



Problems in thermal cycle test of cold window for RIKEN QWR

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Subjects

- How to conduct thermal cycle test ?
 - Our results in $\left\{ \begin{array}{l} \text{February (77 K / 4 K)} \\ \text{June (77 K / 40 K)} \end{array} \right.$
 - Cooling velocity ?
 - Number of times of thermal cycles ?
 - Implement for leakage test ?
-

Additional subject

- When multipacting is encountered in VT for QWR, power coupler should be overcoupled ?

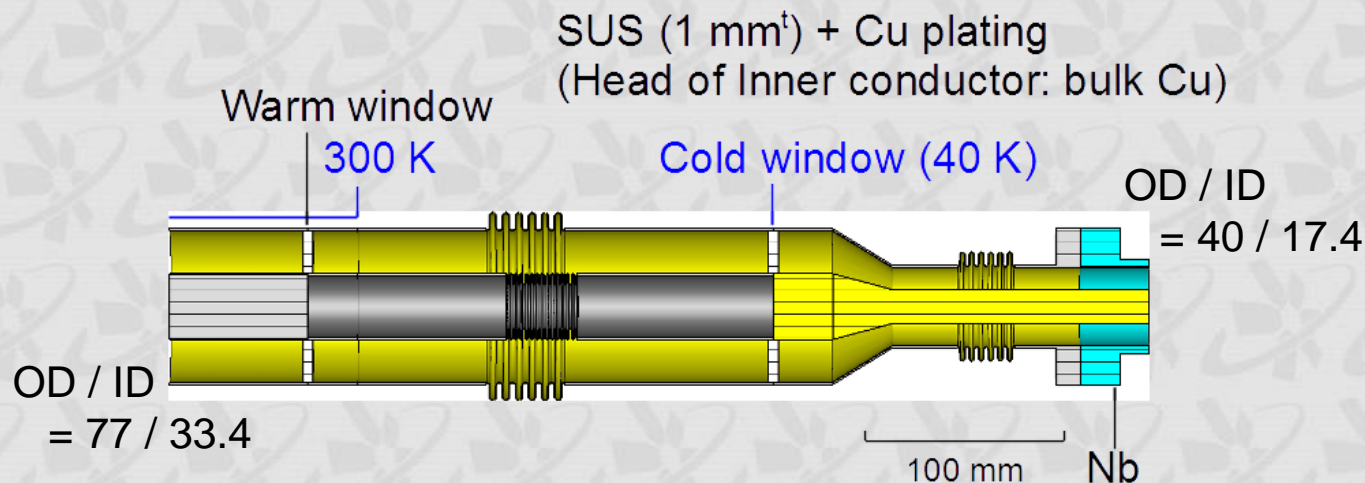
General description

Prototype of SC-QWR for low β heavy-ions

One cryomodule which mounts two QWRs
(Presently, only one QWR is being constructed)

Power coupler

- Coaxial
- Double windows (disk type, RT and 40 K)
- Frequency: 75.5 MHz
- Maximum RF power: 10 kW, CW



Specifications of ceramics

Two power couplers

Warm window: Kyocera

Cold window: Kyocera / NTK



	Kyocera/479B	NTK/HA997
Purity of alumina [%]	99.80	99.70
Density [$\text{g}\cdot\text{cm}^{-3}$]	3.9	3.9
Bending strength [MPa]	300	300
Electric permittivity	9.9 @ 1 MHz	10.0 @ 1 MHz
Dielectric loss [10^{-4}]	0.4 @ 8 GHz	<1 @ 10 GHz
Thermal conductivity @ 20°C [$\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$]	29	31

Thermal cycle test in February — 77 K

Cold windows enfolded with three-fold aluminum foils were dunked in LN₂ directly for **ten times**

