Cryomodule Test Bunker for ILC Technology Network (Cryogenic systems)

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(refrigerator group)

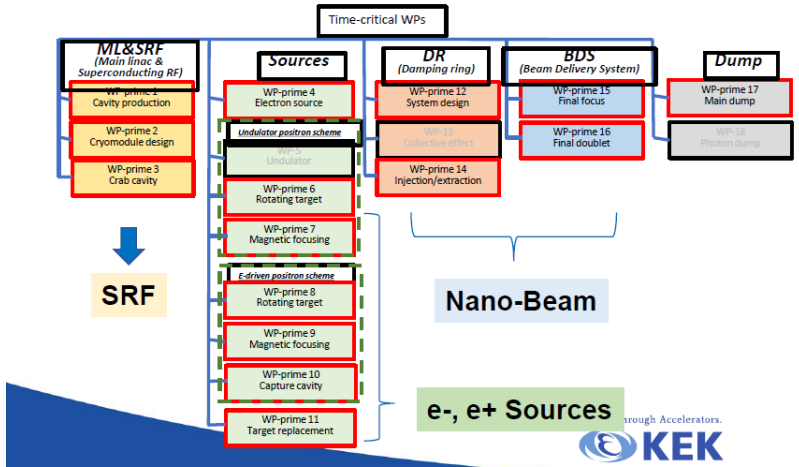
What is ITN.

ITN:ILC technology network

- The ILC project has not started yet.
- Technological development should be continued.
- ITN is an international initiative comprised of many bilateral collaborations.
- For WP1 and 2, one cryomodule will be built and that performance will be measured.

From AFAD2023

Prioritized WP for ILC Technology Network



WPP	1	Cavity production	SRF
WPP	2	CM design	
WPP	3	Crab cavity	
WPP	4	E- source	e-, e+ Sources
WPP	5		
WPP	6	Undulator target	
WPP	7	Undulator focusing	
WPP	8	E-driven target	
WPP	9	E-driven focusing	
WPP	10	E-driven capture	
WPP	11	Target replacement	
WPP	12	System design	Nano-Beam
WPP	13		
WPP	14	Injection/extraction	
WPP	15	Final focus	
WPP	16	Final doublet	
WPP	17	Main dump	

Step of ILC development

The ILC project will be done in the following steps.

• ITN	8cavities	1 cryomodule	5 years → New!!
• Prelab	120cavities	4~6cryomodules	5 years
• ILC construction	8000cavities	900cryomodules	10years

⇨ILC operation

ITN

1 cryomodule including 8cavities will be made.
A low-temperature experimental facilities will be established to measure the cryomodule.

Prelab

40 cavities and 1~2cryomodules will be made in Japan.
4~6cryomodules including foreign cryomodules will be tested.
1cavity/week, 1~2cryomodules/year → easy!

ILC construction

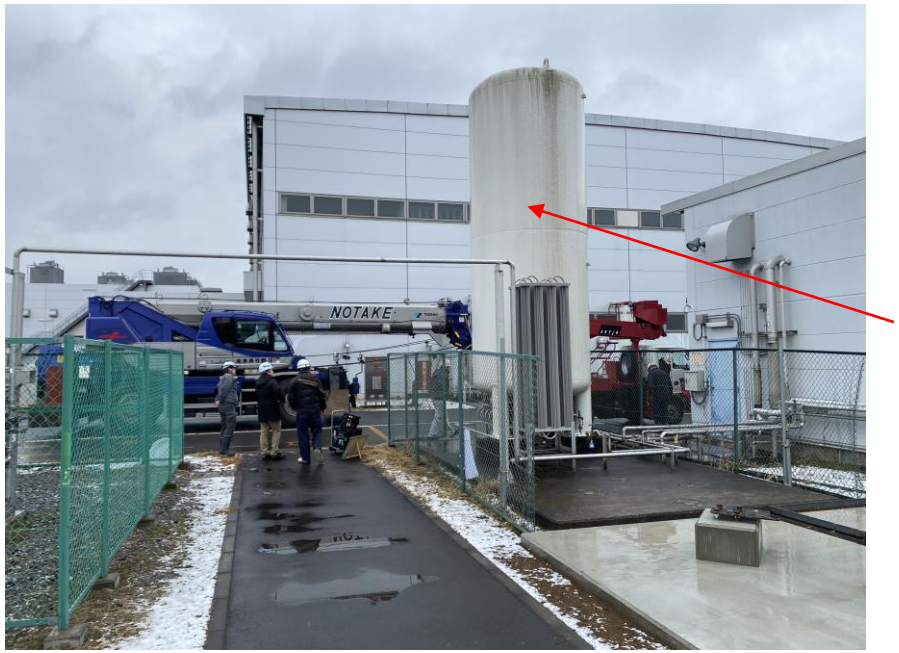
The first 5% of cryomodules will be inspected in Japan.
1/3 of cryomodules made in Japan are inspected at random. → totaly140cryomodules
2500cavities will be made in Japan. More than 2500 times of VT should be done.
5~cavities/week , 1~2cryomodules/month(In case of 100% inspection 8cryomodules/month)
Not very difficult. But efficient operation should be realized.

Schedule of ITN

CM test

	2023	2024	2025	2026	2027
CE(LN_2 tank) replace	Done				
Helium purifier		○			
Control system update		○	○	○	
Change HPGS category. (He Liquefier)				○	
Liquid helium transfer line		design	○	○	
2K refrigerator		design	○	○	
Pump (warm compressor)	Done				Add?

