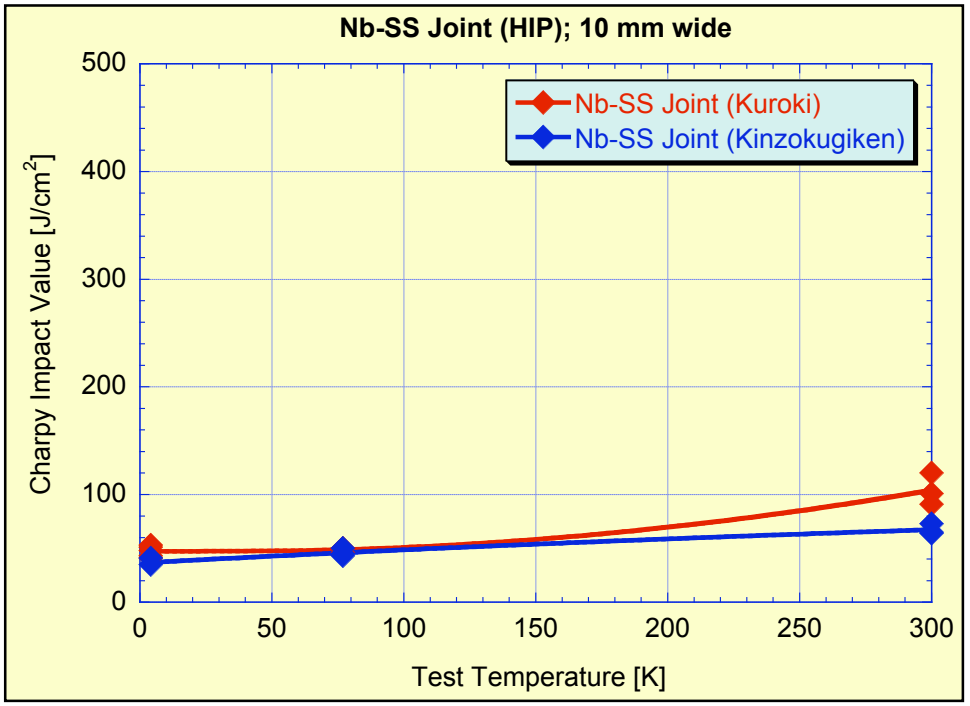




- No distinguishable difference of test results with notch positions at LHe temperature

Nb-SS Joint (6)





- Difference of test results between two companies not large
- Data of Kinzokugiken lower than those of Kuroki

Summary

- A series of impact tests have been carried out at a Japanese company (Kawaju Techno Service Corp.) with metal materials and welded materials for application of special approval in accordance with high pressure safety regulations in Japan
- The High Pressure Gas Safety Institute (KHK) requires information on whether samples were completely fractured or not, and also on brittle fracture surface ratio with test temperature.