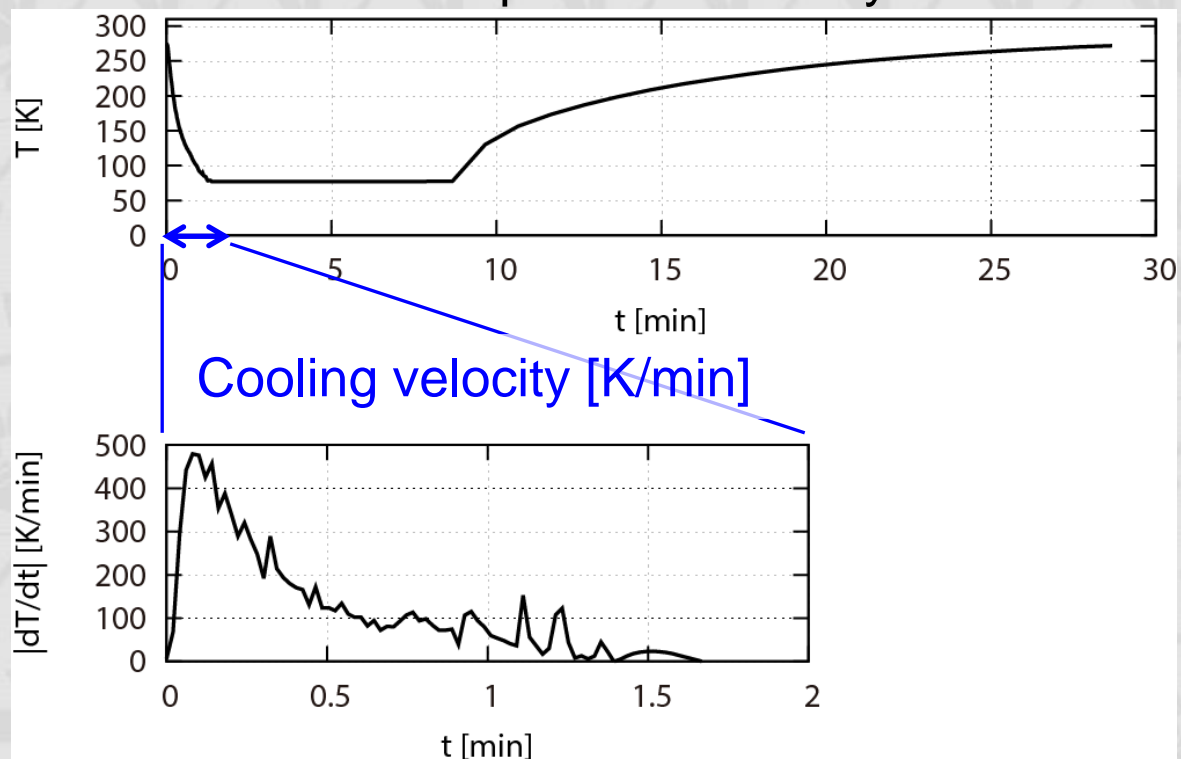


Leakage test

Kyocera: **No leak**

NTK: **No leak**

Example of thermal cycle



Thermal cycle test in February — 4 K

Cold windows enfolded with three-fold aluminum foils were cooled down using cold He gas and dunked in LHe for **two times**.

