2K Cryogenic System Design for cERL at KEK

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KEK
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Background and Goal

- We had an old helium refrigerator (TCF200 500W at 4.4K or 250L/h) got from NIMS (National Institute for Material Science).
- Design, construction and operation of 2K 40W cryogenic system for ILC prototype cryomodule was successfully completed. For base line design of cERL 2K system, we adopted this.
- High performance transfer line system and JT heat exchanger have been developed by our group at KEK.

- cERL 2K cryogenic system;
  - Two 2K refrigerators for injector and main linac.
  - Cooling power of each 2K ref. can increase up to 80W by addition of pump units.
  - Total cooling power can upgrade by adding a new liquefier.
Helium Ref. System for cERL

- Helium Ref. Cold Box TCF 200
- Liquid Helium Dewar 3000L
- Multi-transfer Line
- Purifier
- TCF 200
- Liquid Nitrogen
- Circulation System
- High Pressure Helium Compressor
- Screw Type Helium Compressor
- Liquid Nitrogen
- High Pressure Helium Gas Storage
- Medium Pressure Helium Gas Storage
- Gas Bag
- High Pressure Helium Gas Storage

Heat Load:
- 10 mA x 10 MV x 4 units
  - 2 K: 46 W
  - 4.5 K: 30 W
  - 80 K: 191 W
- 10 mA x 15 MV x 4 units
  - 2 K: 102 W
  - 4.5 K: 30 W
  - 80 K: 191 W
- 100 mA x 10 MV
  - 2 K: 31 W
  - 4.5 K: 94 W
  - 80 K: 1000 W
**2 K Super-fluid Helium**

How to make 2K Super-fluid Helium?

*Use the latent heat of vaporization of helium*

- **Cold Pump** Large System CEBAF, LHC, ….
- **Warm Pump** Small System KEK

**Saturated Vapor Pressure of Helium**

<table>
<thead>
<tr>
<th>Temperature [K]</th>
<th>Pressure [bar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03 bar</td>
<td>2.0 K</td>
</tr>
<tr>
<td>1.2 bar</td>
<td>4.4 K</td>
</tr>
</tbody>
</table>

**Enthalpy [J/g]**

- **Liquid State**
  - **2.0 K**
  - Latent heat of vaporization

**Gas State**

- **2.0 K**
- **20 J/g**

**Liq. He 1 l / 8 kg / 8 x 20 = 2.5 kJ**

**Liq. He 1 l/hr -- 2.5 / 3.6 = 0.7 W**

Cooling Power 1W -- Liq. He Consumption 1.4 l/hr
JT-Heat Exchanger

Production ratio of 1.8K liquid helium can increase from 62% to 89% by lowering the temperature of expand liquid helium from 4.2K to 2.2K using the cold vaporized gas through JT-heat exchanger.

Because saturated pressure of the 2K helium is very low, i.e. ~ 0.03bar, specially designed heat exchanger is required.
2K cold boxes are installed near by cryo-modules.

4K He liq. / ref.; supply liq. He to the 2K cold boxes and cool the 4K heat loads.

2K cooling; is made by pumping at room temp.

Note: 80K thermal shields are not shown.
To cool down the cryomodule from room temperature to 2K through 4.2K and to control the 2K liquid helium level constant during RF operation of SC cavity, many control valves are installed.
Heat Exchanger


Comment:

Version 1: Lamination Type
(1.8 K Magnet Cooling System)

Version 2: Finned Tube Type 1/8"
(2 K ILC Cavity Cooling System)

Version 3: Finned Tube Type 1/4"
(2 K cERL Cooling System)

Lower pressure drop structure in return line
Leak tight: the body made of steel parts
and assembled by argon welding

Heat Exchanger Fin
made by punching press

Heat Exchanger
Cross-section

Liq. Helium In
SUS 60.5D

Copper
1/8” Pipe

Heat Exchanger fins are brazed
to coiled tube

Liq. Helium Out

Cold Return Gas

Cold Return Gas
System flow of cERL Cryogenic System

- Helium Ref. TFC 200 Cold Box
- Multi-channel Transfer Line
- Cold Helium Gas Return
- Liq. Helium Dewar 3000L
- 4.4 K Pot
- 2 K Ref. Cold Box #1
- 5K Shield
- 80K Shield
- 4.4 K Pot
- 2 K Pot
- 5K Shield
- 80K Shield
- Liquid Nitrogen Circulation System Cold Box
- Screw Compressor 5 bar 30 Nm3/hr
- Liquid Nitrogen
- Helium Compressor
- Pumping System
High Performance Transfer Line 1

Small heat leak to cold helium piping ~ 0.05 W/m

80 K aluminum thermal shield, cooled by liq. nitrogen, intercept the heat leak form the room temperature parts.

Small cold mass --- thin stainless tube (0.5 t)

Stable operation during transient condition, i.e., recovery from the cold helium flow stop.

Easy to assembling

Leak tight
  stainless welding

Good thermal contact
  Thermal shield is made by extrusion

Sub-transfer
  80 K aluminum thermal shield

Need liq. nitrogen circulation system

“Development of a High Performance Transfer Line System”
High Performance Transfer Line 2

By the 80K aluminum thermal shield cooled by liquid nitrogen, the heat leak to helium line can reduce to ~ 0.05 W/m

Main Multi-Transfer Line

- **Liq. He Flow**
  - Φ18, 0.5t SUS316L

- **Gas He Return**
  - Φ28, 0.5t SUS316L

- **Liq. N2**
  - Φ14, 0.5t SUS316L

- **80K Al Shield**
  - Φ100, 2t

- **G10 Support Plate**

阀门箱
80K Al Thermal Shield

80K Al Thermal Shield
Main Multi-Transfer Line
2K Cryogenic System for cERL 1
2K Cryogenic System for cERL 2
Summary

- The cERL 2K cooling system consisted of helium refrigerator TCF200, two 2K refrigerators with helium gas pumping system and multi-transfer line was proposed and designed in 2008.
- The main components of the system were constructed and installed in the experimental hall of the cERL by the end of FY 2009.
- Before start the new operation of helium refrigerator for cERL, we cleaned up oil in the flow line of the 1st heat exchanger using the solvent and replace the charcoal by new one.
- The commissioning of the helium refrigerator was started in September of 2010.
- The commissioning of the 2K refrigerator and helium transfer line without the cryomodule will be carried out and 2K cooling capacity will be checked very soon.