Vacuum pump for 2K refrigerator:
Tests will be conducted.
(noise, vibration, mass flow …)

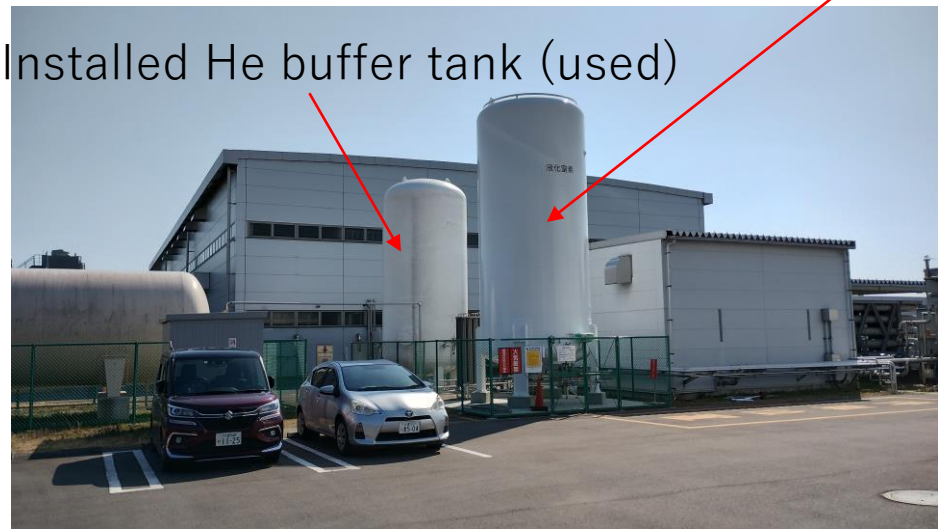


Old CE
(liquid nitrogen tank)

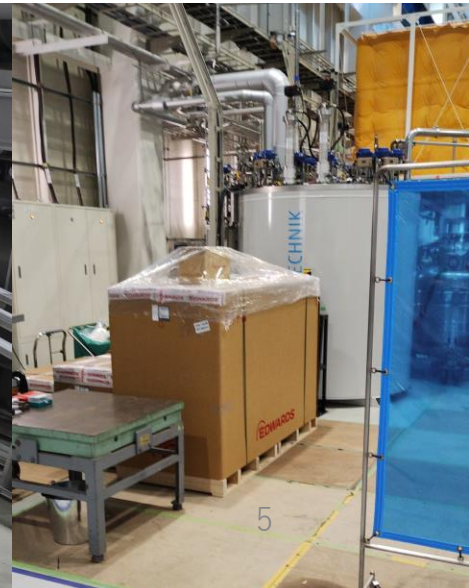
CE was upgraded

New bigger CE

Installed He buffer tank (used)



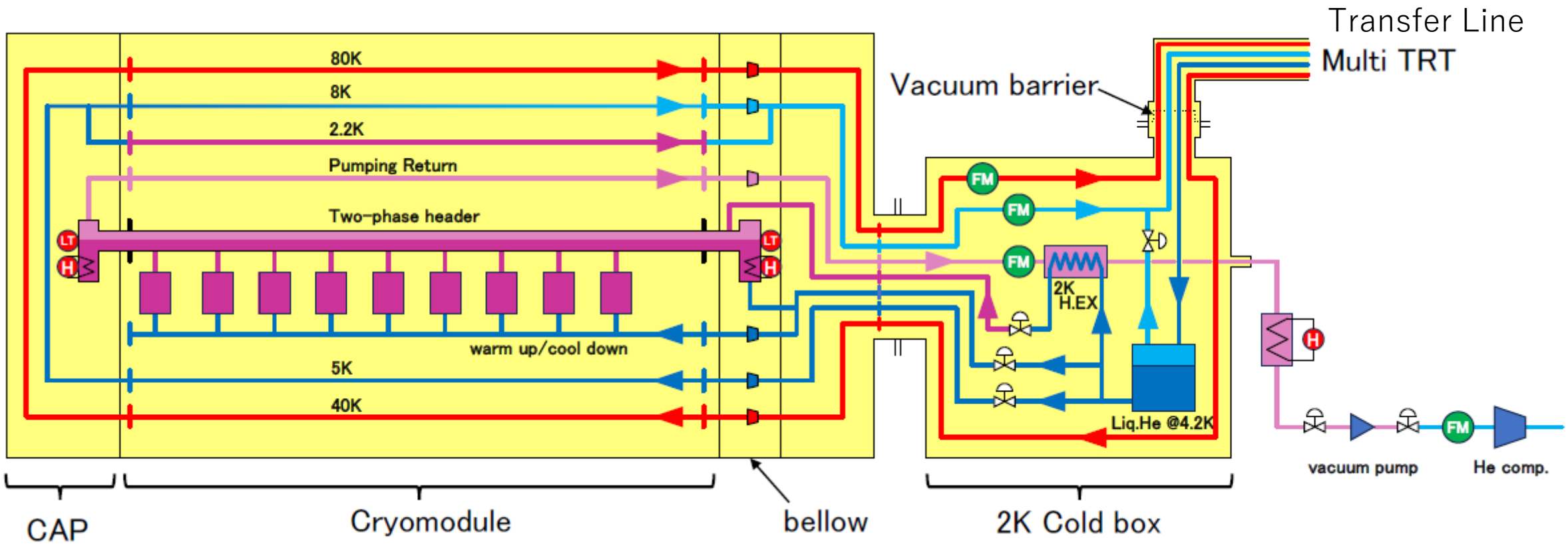
Pumps arrived



Items to be done

- CE (liquid Nitrogen storage tank) upgrade
- Add a helium tank
- Control system update for liquefier and 2K refrigerator
- Prepare helium purifier
- Change the category of HPGS of Helium refrigerator
  (General → Refrigerator)
- Build liquid helium transfer line (TRT) (Regulation on Safety of General High Pressure Gas)
- Build 2K refrigerator
- Prepare vacuum pump for 2K refrigerator

