KEKB/SuperKEKB Cryogenics Operation

eeFACT2018@HKUST

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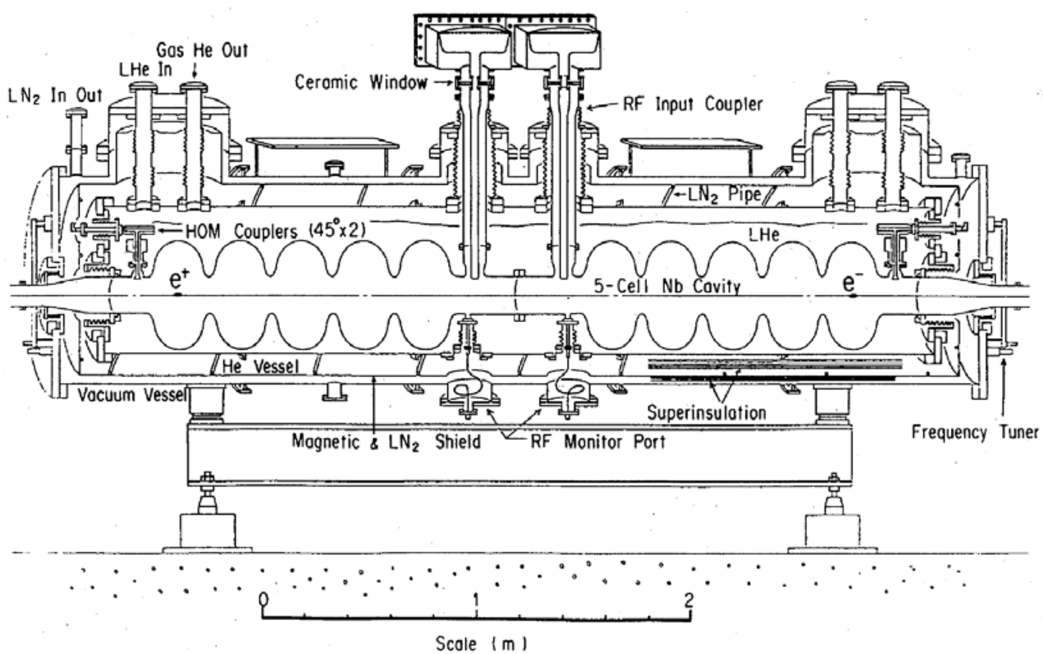
History of refrigerator for superconducting cavity.

TRISTAN without Superconducting cavities (SCC)	1986~
TRISTAN with SCC	1988~1995
KEKB with SCC	1998~
KEKB with SCC and Crab cavities	2007~2010
SuperKEKB with SCC	2016~

TRISTAN (1988~1995)

- 32GeV – 32GeV electron-positron collider.
- 8 cryostats were installed. (1988)
- 8 cryostats were added. (1989)

16 cryostat
x 2 cavities/cryostat
x 5 cells/cavity
=160 cells



TRISTAN (1988~1995)

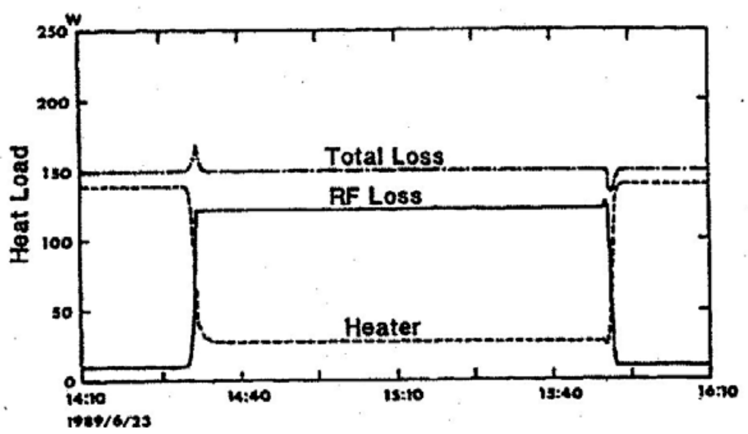
The heat load at 4.4K was quite large.

Components		Heat loads
Cryostat	22.8 W/cryostat x 16	364.8 W
Transfer Lines (380m)		412.4 W
Cold Valves & Joints		147 W
RF Loss	90 W/cavity x 32	2880 W
Total		**3804.2 W**

If

150 W/cavity

5700 W



The RF loss was not stable.

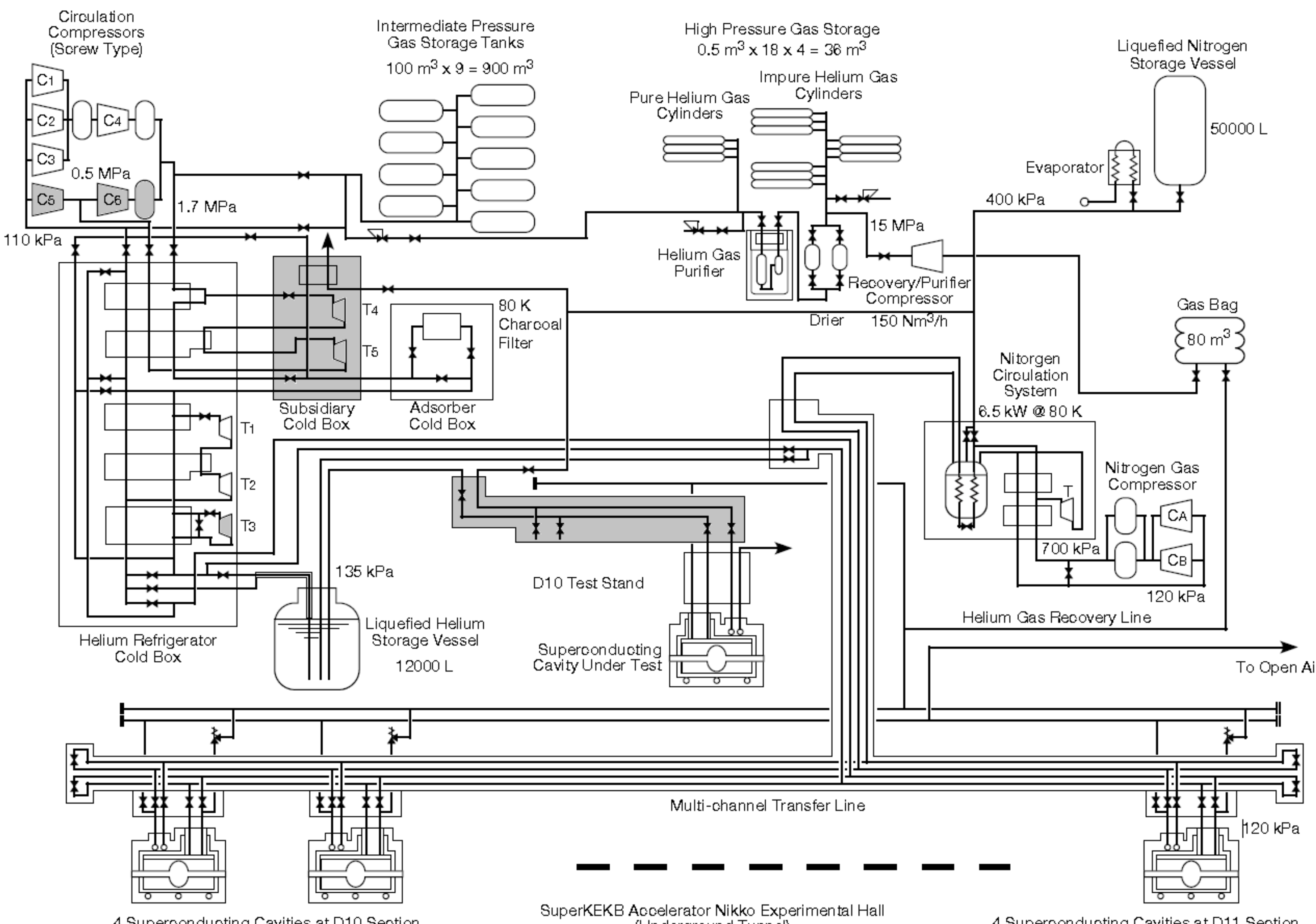
Beam Injection (~30W/cavity)

