Improvement of magnetic condition for KEK-STF vertical test facility toward high-Q study

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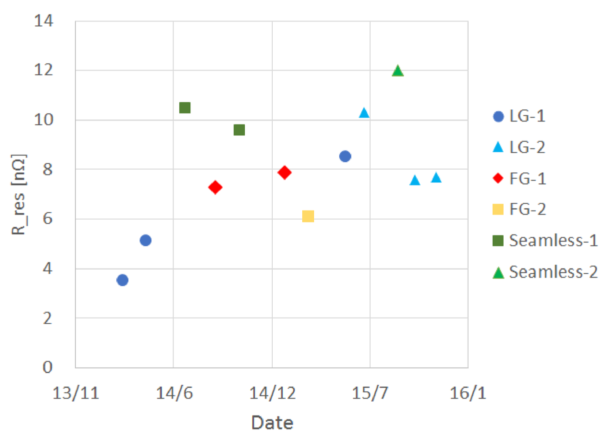
Abstract

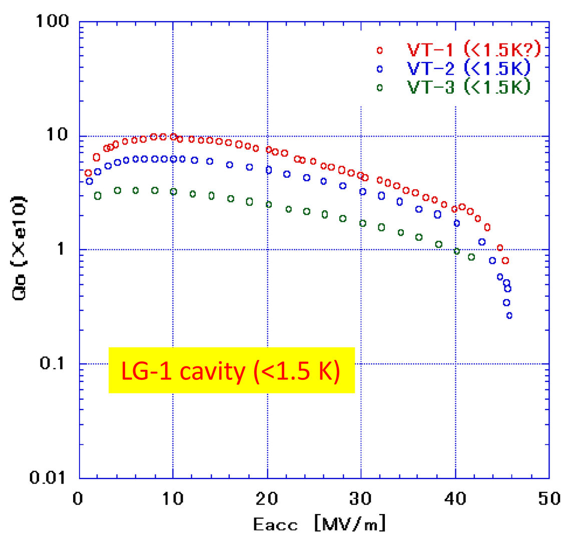
Improvement of unloaded Q-values of SRF cavities are important to reduce surface loss of cavity and heat loads of He refrigerators. R&D activities have been developed worldwide. We also started work toward high-Q, but soon realized that magnetic condition of KEK-STF vertical test facility was not good enough to carry out high-Q measurements. First, magnetized components were searched. Shafts to move variable coupler were found to be most magnetized one and exceed more than 1 Gauss. Magnetized components were exchanged to non-magnetized one. In order to further reduce remnant magnetic field, a solenoid coil was prepared and used to cancel it. To suppress flux trapping, a heater was located around an upper beampipe of cavity and made thermal gradient. Owing to these efforts, Q-value of more than $1x10^{11}$ can be measured with a condition of residual resistance of ~3 nΩ. Clear flux expulsion signal can be also observed. In this presentation, we report about efforts to reduce ambient magnetic field and to realize high-Q measurements. Results of vertical tests, including flux expulsion measurements, are also presented.

Rres history of single-cell cavity vertical tests



History of obtained Rres for single-cell cavities

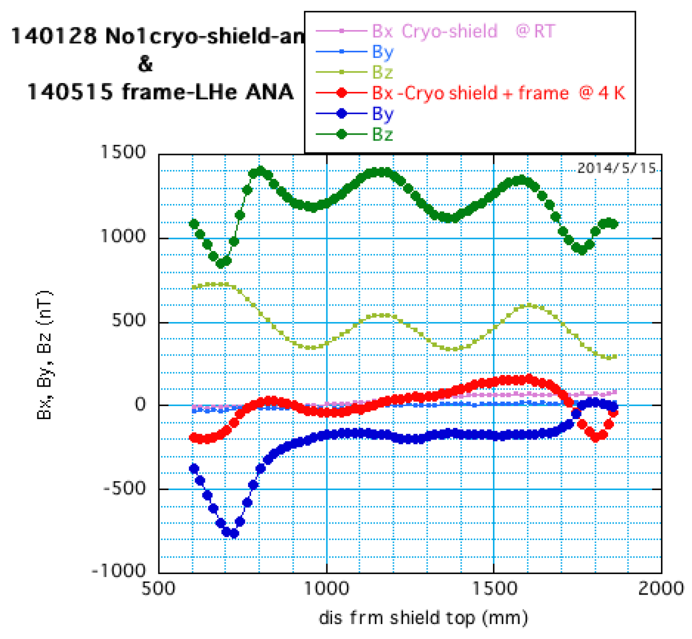
- R_res gradually increase?
- Q-values of LG cavity were gradually decrease.
- Not stable for high-Q measurement



History of Q-E curve for LG cavity

- Q-values of LG cavity were gradually decrease.
- Very good Q-value at first VT could never be reproduced.