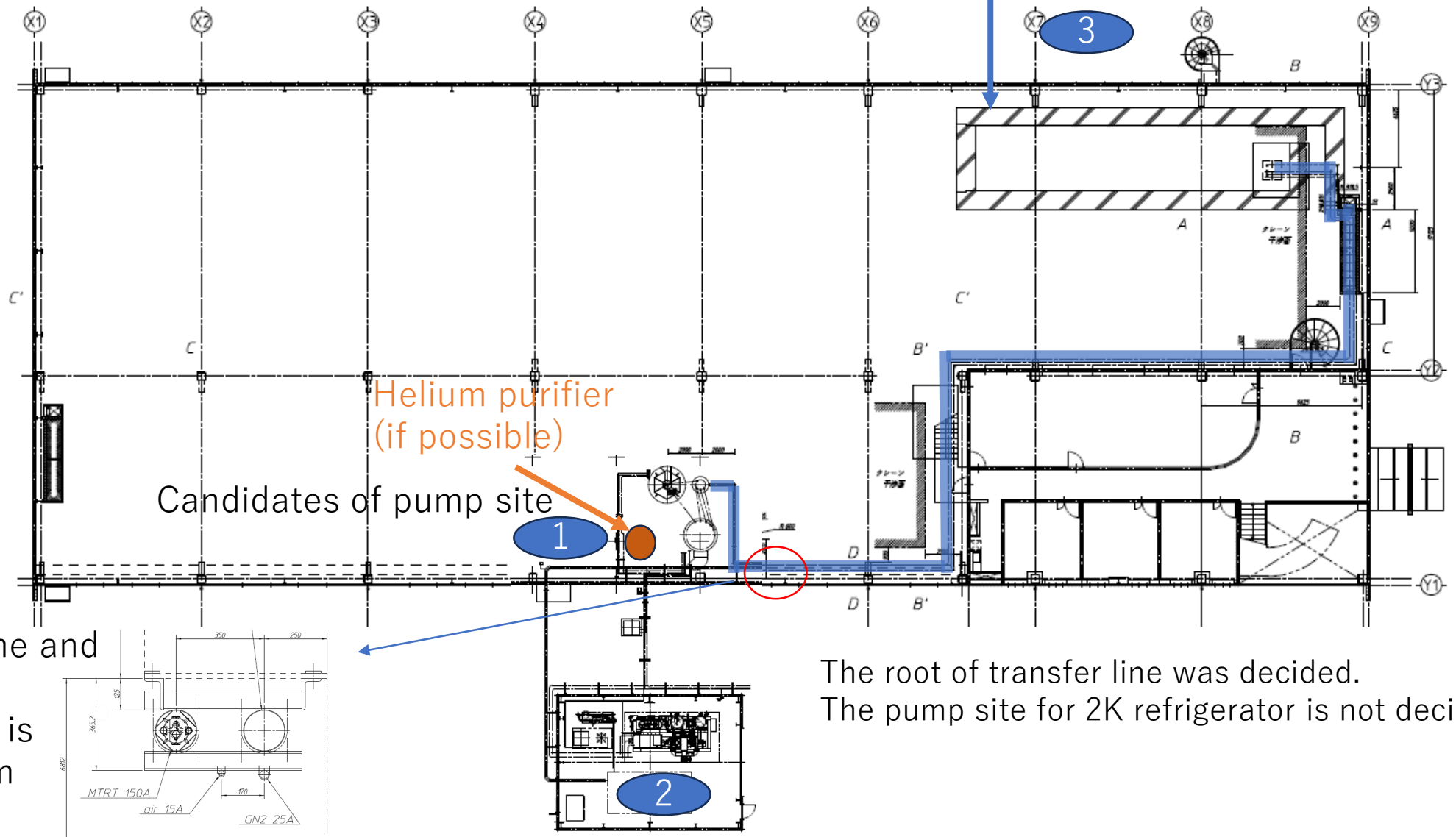
Schematic view of the 2K refrigerator



FM : Flow Meter

Layout of COI building

CTB should be established here due to the floor strength.



Transfer line and return line.
The length is about 100m

The root of transfer line was decided.
The pump site for 2K refrigerator is not decided.

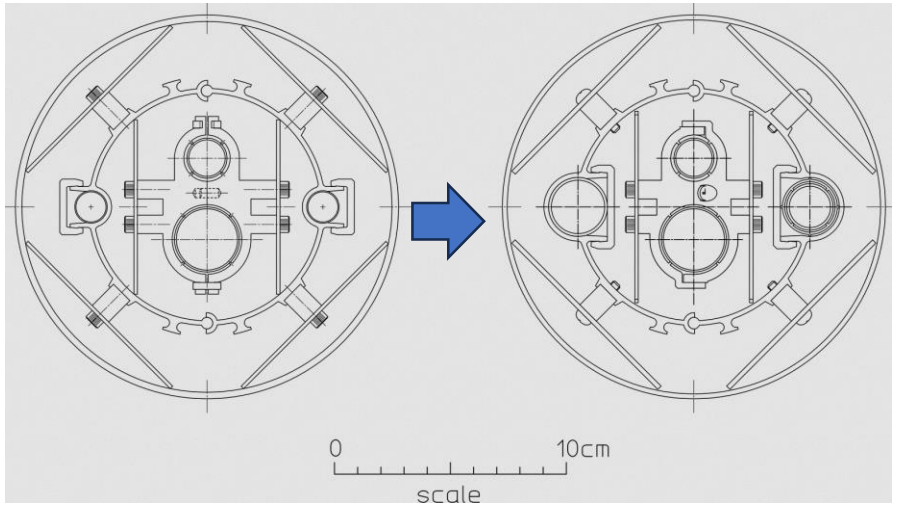
He transfer line design

- 4 pipes are contained in the transfer line.