↓
Leakage test

Kyocera: **No leak**

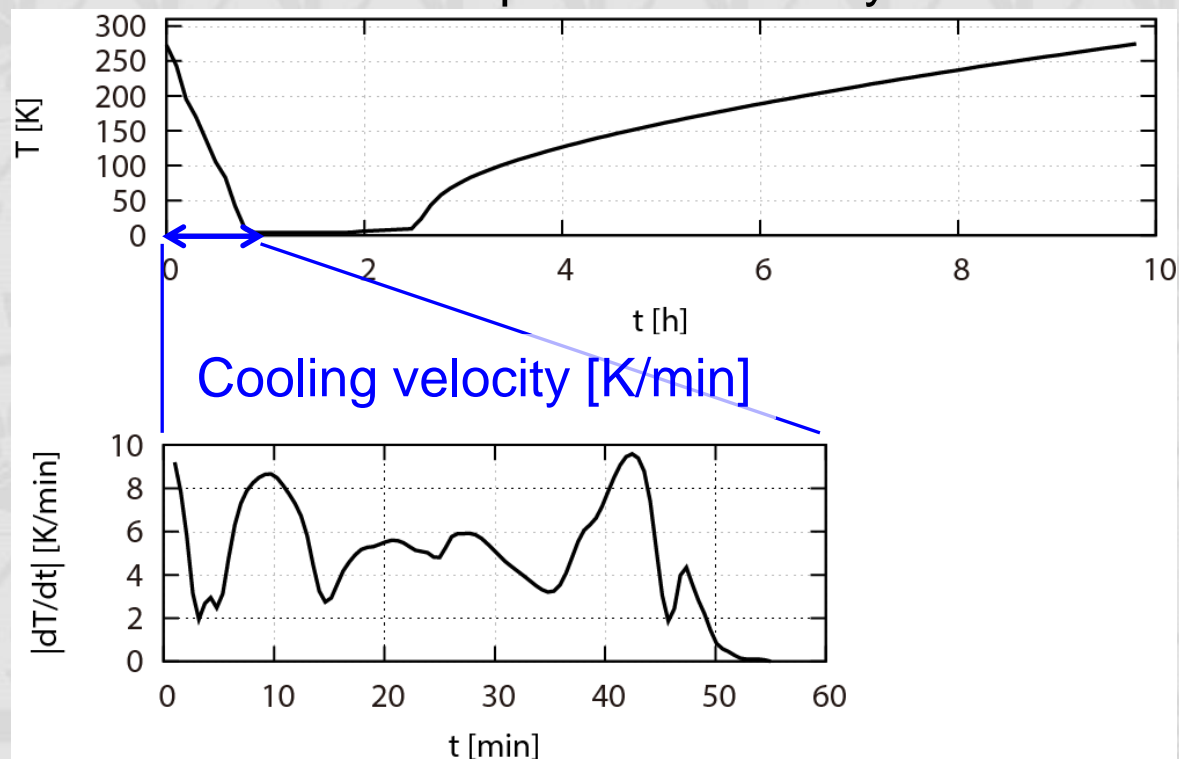
NTK: **Leak**

↓
Test for Kyocera
window was continued
for **six times**.