Remnant field inside STF VT cryostat(@4K)



- Measurement was done with support tools for 9-cell measurement at 4K.
- Remnant field was 12〜13mG.
- Part of contribution come from support tools 〜5mG

Contribution from remnant magnetic field inside VT dewars are not negligible for high-Q study.

Magnetized measurement on VT components

- Use 3-axis flux gate sensors borrowed from KEKB magnet group
- Measure magnetization inside a cylinder of magnetic shield (〜300Φ x 1m)
- Maximum absolute value was recorded for each components
- Almost all components used for single-cell vertical tests were investigated.

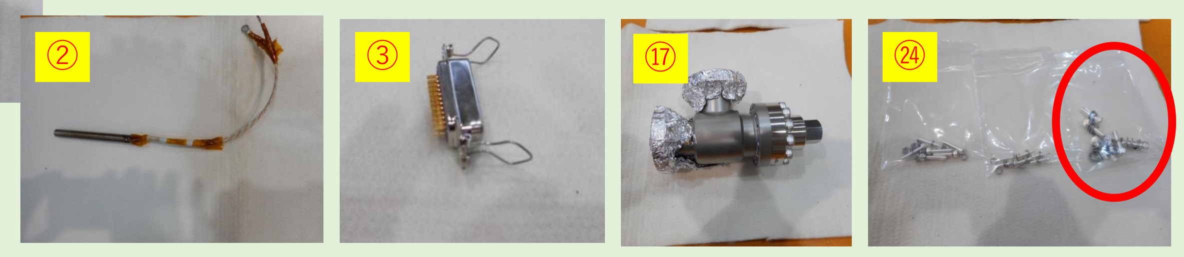
Components which is strongly magnetized

From T. Yanagimachi(9/26)

No.	name	Magnetic field [mG]
14	Φ034 metal valve ①	430
15	Φ034 metal valve (which observed vacuum leak)	80
19	Φ034 metal valve ②	59
25	Volts and washers for support of input coupler shaft	140
28	Nuts and washers for hanging cavity	110
29	Stat-volts, nuts and washers for hanging cavity	300

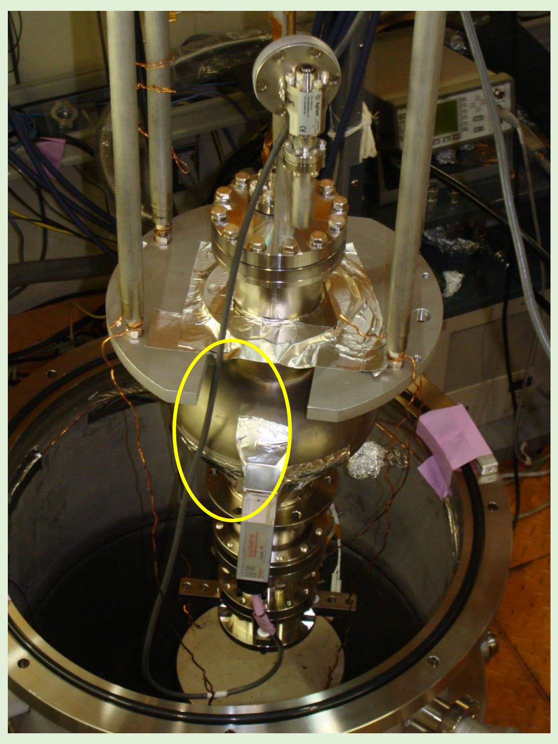
Components which are relatively strongly magnetized

No.	name	magnetic field [mG]
2	Heater ① (Cable red)	40
3	D-sub connecter	30
4	D-sub connecter stopper	40
8	D-sub inside	26
17	Φ70 metal valve	24
21	Volts and washers for Top and bottom flanges	40
23	Set of volts (034 duct, pickup)	36
24	Set of volts (034 dust, pickup)	26
26	Stat volts for hanging cavity (cavity side)	40
27	Stat volts for hanging cavity (support ring side)	28
33	Volts for input flanges (M6x10?)	44