2minites

Top energy operation

(90~120W/cavity)

Cryogenic system for Superconducting Cavities.



1988
4kW @ 4.4K
(Design)

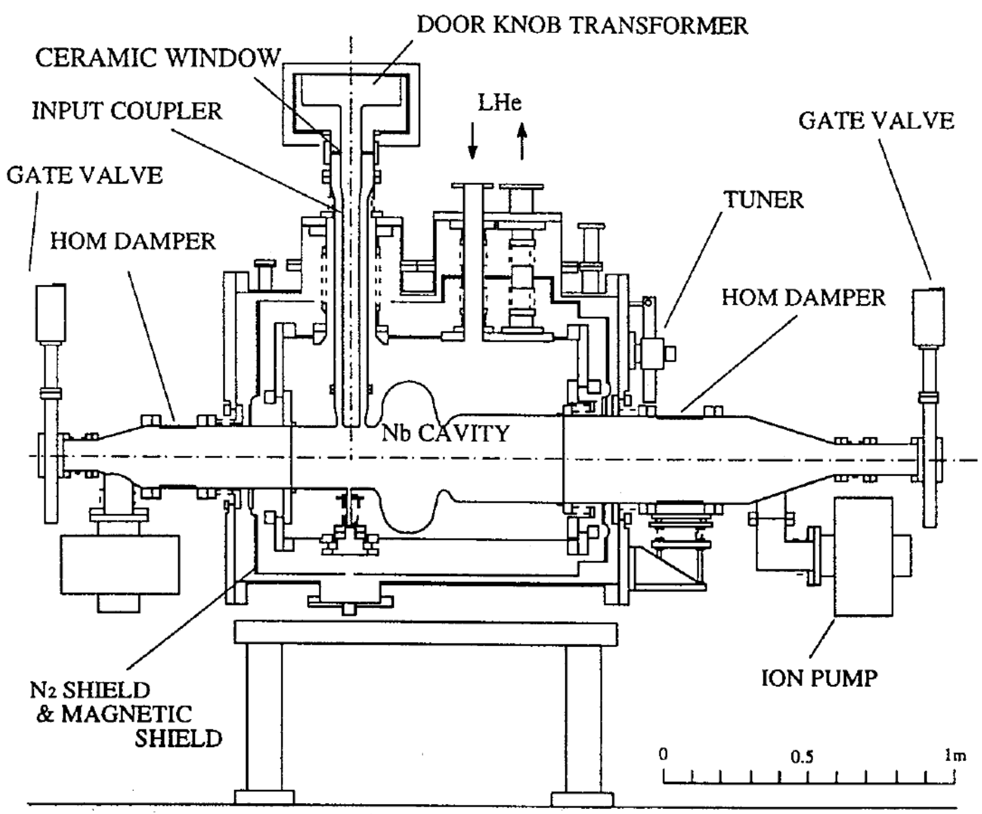
Compressor (C5,C6) were added.

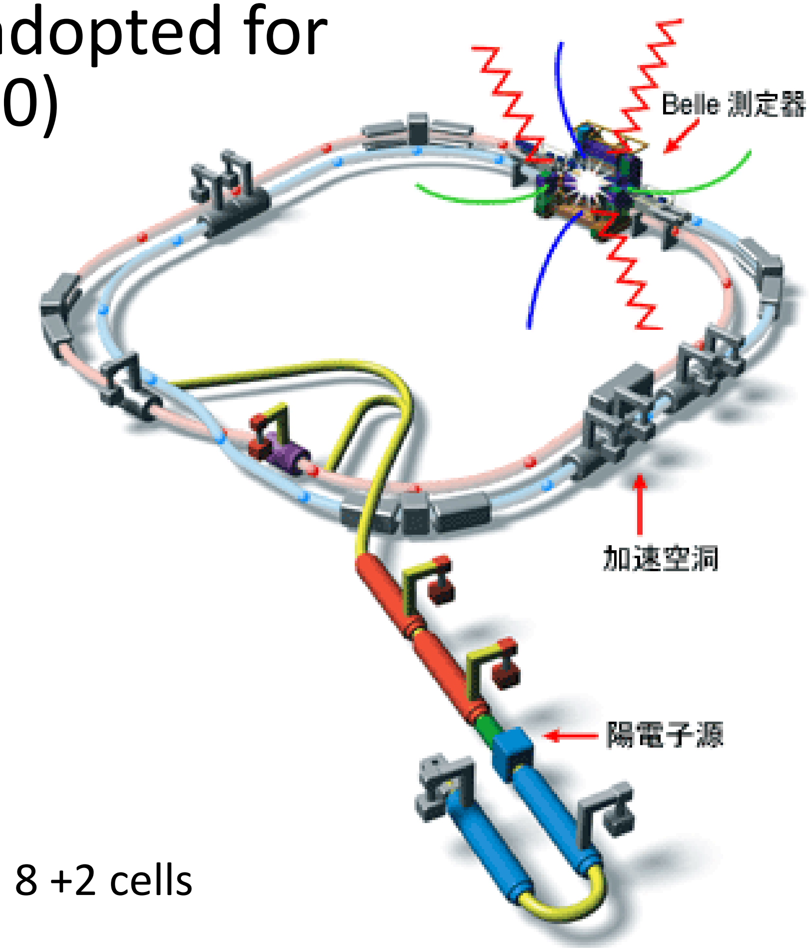
Supercritical turbine expander (T3) was added.

