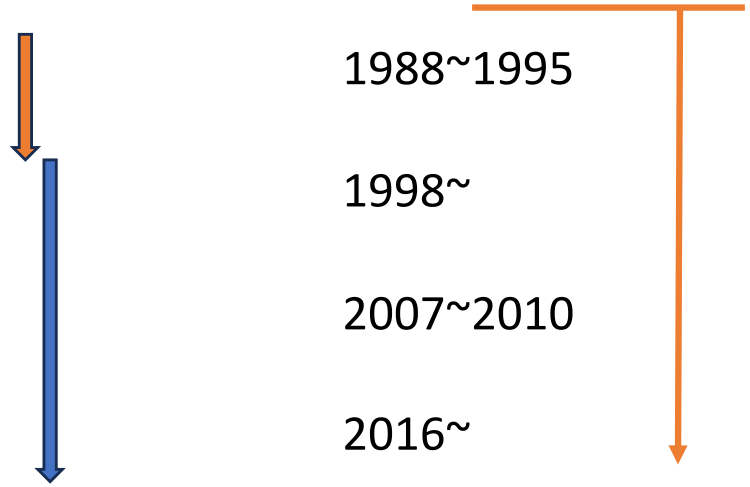
Cryogenics
(Helium refrigerator for SRF)

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(refrigerator group)

History of our refrigerator

TRISTAN without Superconducting cavities (SCC)		1986~
TRISTAN with SCC	(3.8kW)	1988~1995
KEKB with SCC	(1.6kW)	1998~
KEKB with SCC and Crab cavities		2007~2010
SuperKEKB with SCC		2016~



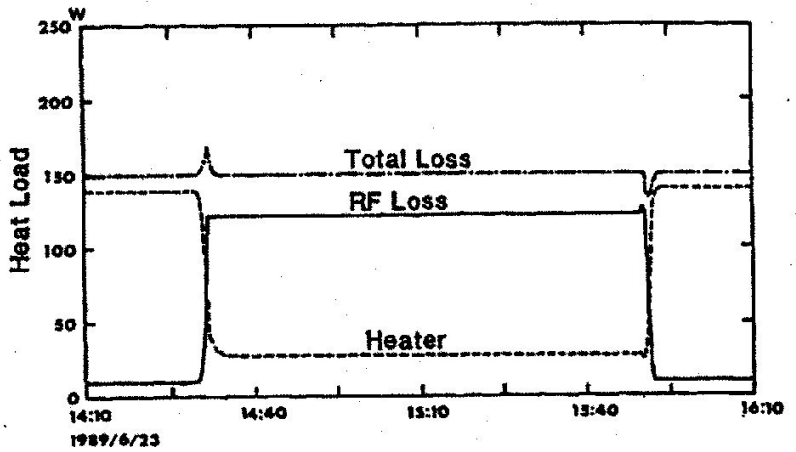
TRISTAN (1988~1995)

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

Compensation heater power is included



The RF loss was not constant.

Beam Injection (~30W/cavity)

⬇ 2minites

Top energy operation

(90~120W/cavity)

KEKB (1998~2010)
SuperKEKB (2016~)