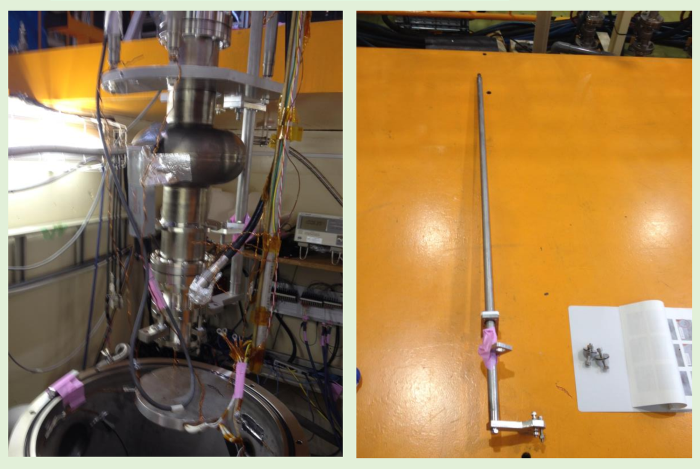


Flux measurement inside VT dewar

- 3-axis flux gate was located on equator on single-cell cavity, shown as right figure.
- Top flange of cryostat was closed with a few cm space for cable of flux gate sensor.
- Cavity position is almost same with nominal VT.
- By changing position of flux gate sensor, rough distribution is observed.



Effects of SUS shafts



SUS shafts for variable coupler were highly magnetized. More than 1 G!!

SUS shafts made big and asymmetric magnetic field distribution inside VT dewar.

Magnetic field with shafts inside vertical test dewar

Angle	Bx [mG]	By[mG]	Bz[mG]	B[mG]
0	-7	-11	-6	15
90	-6	2	-9	11
180	6	-11	-7	15
270	8	130	-49	139

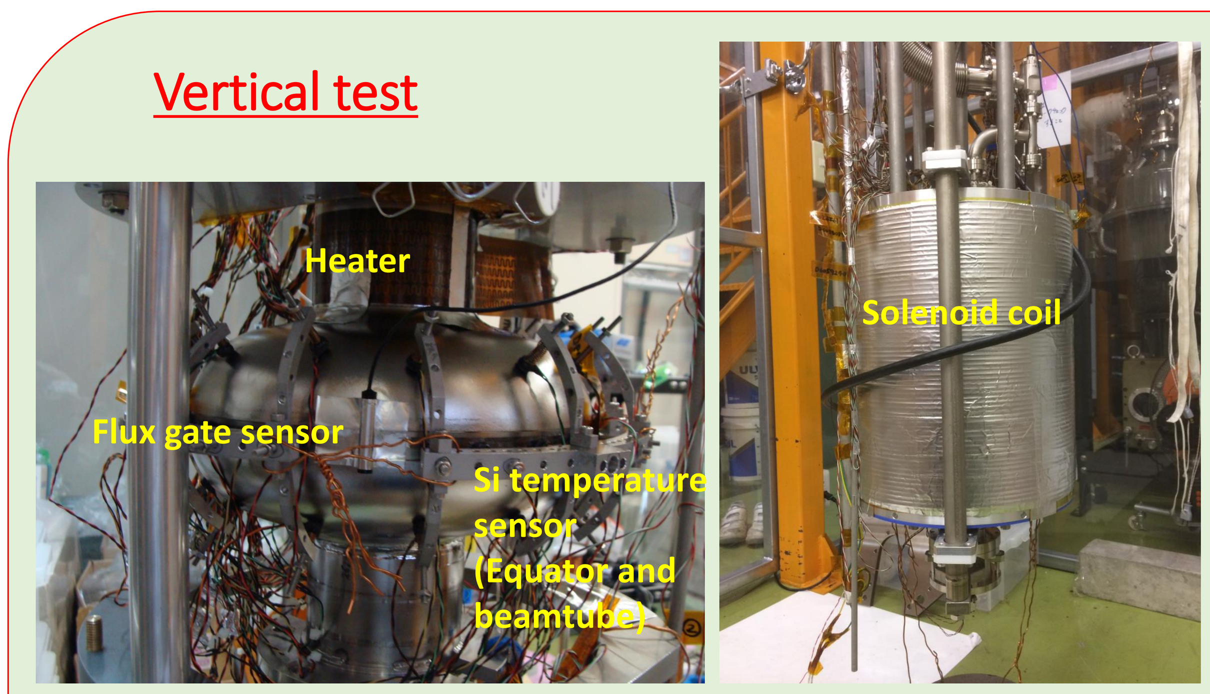
If both shafts were removed B ≦ 2mG for any positions.