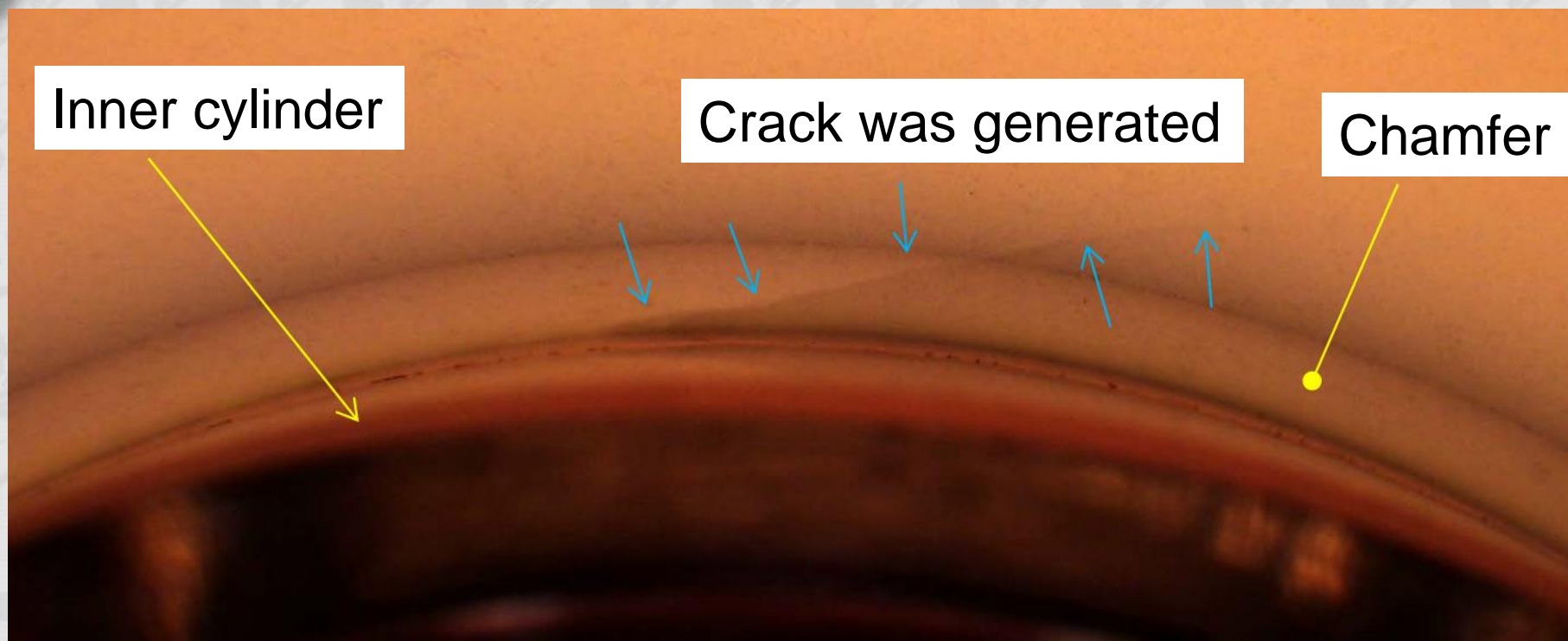
↓
Leakage test

Kyocera: **No leak**

Example of thermal cycle

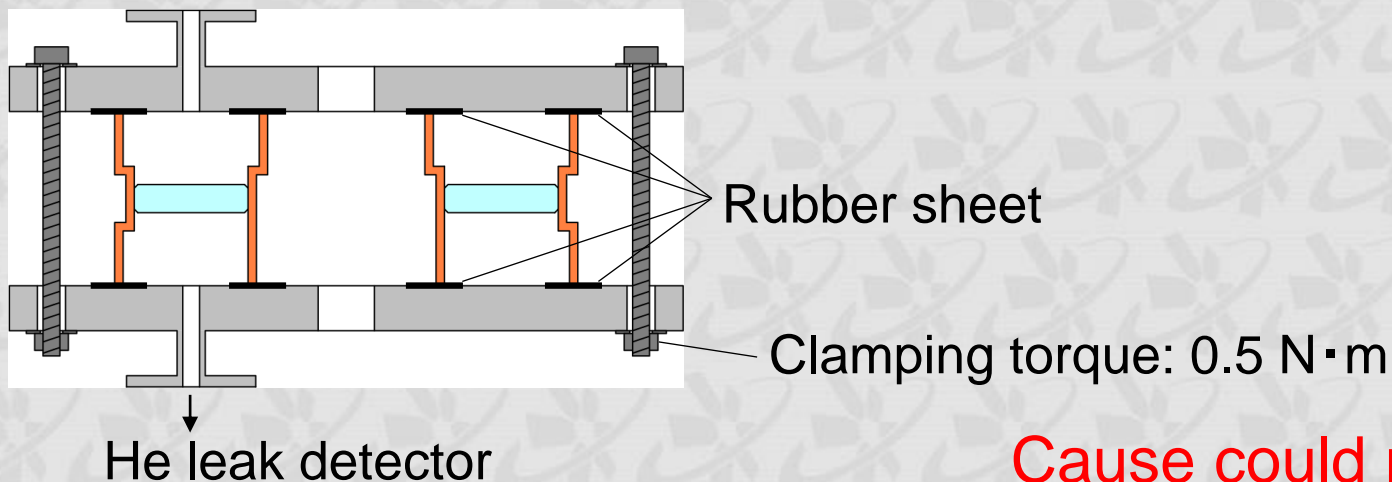


Crack in NTK window



Cause for crack ?

- Too rapid cooling ?
...but, crack was not generated by 77 K cycles.
→ accumulation of fatigue by 77 K cycles
and final blow by 4 K cycles ?
- Inappropriate implement for leakage test ?
Inner and outer cylinders were sealed all together.
→ slight misalign between inner and outer cylinder
caused unnecessary force to brazing area ?



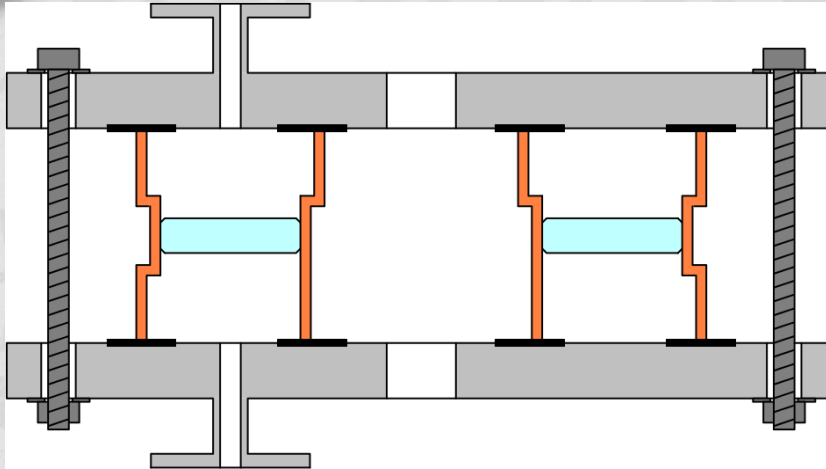
Cause could not be identified.