1989
6.5kW @ 4.4K
(Design)
8.1kW @ 4.4K
(Achieved)

KEKB (1998~2010)

- 8GeV – 3.5GeV electron-positron collider.
- 8 cryostats for SCC were adopted for HER.
- 2 cryostats for crab cavity were adopted for HER and LER (1 by 1). (2007~2010)

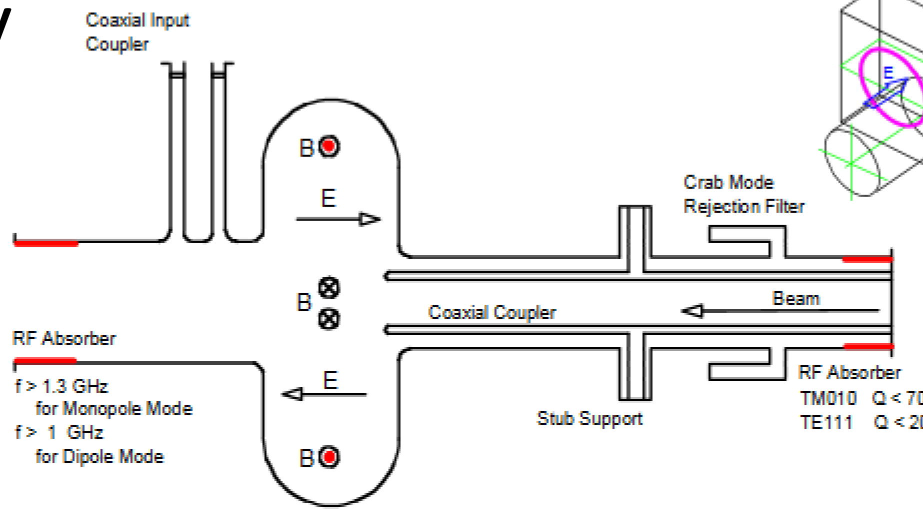


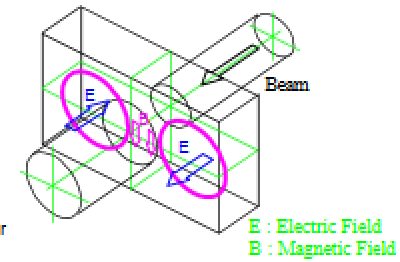


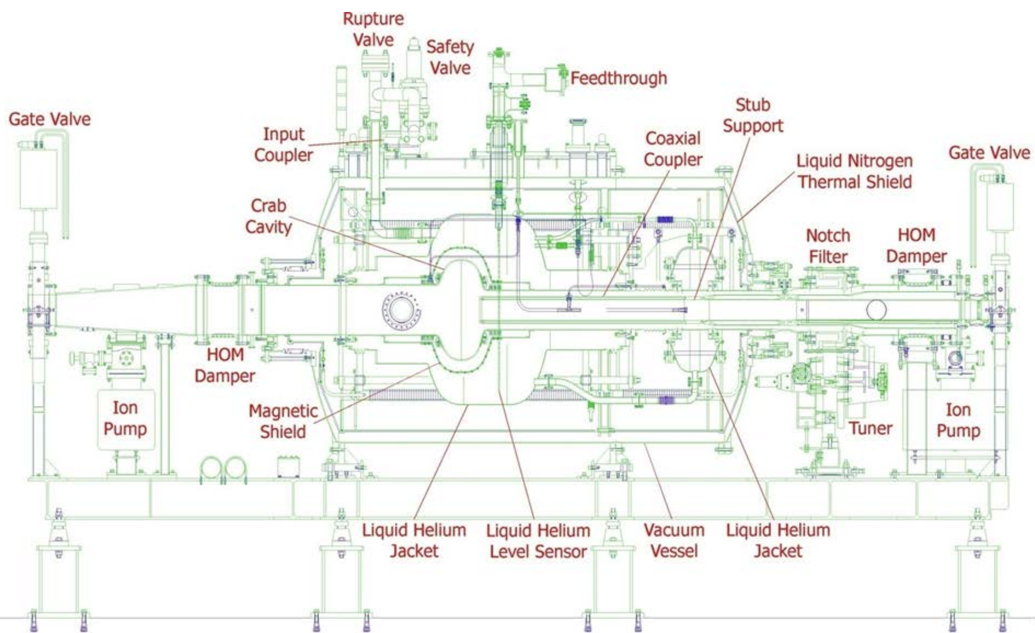
8 +2 cells

Crab Cavity

Two crab cavities were adopted in KEKB from2007 to 2010
The coaxial coupler faced in the cavity. It should be superconductor.
To cool it, 5 g/s of liquid He was spend. (~100W)



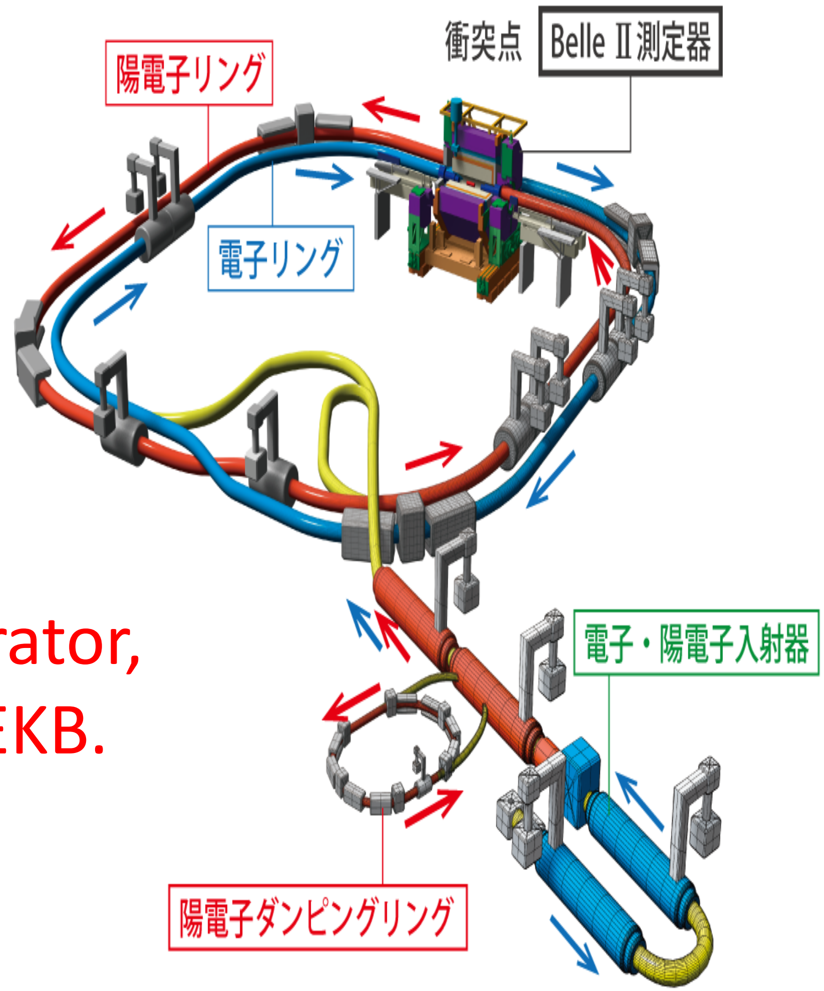




In SuperKEKB, it was decided not to be used due to the strategy change.
They were removed.