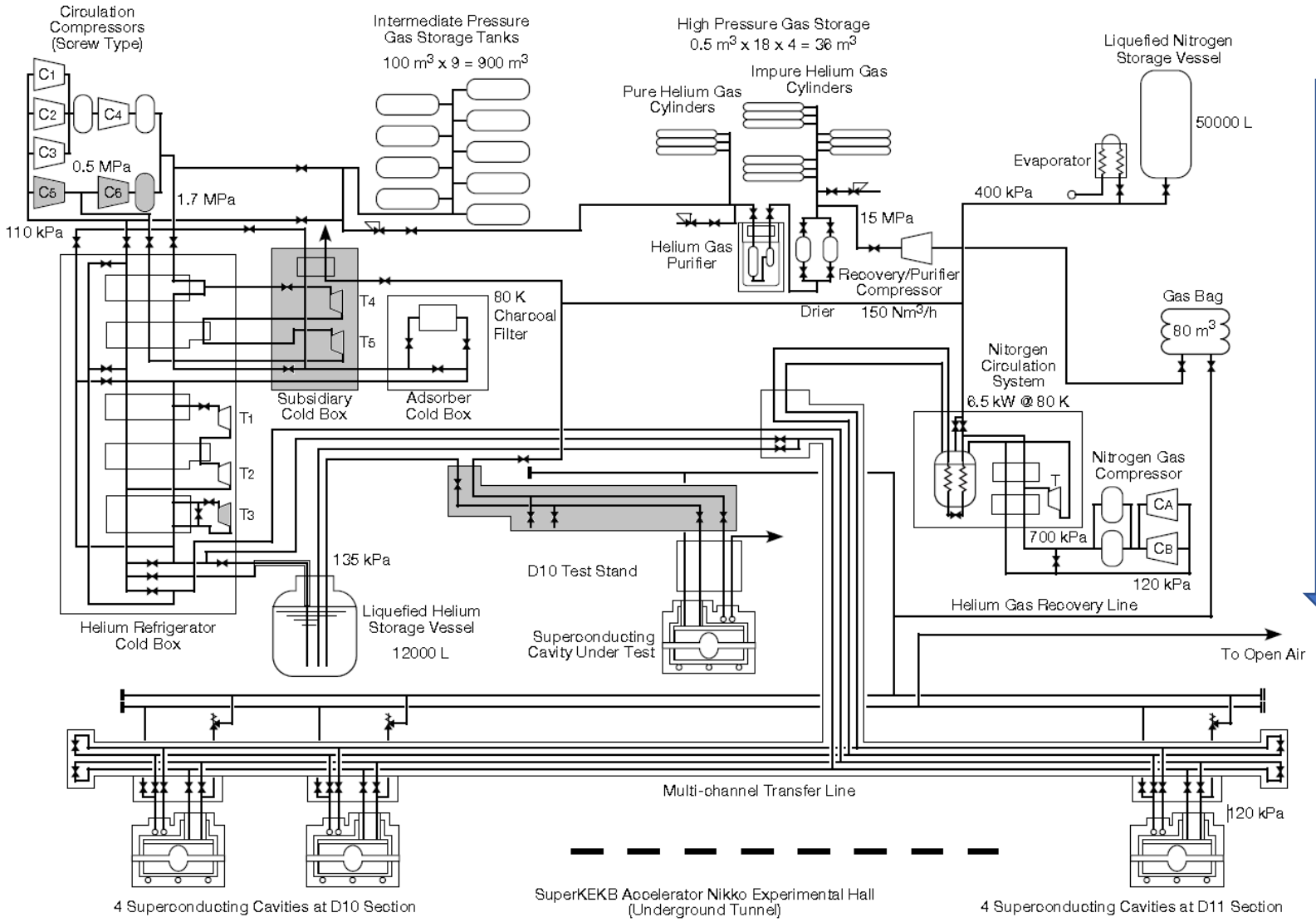
Components		Heat loads
Cryostat	30 W/cryostat x 8	240 W
Transfer Lines (380m)		412.4 W
Cold Valves & Joints		147 W
RF Loss	100 W/cavity x 8	800 W
Total		**~1600 W**

~800W

Compensation heater power is included

- The heat load was smaller than TRISTAN's.
- The RF loss is stable during beam operation.
- The compensation heaters are even used.
- The refrigerator is powerful enough.

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)