Cold windows were re-manufactured for both Kyocera and NTK.

Thermal cycle test for new cold windows:

- Slower cooling velocity
- Do not cool down to LHe temperature
- Decrease of the number of times of thermal cycles
- Decrease of the number of times of leakage tests
- Redesign of implement for leakage test

Redesign of Implement for leakage test



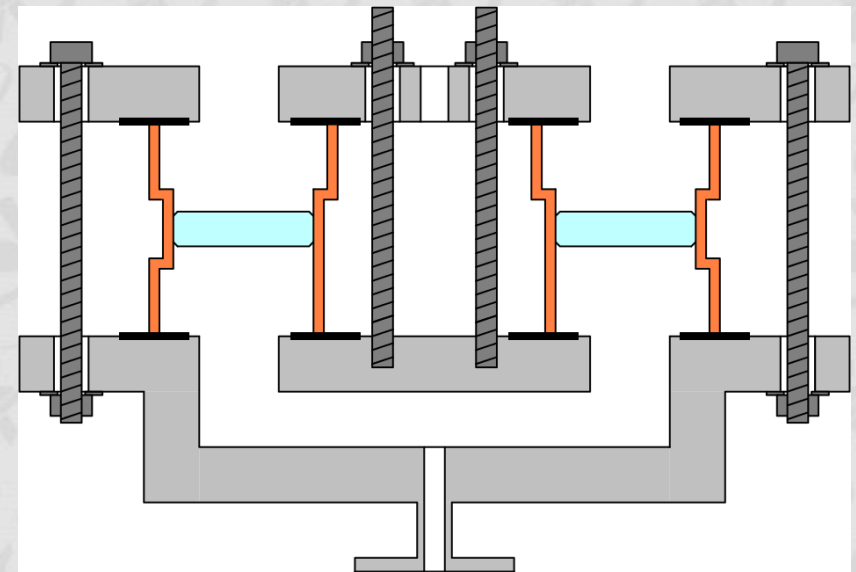
Old version:

Inner and outer cylinders are sealed all together.



New version:

Inner and outer cylinders are sealed individually.