One pair(outside) is for cooling the radiation shield.

Another pair(inside) is for handling the liquid helium.

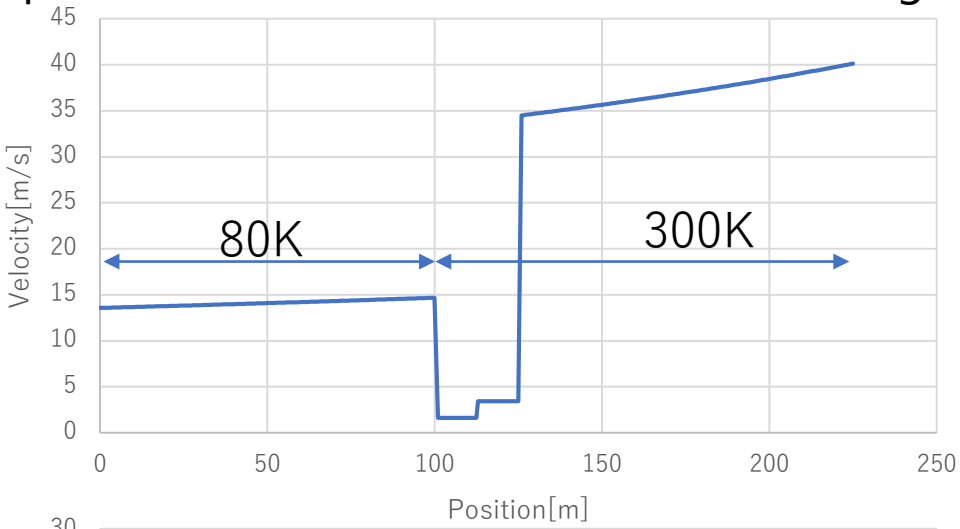
- This is based on the KEKB's TRT design.
- Since liquefied nitrogen is not used, the pipes for shielding are larger. And the supply pipe is not in contact with the shield.

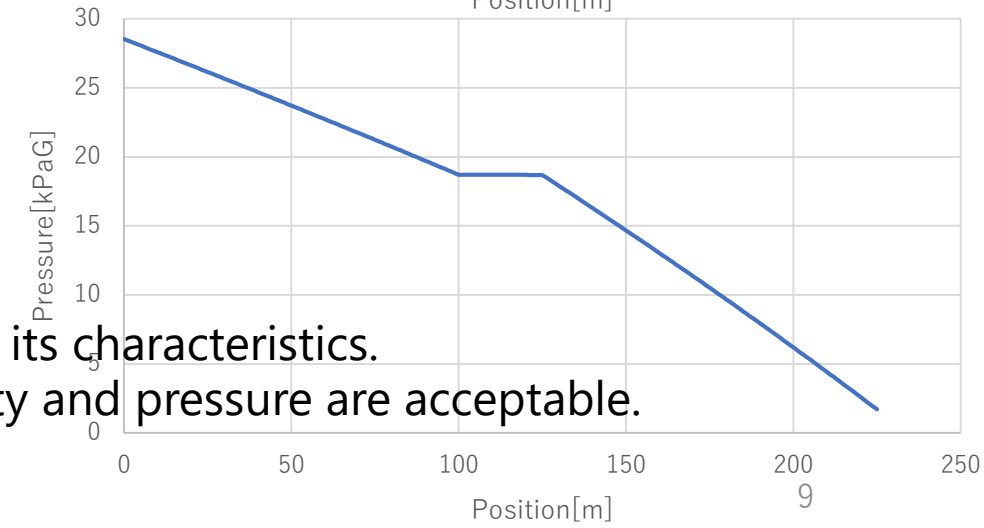


TRT: The design is almost complete.