Maintenance and Updating

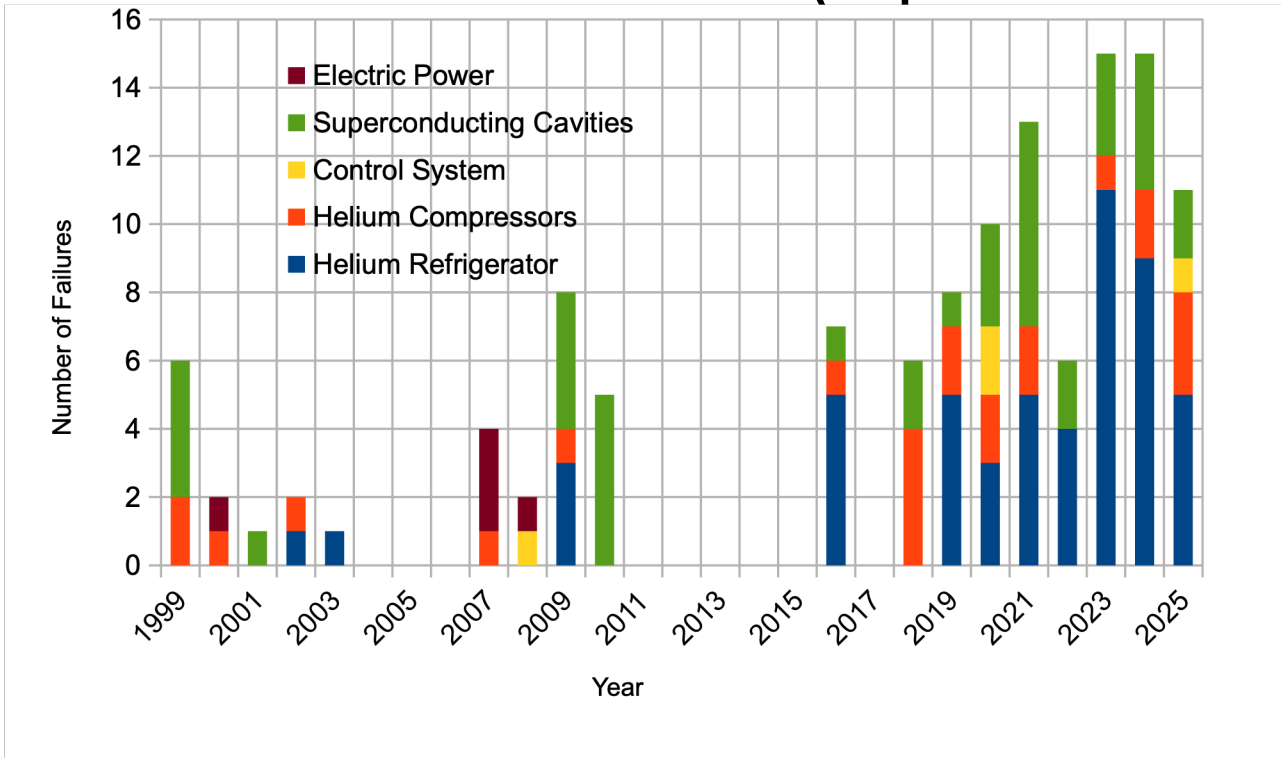
- The cryogenic systems were inspected every year by the prefectural government. The legal inspection is a good guideline for maintenance.
- Check and adjust the actuators of the controlled valves, pressure gauges and thermometers in the inspection cycle. And some one that can not be adjusted is replaced.
- It is recommended to replace the input / output module of the control system every 5 ~ 7 years. (However, the update cycle is often extended.)
- Compressor open inspections are performed at the manufacturer's recommended operation hours or at least every 10 years.
- Since the manufacturer has withdrawn from the refrigerator business, new turbines can’t be purchased. But They maintain and operate the refrigerator. →Three spare turbines (T1,T2 and T3)are kept.

This is a major cause for concern.

Spare turbines

- The manufacturer cannot produce new turbines, but we have spare turbines.
- In about 37 years of operation, the turbines have never been damaged.
- If two turbines(T1 and T2) are working, it can be operated as a 4kW refrigerator. And that is enough for SuperKEKB.

Troubles (up to 2025)



KEKB

SuperKEKB

The total operation time

TRISTAN : 38,000 hours

KEKB : 62,000 hours

SuperKEKB : 28,000~ hours

Year:

Hour of inhibition/ hour of operation

2016: 0 / 3343

2017: 0 / 0

2018: 0.1 / 4362

2019: 39.4/ 5334

2020: 4 / 5099

2021: 0 / 5292

2022: 3.7 / 3246

2023: 0 / 0

2024: 0 /1200~

2025: 0 /1750~

In recent years, the number of troubles has been increasing.

However, by preparing spare parts and/or using alternative functions, the operating rate of the refrigerator is maintained still high.