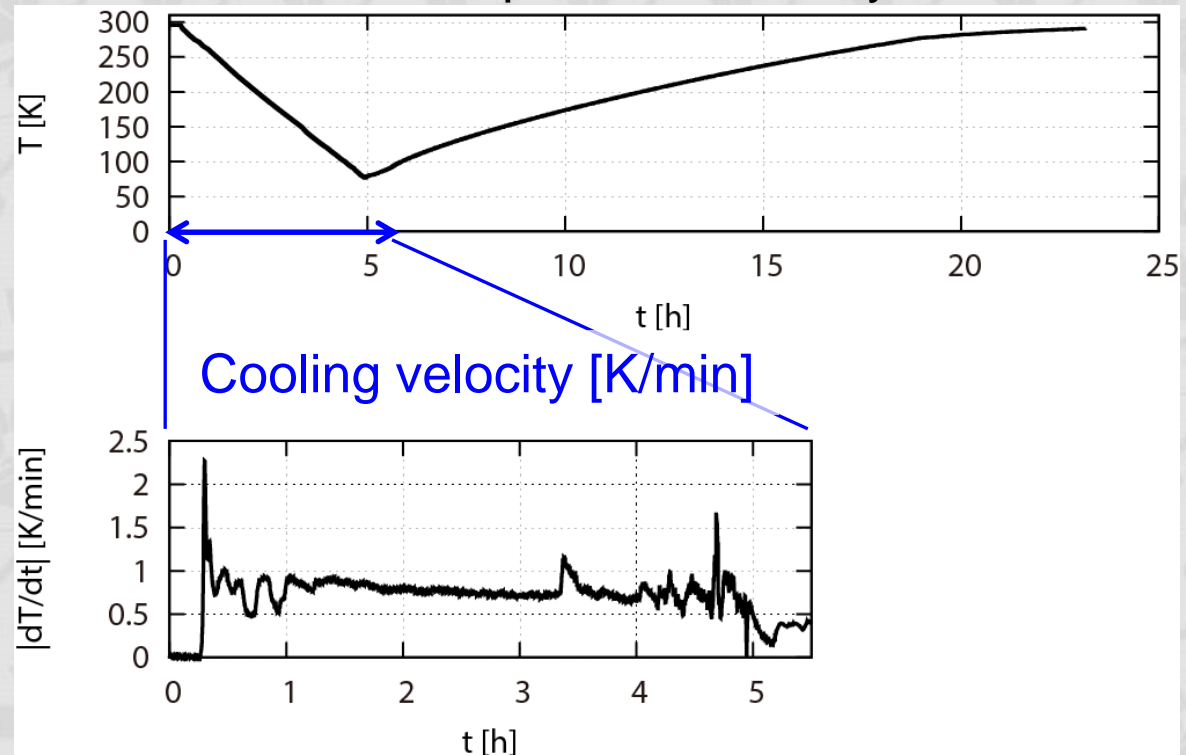


Thermal cycle test in June — 77 K

Cold windows enfolded with **ten-fold** aluminum foils were slowly cooled down to 77 K using cold He gas for **three times**.

No leakage test
at this time
Visual inspection only

Example of thermal cycle



Thermal cycle test in June — 40 K

Cold windows enfolded with **ten-fold** aluminum foils were slowly cooled down to 40 K using cold He gas for **two times**.