SuperKEKB (2016~)

- 7GeV – 4GeV electron-positron collider.
- 8 cryostats for SCC were adopted for HER.
- Crab cavities were removed



From the viewpoint of the refrigerator, there is almost no change from KEKB.

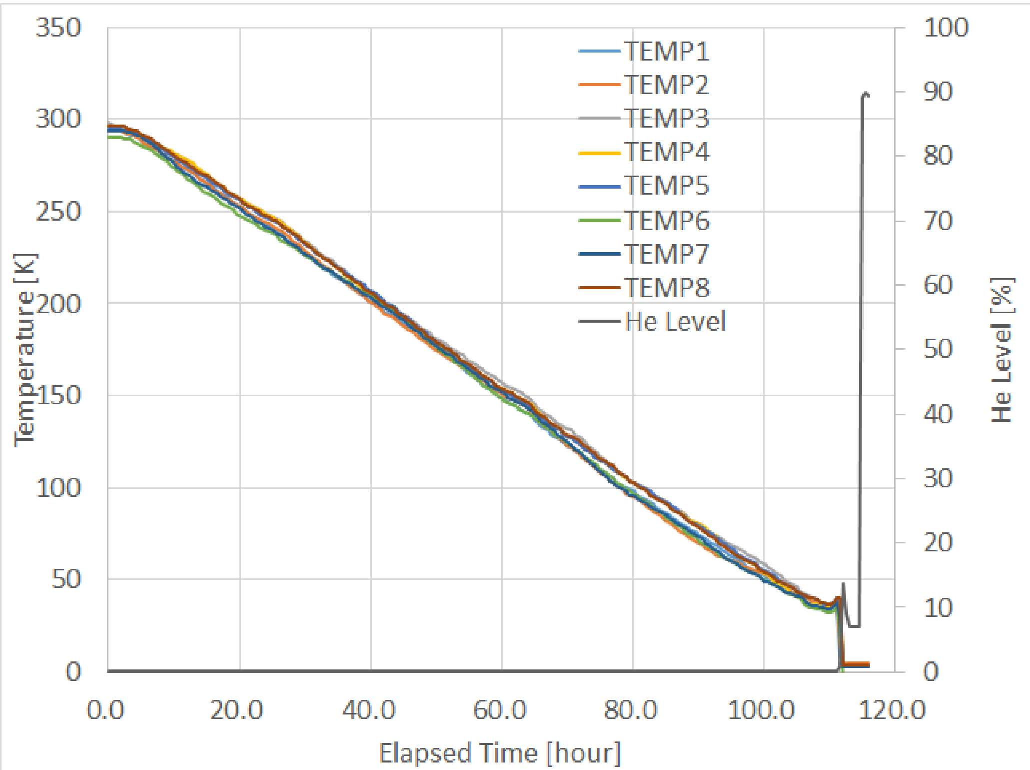
KEKB (1998~2010)
SuperKEKB (2016~)

Components		Heat loads
Cryostat	30 W/cryostat x 8	240 W
Transfer Lines (380m)		412.4 W
Cold Valves & Joints		147 W
RF Loss	100 W/cavity x 8	800 W
Total		**~1600 W**

Include compensation heater

- The heat load was smaller than TRISTAN’s.
- The RF loss is stable. (But compensation heaters are even used.)
- TRISTAN's refrigerator has sufficient capacity, even if the crab cavities were adopted.

Cool down



Procedure

Temperature controlled helium gas is supplied from the refrigerator to cool the cavities.

Cooling is started by using helium gas cooled by liquefied nitrogen.

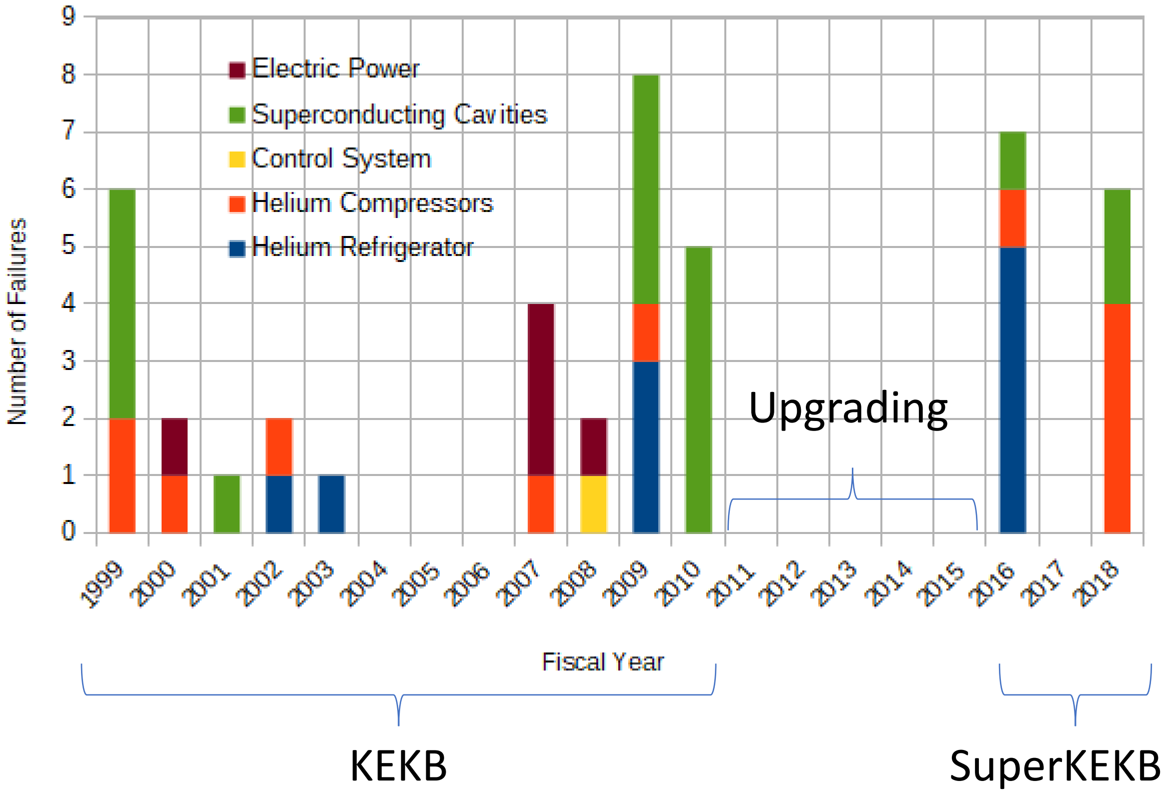
When the cavity temperature reaches 150 K, the turbines were stated.