Flow rate = 3g/s

Temperature distribution at the start of cooling

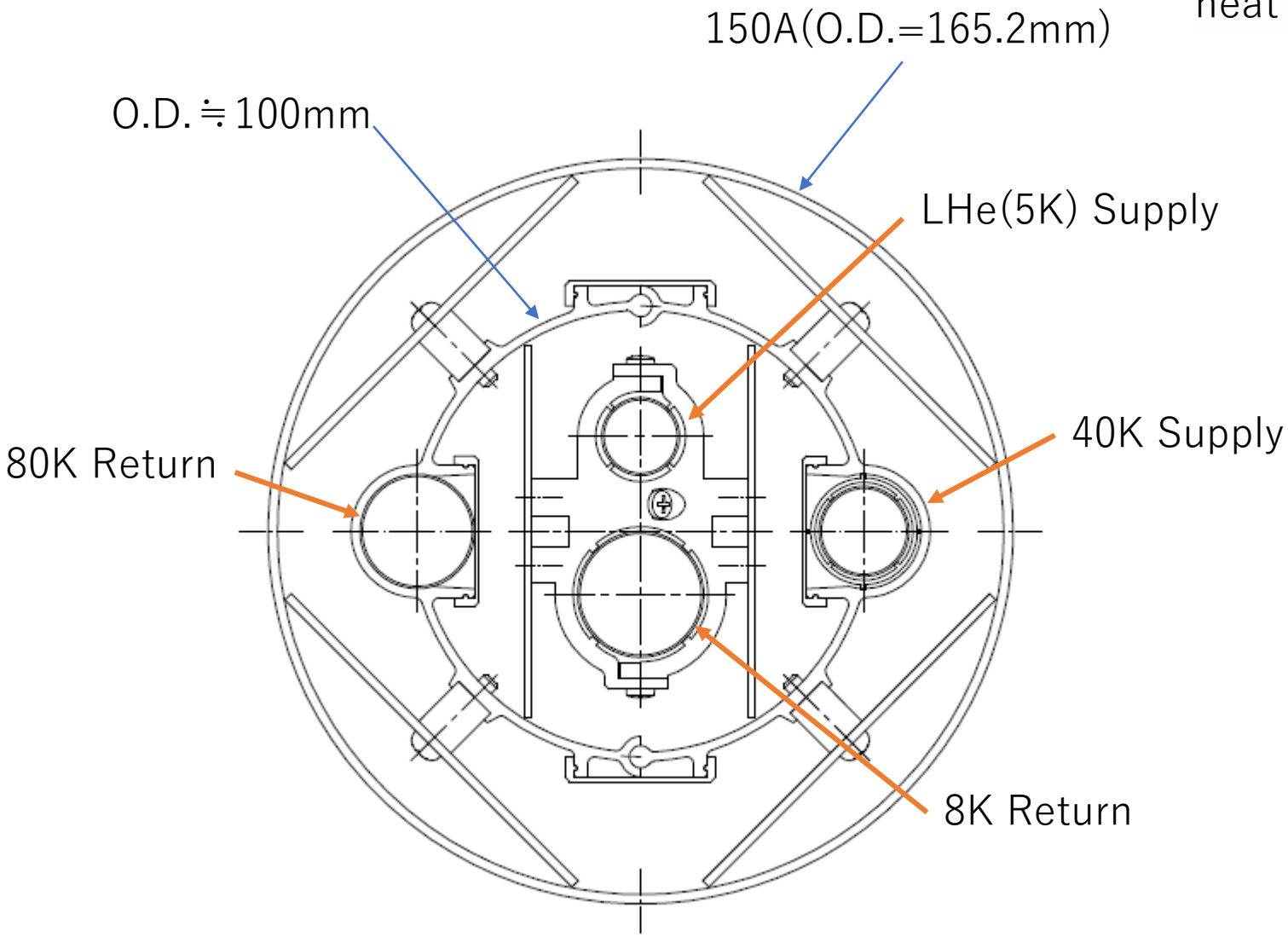


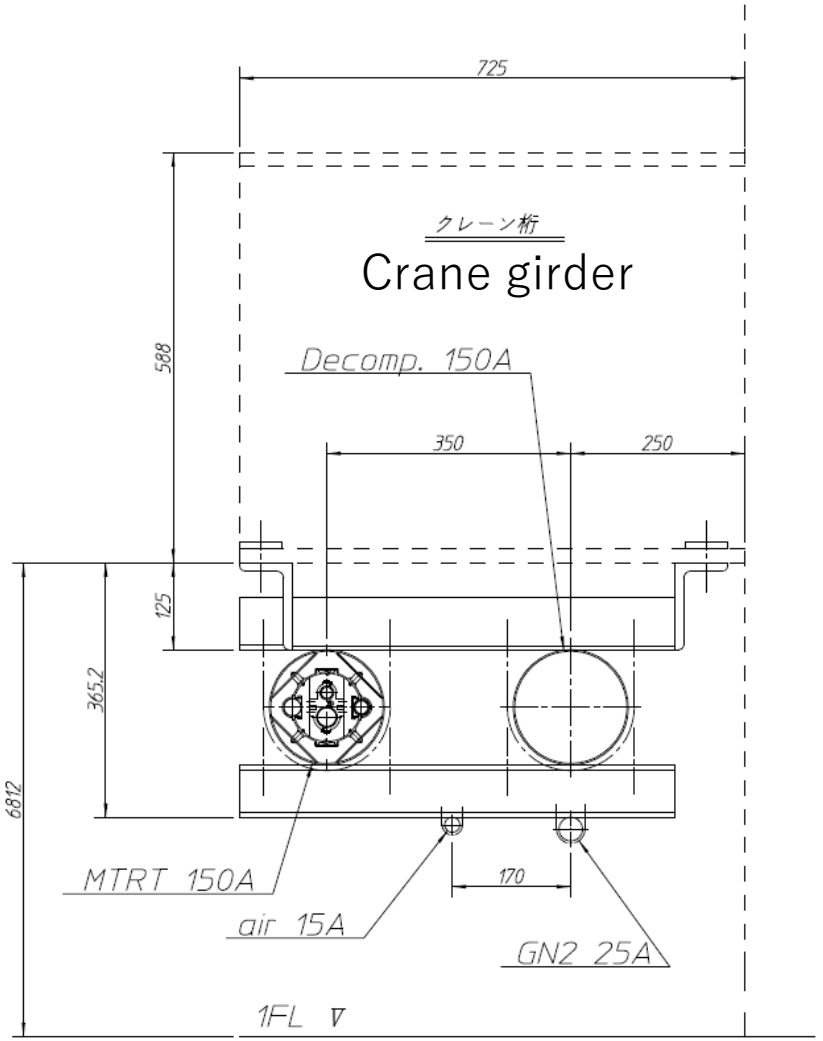


Calculated its characteristics.
Gas velocity and pressure are acceptable.