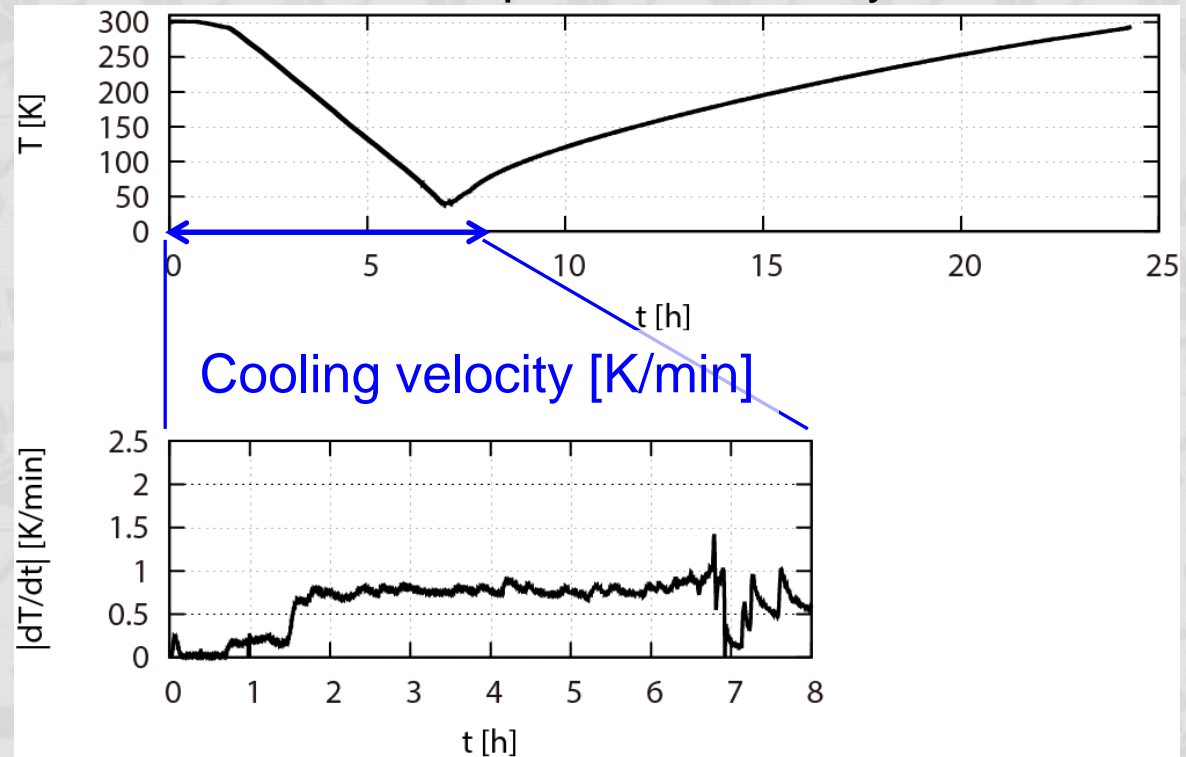


Leakage test

Kyocera: **No leak**

NTK: **No leak**

Example of thermal cycle





I want to hear your opinions:

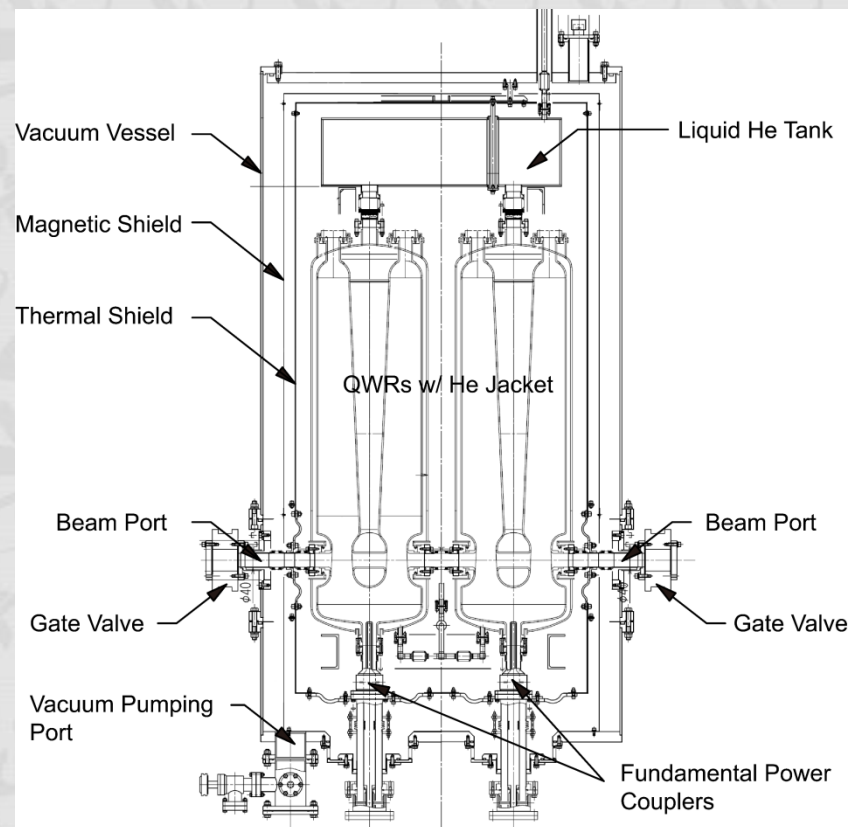
- Cause for crack in 1st window ?
 - too rapid cooling, and/or
 - inappropriate implement for leakage test, or
 - other reasons ?
 - Proper cooling velocity of window ?
 - Number of times of thermal cycles ?
 - Design of implement for leakage test ?
-
- When multipacting is encountered in VT for QWR, power coupler should be overcoupled ?
(In that case, to what extent ?)

Brief introduction of RIKEN QWR

Prototype of SC-QWR for low β heavy-ions:
One cryomodule which contains two QWRs

Specifications

Resonant frequency [MHz]	75.5
G	23.3
R_{sh}/Q [Ω]	714
Q_0 ($R_s = 25$ n Ω)	9.3×10^8
E_{acc} [MV/m]	4.5
E_{peak} / E_{acc}	6.3
B_{peak} / E_{acc} [mT/(MV/m)]	10.6



Basic concepts of cryomodule

- Resonator vacuum is separated from the vacuum of the cryostat
- Power coupler has coupling tunable mechanism without warming up or release of vacuum
- Single-stage thermal shield (40 K) cooled with a small cryo-cooler
- Room temperature magnetic shield