We recognized much components are magnetized.

◆Exchange SUS shafts to Ti
◆Exchange or remove SUS components as much as possible
◆Exchange metal valve to less magnetized one

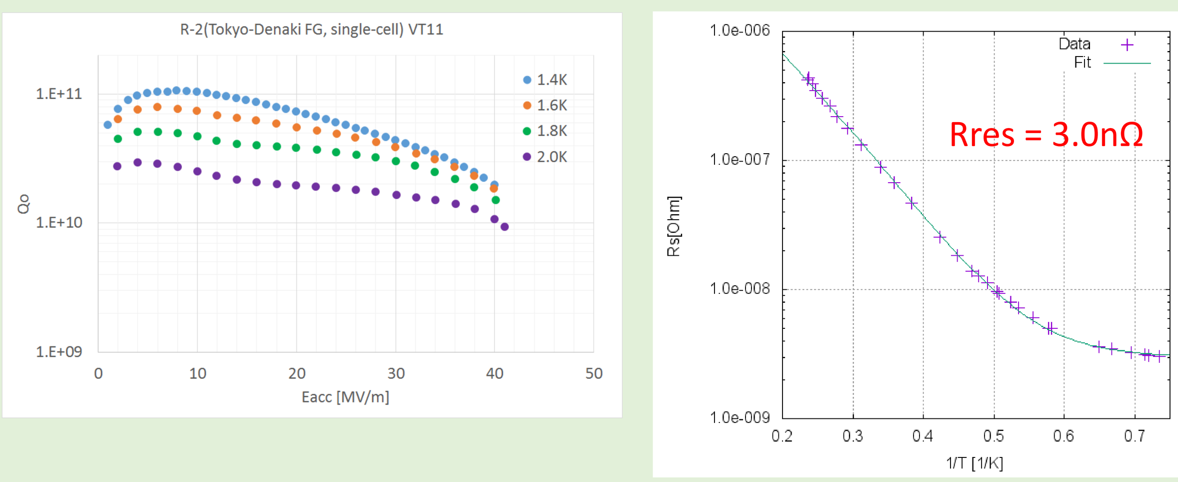
And vertical tests were carried out after that.

Vertical test



Flux gate sensor: Measure magnetic flux around cavity
Si temperature sensor: Measure temperature around cavity
Heater: Make temperature gradient on cavity surface
Solenoid coil: Cancel (control) of magnetic field

Vertical test results after improve of magnetic condition

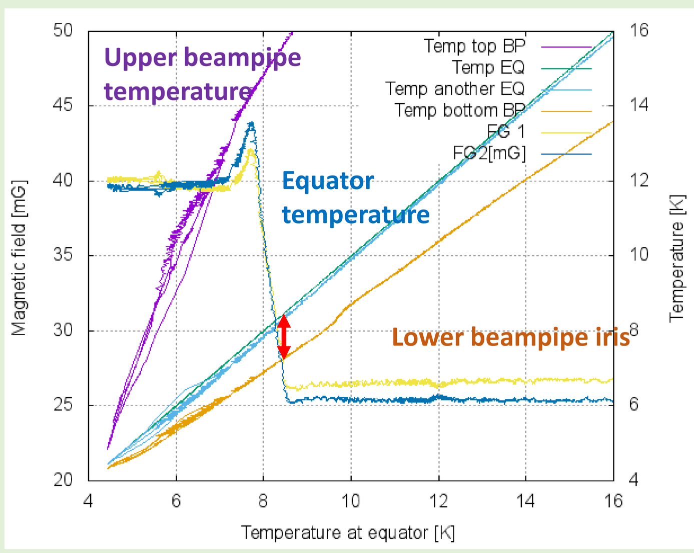


- FG single-cell cavity (Tokyo-Denkai)
- Nominal recipe (Not N-doping)
- With cancelling coil
- With thermal gradient by heater

Very high-Q was observed after the effort for demagnetization

HighQ results are stably obtained and reproducible.