Transfer line

80K:the surface area is about 30m^2.
If more than 10 layers of SI are installed, the heat load is about 70W



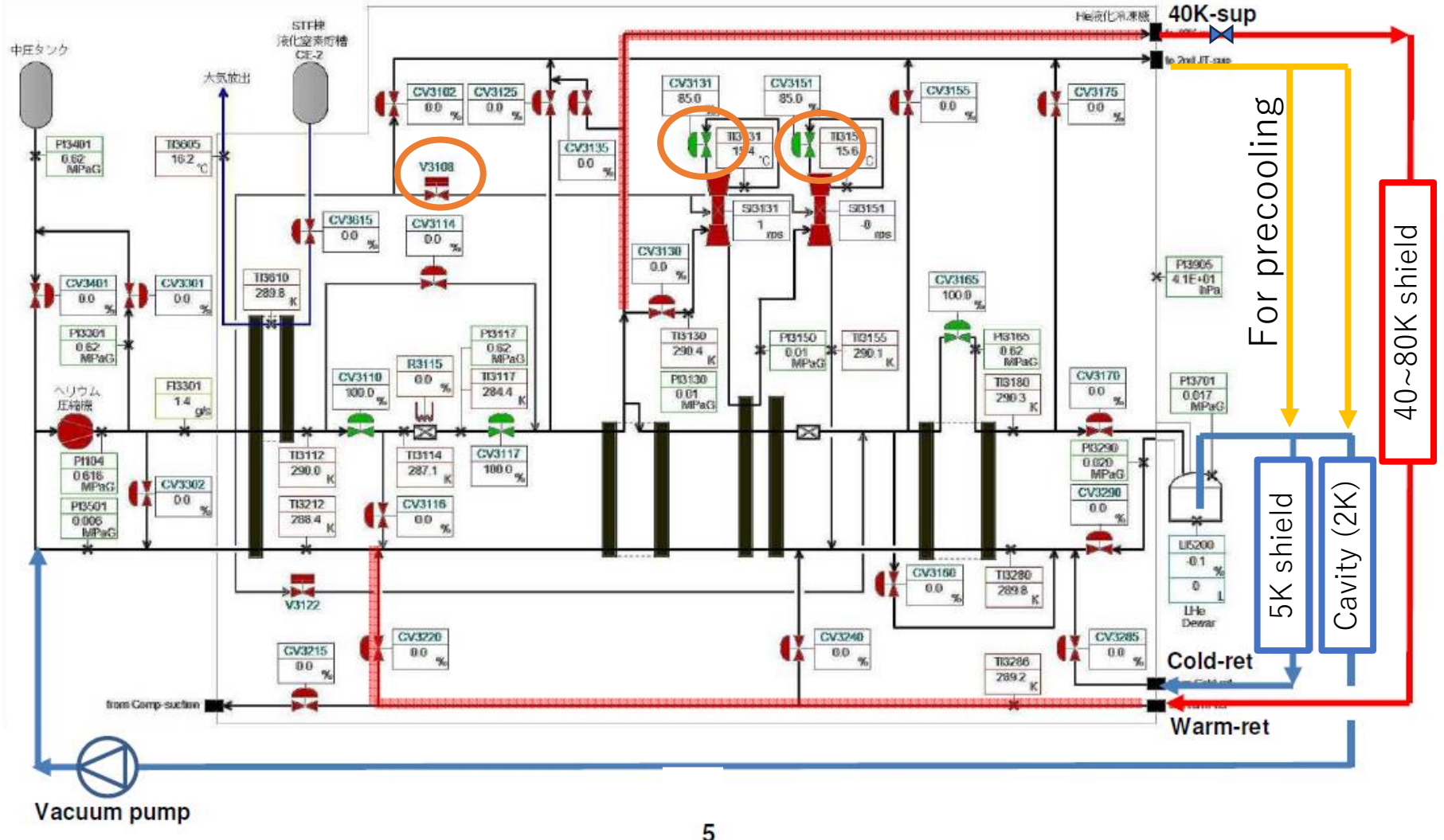


5K:heat load is about 10W.(less than 0.1W/m)

Control system update

We negotiated with the manufacturer of the He refrigerator.
The logic that controls the turbine has not been exposed.
The manufacturer want to keep the control of three valves.

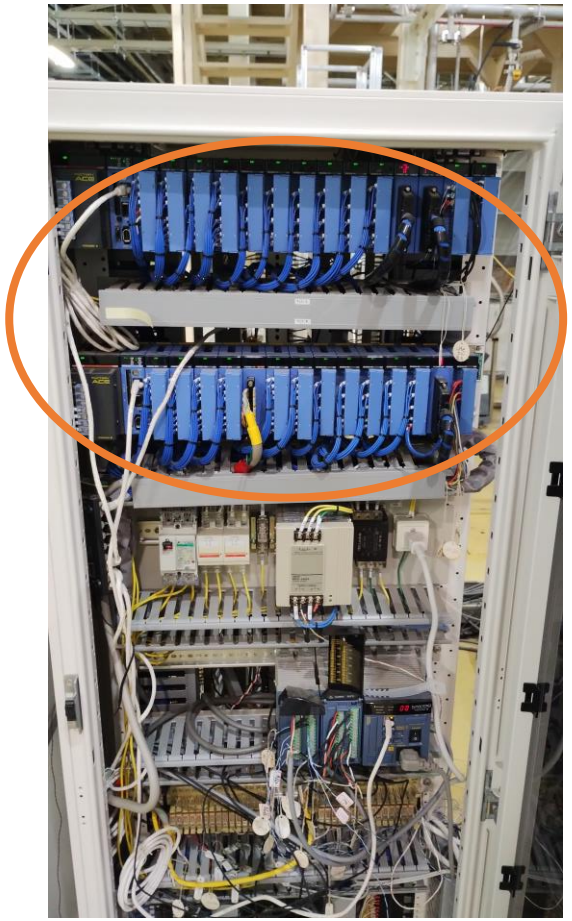
Valves used for turbine control



Control system update

FY2024:Programming test
😊
FY2025:Construction
FY2026:Operation test

EPICS base control system
(KEK's (OS:Linux))
Accelerators are controlled by EPICS.