When the cavity temperature reaches 40 K, liquid helium was supplied.

- All of cavities cooled down slowly until 40K. (~2.5K/h)

To reduce deformation due to temperature difference, to suppress vacuum leakage and alignment error.

Trouble



The total operation time

TRISTAN : 38000 hours

KEKB : 62000 hours

SuperKEKB : 7700~ hours

Initially there were many stops due to expansion turbo tripping, interlock due to superconducting cavities and power outage.

Malfunction due to aging of electronic equipment is increasing.

Maintenance and Updating

- Maintenance are carried out in accordance with the High Pressure Gas Safety Act.

Required inspection period

Item	Maintenance cycle
Whole system	1 year
Compressor	2 year
Pressure gauge	2 year
Thermometer	2 year
Cold evaporator	3 year
others	1 year

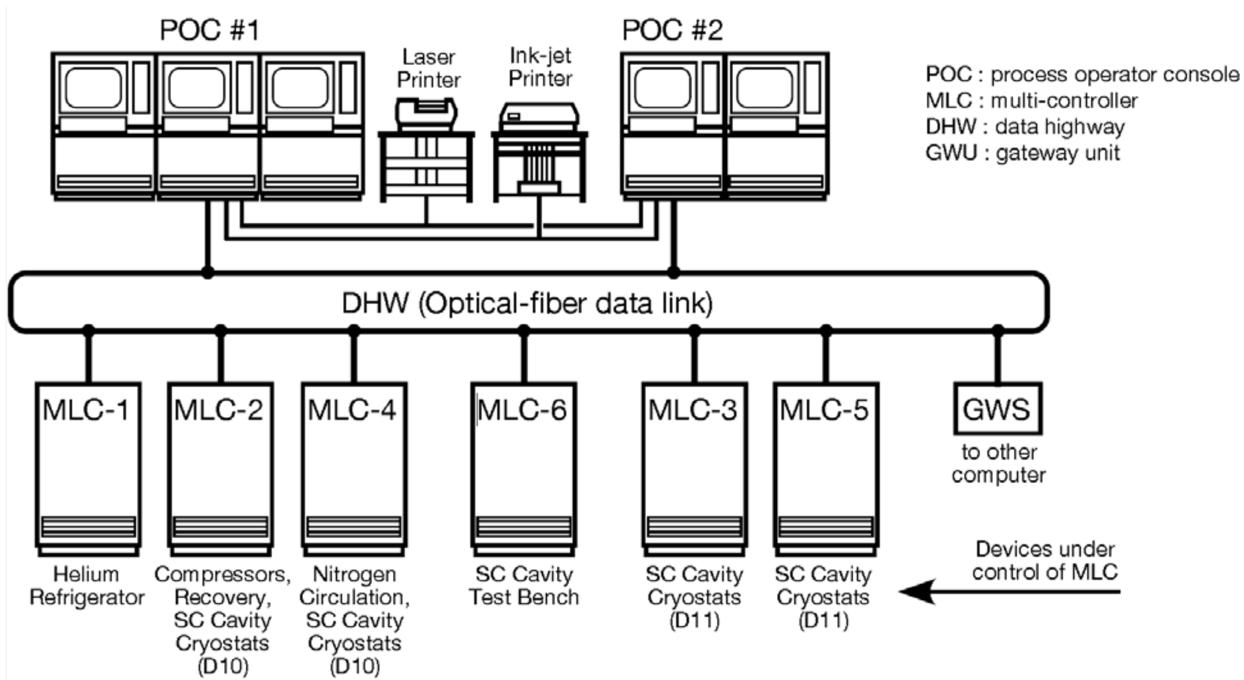
item	Open inspection cycle
Recovery compressor	10 years or 3000 hours operation
Circulating compressor	10 years or 30000 hours operation
others	exemption

Maintenance and Updating

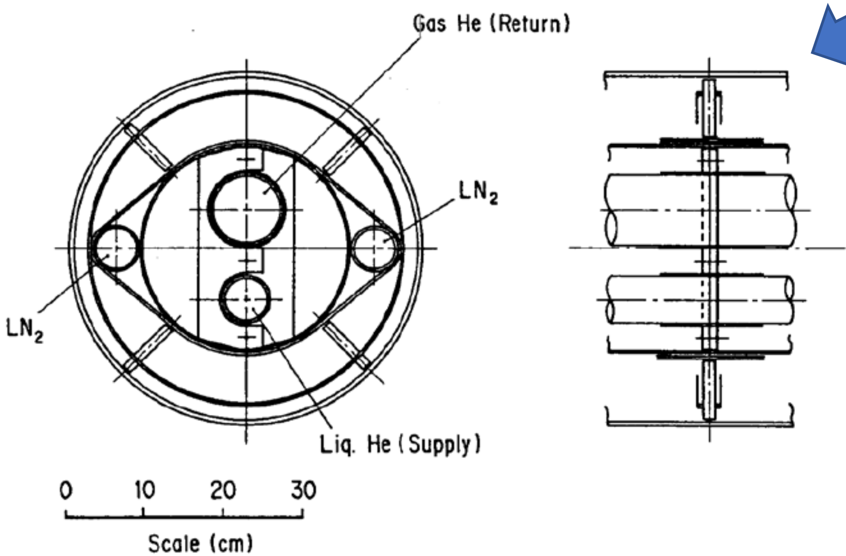
- The cryogenic systems were inspected every year by the prefectural government. The legal inspection is a good guideline for maintenance.
- Filter replacement of control rack is done every year.
- Check the actuators of the controlled valves, pressure gauges and thermometers in the inspection cycle and replace those that can not be adjusted.
- It is recommended to replace the input / output module of the control system every 5 ~ 7 years. (However, the update cycle is often extended.)
- Compressors are open checked at the manufacturer's recommended operation time. Replacement of parts such as the oil separator is also carried out at this time.
- If needed, painting of tanks is done. Just before legal inspection.

Control system

- Initially a control system EX-1000 which made by Hitachi was adopted in 1988.
- The control system was updated to EX-7000 in 2002.
- EX-8000 was adopted in 2012.