Flux expulsion during cool-down(add 16mG with coil)



- FG single-cell cavity (ULVAC)
- Nominal recipe (Not N-doping)
- 900 degree heat treatment applied
- Add +16mG with coil (Total 9 + 16 = 25mG)
- With thermal gradient by heater

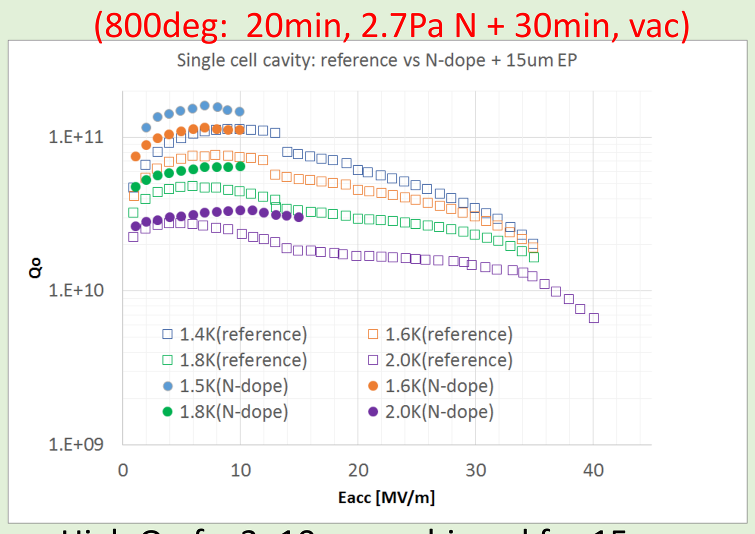
- Clear flux expulsion(~90%) can be observed.
- Temperature gradient of more than 1 degree between equator and lower beampipe iris.

See poster THPB021 「Trial of Nitrogen Infusion and Nitrogen Doping by Using J-PARC Furnace, T. Konomi, et. al.」

N-dope/N-infusion trial using J-PARC furnace

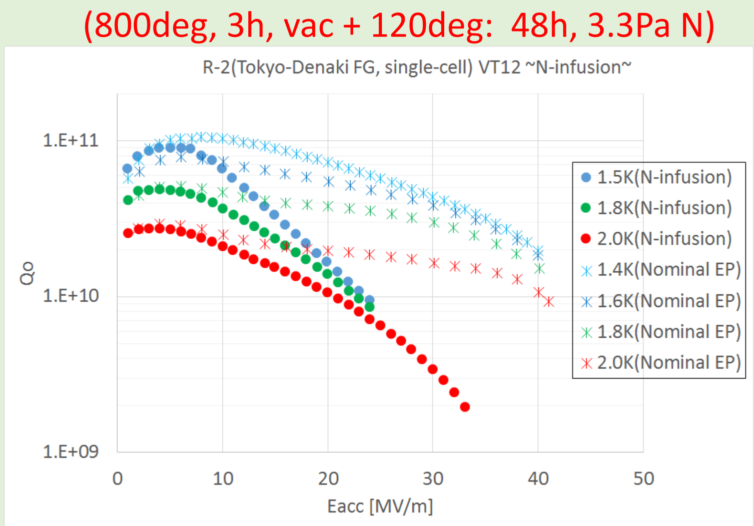
- J-PARC has oil-free furnace with cryo-pump and TMP.
- We try to use it for N-doping / N-infusion.
- Normally used for beamduct degassing.

N-doping
(800deg: 20min, 2.7Pa N + 30min, vac)



- High Q of > 3e10 was achieved for 15 MV/m at 2.0K.
- Very high-Q (>1e11) was obtained at low temperature.
- First successful N-doping in Japan.
- Quench field was limited to 16 MV/m.

N-infusion
(800deg, 3h, vac + 120deg: 48h, 3.3Pa N)



- The cavity applied "N-infusion" process showed degradation of Q-value at > 5MV/m.
- Reason of degradation is under study
- Quench field was limited to 33 MV/m.

Summary

- It was difficult to achieve high-Q at KEK-STF vertical test.
- It was also difficult to see clear flux expulsion.
- Magnetization was investigated for each components of vertical tests.
- Some components were highly magnetized. One of highest was shaft for variable coupler.
- Magnetized components were removed or exchanged. Also solenoid coil was prepared.
- After these effort, high-Q could be stably measured and clear flux expulsion signal was observed.
- High-Q study, including N-doping and N-infusion, is on going with this good magnetic condition.