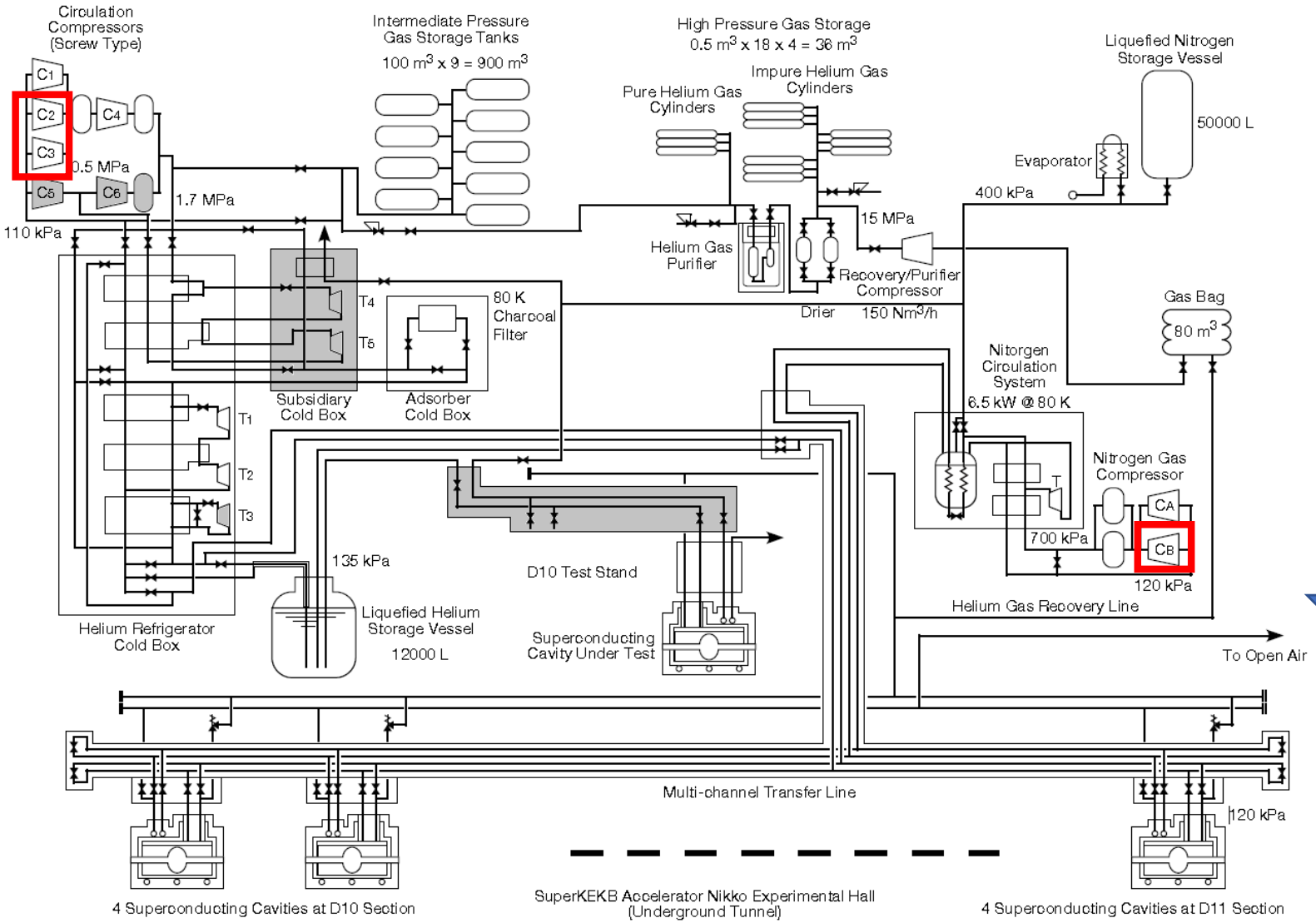
(Hour of inhibition is not hour of repair. If it is in operation even during repair, it is included in the operation time.)

2026

- Operations were suspended for half a day due to a power outage.
- Following the planned power outages in the summer, a malfunction was discovered in the compressors. It is currently being repaired.

(The compressors have been undergoing regular maintenance by the manufacturer.)

The equipment marked with hatching on the drawings is important for the refrigeration system's efficient operation; however, KEKB can still be operated without it.
We are currently experiencing malfunctions with several compressors, and we are working closely with the manufacturer to address the situation.



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(Design)

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

Summary

- The SuperKEKB refrigerator has been operated for more than 35 years since its commissioning for TRISTAN.
- The refrigerator manufacturer can no longer produce new turbines; however, we have spare turbines.
- All other equipment can be maintained and refurbished through conventional maintenance activities.
- With spare turbines and established maintenance capabilities, we expect the cryogenic system to remain operational for the foreseeable future.