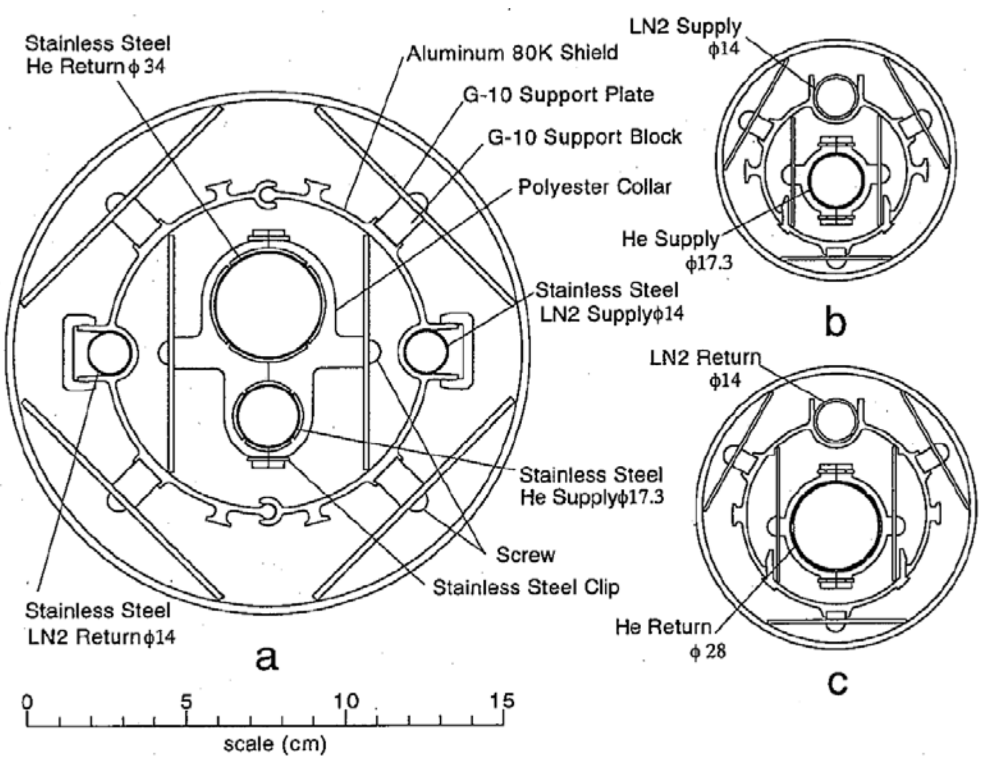


Transfer Line

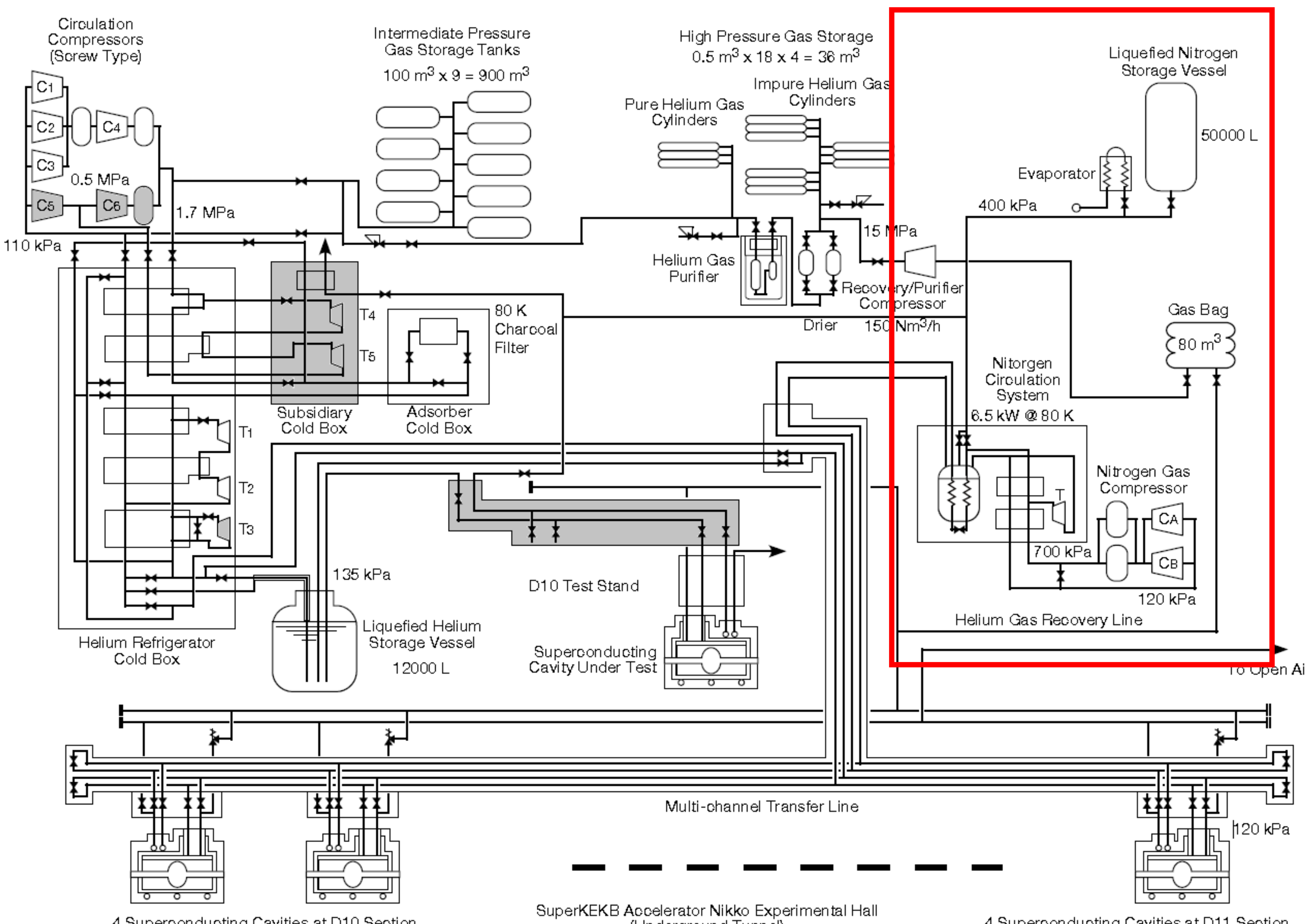


Transfer Line developed for TRISTAN
This transfer line adopted for connection between the liquid helium dewar and the accelerator tunnel.
The heat load is about 1W/m.

Transfer Line developed for KEKB
This transfer line adopted for connection between the liquid helium dewar and the D10 test stand.
The heat load is about 0.05W/m.



Cryogenic system for Superconducting Cavities.