These control system use same platform.
They can be merged.

図 1　EzMPICSIII の外観

Refrigerator control system
(manufacturer's (OS:VxWorks))

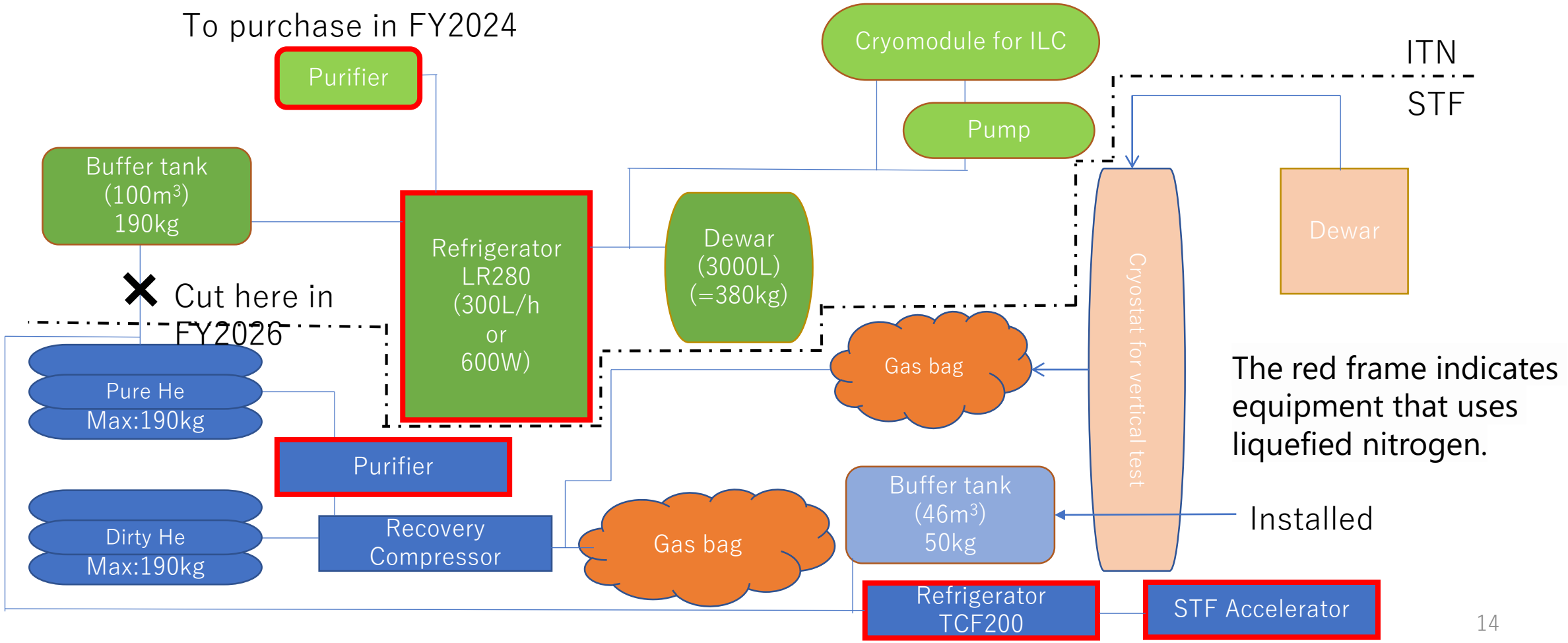
Our refrigerator control system at cERL

HPGS category will be changed

- The HPGS category of the refrigerator dewar and buffer tank must be changed.
- Our local government(Ibaraki-ken) only requires pressure test and Airtightness test.
- Devices which managed by different categories of HPGS can not be connected. STF and ITN-CTB system must be separated.

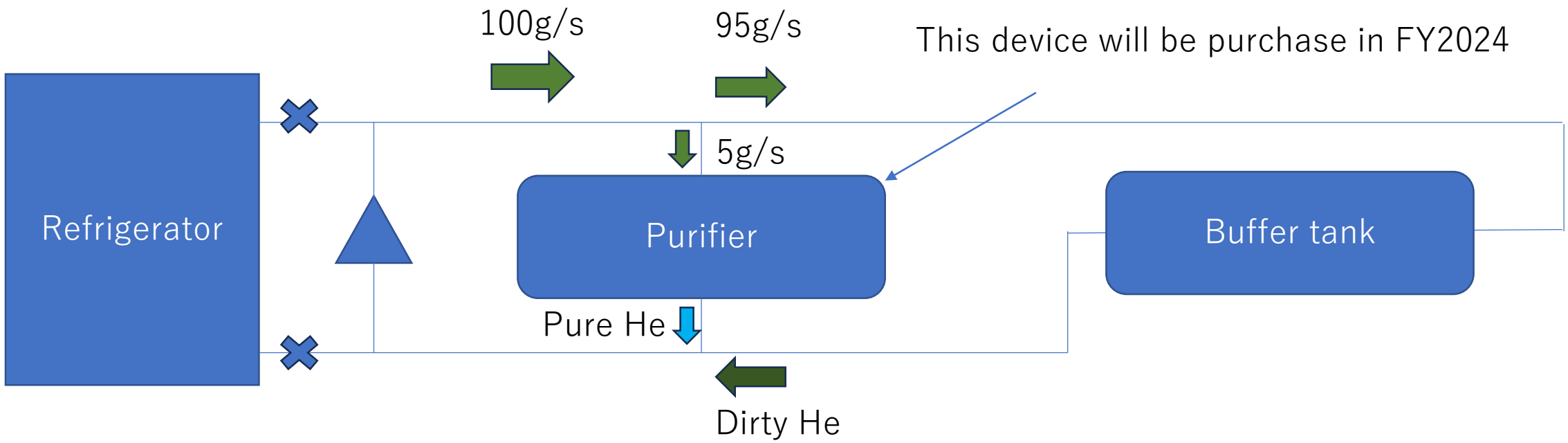
Separation of ITN cryogenic system from STF

The HPGS categories of STF accelerators and ILCs are different.
Under Japan law, devices of different categories cannot be connected, so ITN should be separated from STF.
The red frame shows equipment that uses liquid nitrogen.



Helium purifier

HPGS for refrigerator does not allow to use gas bag and recovery compressor.
Middle pressure purifier should be installed.

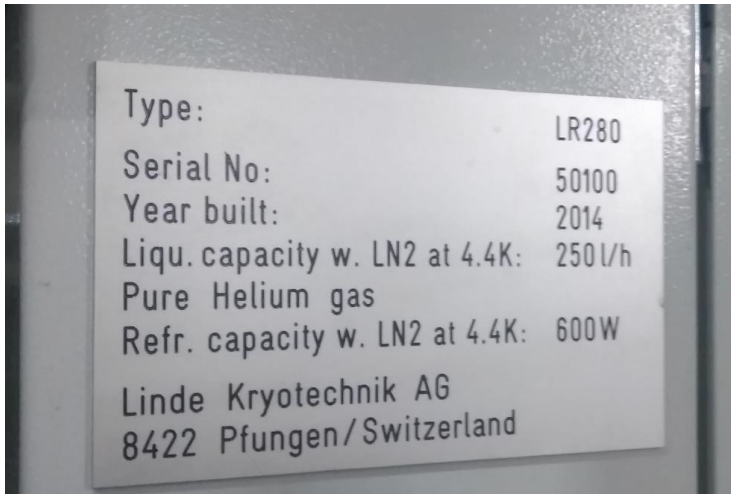


It should be used before operating the helium refrigerator.
The buffer tank has a capacity of 100 m^3 and is filled with about 1.0 MPa.
The impurity concentration decreases by e^(-t/ τ).
If the flow rate is 5 g/s, the time constant(τ) is about 12 hours.

Cooling capacity

When 40K gas is used 20g/s, the cooling capacity becomes half. Thus, the capacity of this cooling mode is 40g/s. We called that cooling mode parasitic mode.

Assuming a temperature rise of 40 K, the cooling capacity per 1 g/s is 200 W.



Capacity of refrigerator:
Parasitic mode : 40g/s
→40×200=8kW

Refrigerator mode:
600W
→Maximum 4K heat load is 600W

Liquefier mode:
250L/s　0.7J/L : latent heat　0.9 : wetness at just after JT valve
→ Maximum 2K heat load is 150W
250×0.7×0.9≒150W

	2 K		5–8 K		40–80 K	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
RF Load		8.02				
Radiation Load			1.41		32.49	
Supports	0.60		2.40		18.0	
Input coupler	0.17	0.41	1.73	3.06	16.47	41.78
HOM coupler (cables)	0.01	0.12	0.29	1.17	1.84	5.8
HOM absorber	0.14	0.01	3.13	0.36	-3.27	7.09
Beam tube bellows		0.39				
Current leads	0.28	0.28	0.47	0.47	4.13	4.13
HOM to structure		0.56				
Coax cable (4)	0.05					
Instrumentation taps	0.07					
Diagnostic cable			1.39		5.38	
Sum	1.32	9.79	10.82	5.05	75.04	58.80
Total	11.11		15.87		133.84	

Summary

- Cryomodule test station is being prepared.
- CE (liquid nitrogen tank) and He buffer tank were extended.
- Liquid Helium transfer line and 2K refrigerator is being designed and will be prepared from 2025.
- The test station will be operated in 2027

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Heat load:

- 12W@2K →12/150=8%
- 16(CM)+10(TRT)W@5K →26/600=5%
- 134+70W@40K →204/8000=3%

Total 16%

If the estimation of heat load is correct, the refrigerator is powerful enough.

Cold mass and heat load

The heat loads of TRT are smaller than the static heat loads of a cryomodule at 40K and 5K, respectively.

- 40~80K region

Aluminum 320kg, Stainless 2500kg

In TDR, Static:75W, Dynamic:59W, cooling capacity : 8kW(Parasitic mode)

- 5K

Stainless 200kg

Static:11W, Dynamic 5W, cooling capacity : 600W(refrigerator mode)

- 2K

Stainless 750kg, Niobium250kg, Titanium 150kg, Cupper 420kg

Static:1.3W, Dynamic 10W, cooling capacity : 200W(liquefier mode)