Liquid Nitrogen Circulation System

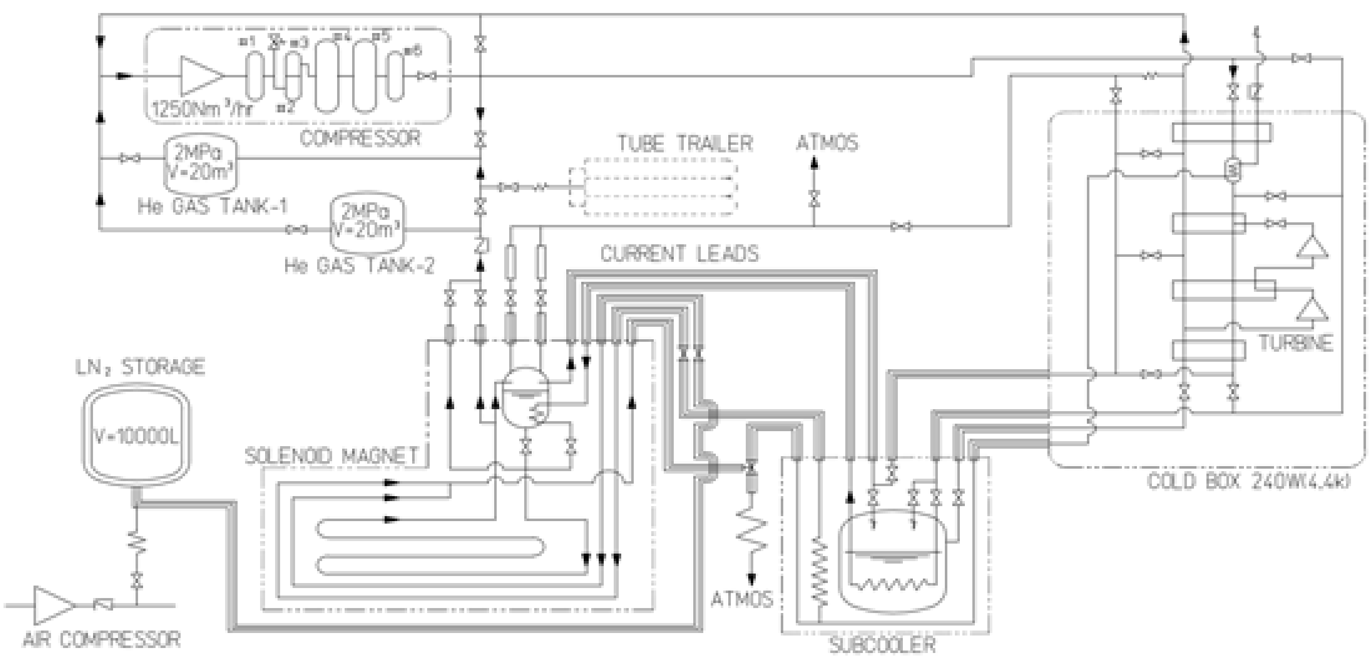
- At KEK, to cool the 80K shield, liquid nitrogen was used.
- In order to reduce the consumption of liquid nitrogen, a liquid nitrogen circulation system was adopted. Its consumption has been reduced from 8000 L/day to 1800 L/day in TRISTAN. (1500L/day in SuperKEKB)
- The system consists of a compressor, a heat exchanger and a turbine expander.

Heat loads at 80K in TRISTAN

Components		Heat loads
Cryostat	48.8 W/cryostat x 16	780.8 W
Transfer Lines (380m)		5569 W
Cold Valves & Joints		294 W
Total		**6643.8 W**

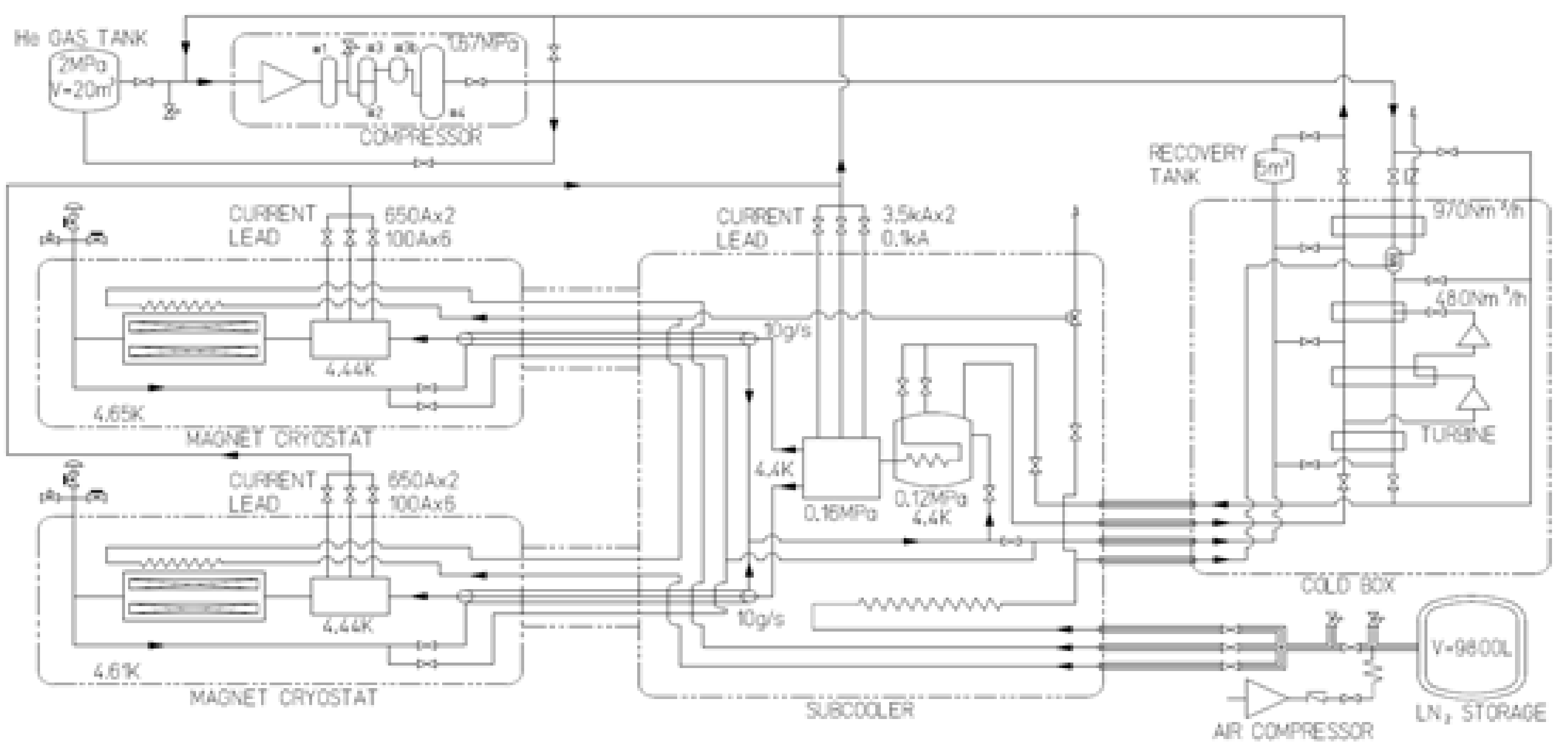
Cryogenic system for SC magnet

- TRISTAN had 4 cryogenic systems (250W@4.4K) for QCS (final focusing system).
- One is dedicated to cool down the Belle solenoid for KEKB/SuperKEKB.
- The heat load and the amount of liquid helium used for current lead cooling of this system were 84W and 26L/h, respectively, with a margin of 102W.

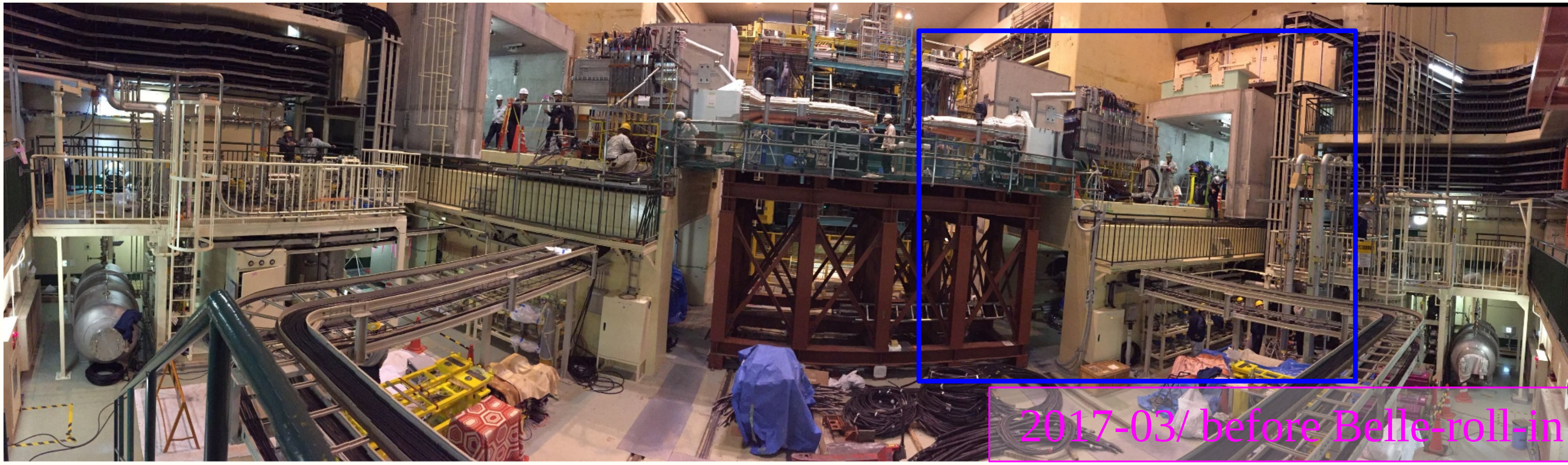


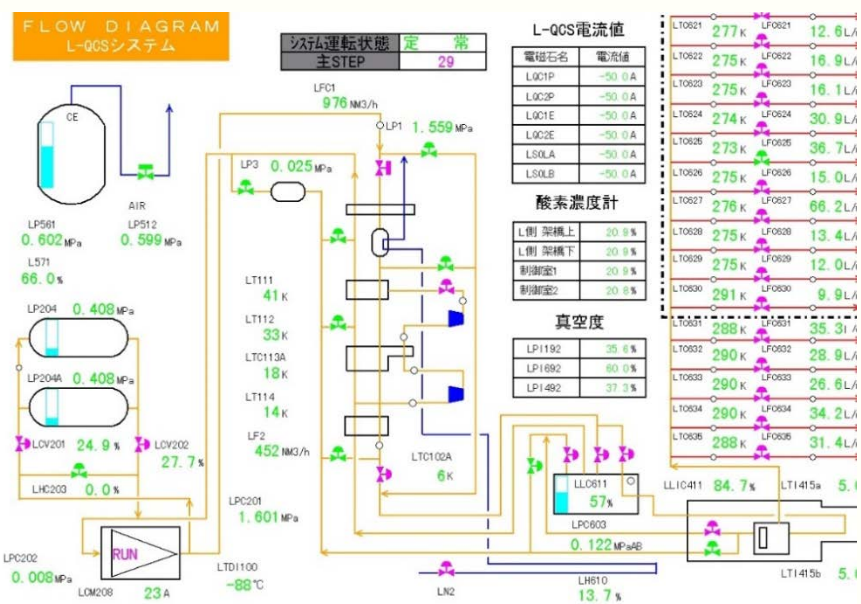
Cryogenic system for SC magnet

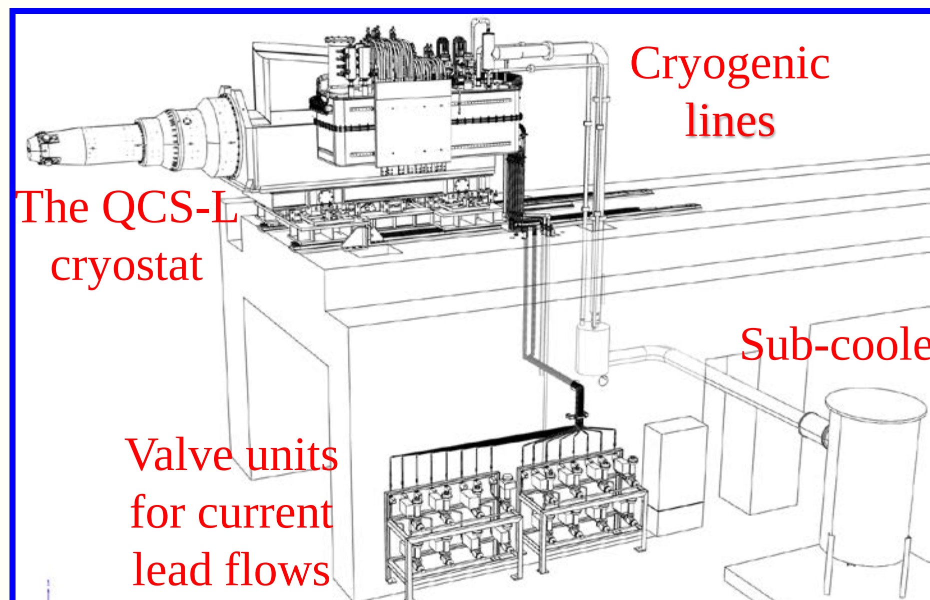
- One was dedicated to cool down the QCS for KEKB. (see figure)
- Two refrigerators are used to cool down the QCS for SuperKEKB.
- The heat load and the amount of liquid helium used for current lead cooling of this system were 75W and 29L/h, respectively, with a margin of 81 W in KEKB.



Cryogenic systems with the QCS-L and QCS-R cryostat







Summary

- In SuperKEKB, superconducting cavities are operated using a cryogenic system constructed for TRISTAN in 1988.
- The demand for SuperKEKB's cryogenic system is not higher than TRISTAN’s. (Low and static heat load)
- Periodic maintenance is required.
- The cryogenic systems for magnet are also diverted from TRISTAN.
- All of cryogenic system are very old, however they are working very well.