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1. **Purpose**

- A neutrino experiment facility using the J-PARC 50 GeV 0.75 kW proton beam is now under construction at Tokai campus of KEK.

- In this project, a superconducting magnet system, which consists of 28 superconducting combined-function magnets, will be installed in an arc section of the primary proton beam line to bend the beam to Kamioka.

- This cryogenic facility is essential to keep superconducting magnets below 5.0 K.
2. Overall Layout

**Neutrino Beam Line**
Superconducting Magnets are installed in main tunnel at -12m level. Radius 105m, Length 150m

**Transfer Line**
100m

**Power Source Control Room**

**Helium Refrigerator on the ground**
16m×34m×8m room

**Tank Yard**
2. Layout of Cryogenic Components

Magnet String & Transfer Line
Inventory: 3900 ℓ,
Cold mass: 225 ton(Fe)

3 Recovery Tanks
(for Quench)
Volume 100 m³×3

Buffer Tank
for Main Compressor
(steady state)
Volume 100m³×1

Cold Box, Subcooler
SHE Max 300 g/s 4.5 K
LHe pot : 800 ℓ

Main compressor(MCP)
550 kW
DischarGE pressure: 1.5 MPa

Buffer Tank for Main Compressor
(steady state)
Volume 100m³×1

Main Compressor
DischarGE pressure: 1.5 MPa

LN2 > 20000 ℓ
Only precooling and recooling after quech
18000 ℓ/day
For first heat exchanger
(cold box)
# 4. Refrigerator Specifications

## 4-1. Summary of Load (Magnet & Transfer Lines) to Cryogenic System

<table>
<thead>
<tr>
<th></th>
<th>4.5 K Level</th>
<th>Remarks</th>
<th>80 K Level</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coolant</strong></td>
<td>SHE</td>
<td>4.5 K, 0.4 MPa</td>
<td>He Gas</td>
<td>60~100 K, 1.2 MPa</td>
</tr>
<tr>
<td><strong>Heat Load Estimation</strong></td>
<td>336 W</td>
<td>Including beam loss of 150 W</td>
<td>1419 W</td>
<td></td>
</tr>
<tr>
<td><strong>Current Lead</strong></td>
<td>1.0 g/s</td>
<td>7600A</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>+ 20 % Contingency</strong></td>
<td>403 W + 1.1 g/s</td>
<td></td>
<td>1703 W</td>
<td></td>
</tr>
<tr>
<td><strong>Cold Mass</strong></td>
<td>204 ton</td>
<td>Iron basis</td>
<td>6.8 ton</td>
<td>Aluminum basis Iron basis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>225 ton</td>
<td>Iron basis</td>
<td>7.5 ton</td>
<td>Aluminum basis Iron basis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.8 ton</td>
<td></td>
</tr>
<tr>
<td><strong>Inventory</strong></td>
<td>3550 l</td>
<td></td>
<td>1620 l</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3900 l</td>
<td></td>
<td>1780 l</td>
<td></td>
</tr>
<tr>
<td><strong>Pressure Drop</strong></td>
<td>84 kPa</td>
<td>300 g/s, 4.5 K, 400 kPa</td>
<td>36 kPa</td>
<td>40 g/s, 80 K, 1.35 MPa</td>
</tr>
<tr>
<td><strong>Design Pressure</strong></td>
<td>&gt;1.8 MPa(G)</td>
<td></td>
<td>&gt;1.8 MPa(G)</td>
<td></td>
</tr>
</tbody>
</table>
4. Refrigerator Specification

4-2. Required Cooling Capacity

<table>
<thead>
<tr>
<th>SHE Flow Rate</th>
<th>max 300 g/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHE Condition</td>
<td>0.4 MPa(A), 4.5 K</td>
</tr>
<tr>
<td>SHE Return</td>
<td>4.9 K</td>
</tr>
<tr>
<td>Thermal Load to SHE Flow</td>
<td>410 W</td>
</tr>
<tr>
<td>Pressure Head of SHE</td>
<td>85 kPa</td>
</tr>
<tr>
<td>Current Lead cooling gas</td>
<td>1.1 g/s (1 pair)</td>
</tr>
<tr>
<td>Shield Temperature</td>
<td>60~100 K</td>
</tr>
<tr>
<td>Shield Cooling</td>
<td>Cold Helium Gas</td>
</tr>
<tr>
<td>Thermal Load to Shield Line</td>
<td>1710 W</td>
</tr>
<tr>
<td>Shield Cooling Gas Condition</td>
<td>Not specified</td>
</tr>
<tr>
<td>LN2 usage</td>
<td>Only Pre-cooling and re-cooling after quench</td>
</tr>
<tr>
<td>Pre-cooling duration</td>
<td>&lt; 20 days</td>
</tr>
<tr>
<td>Re-cooing duration</td>
<td>&lt;6 hours (30GeV operation)</td>
</tr>
</tbody>
</table>

Schematic diagram of SHE circulation system
4. Refrigerator Specification

4-3. Required Cooling Capacity - Estimation

**Expected Operational Flow Rate:**
- 300 g/s → Pump Load : < 300 W
- Mag. Temp. : ~ 4.8K

**Mass-flow rate is controlled to be 0.3kg/sec at the maximum.**
4. Refrigerator Specification

4-4. Required Refrigeration Capacity – Maker Design

<table>
<thead>
<tr>
<th>KEK Requirement</th>
<th>Thermal Load @4.5 K Level</th>
<th>Thermal Load @shield Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet &amp; Transfer Line</td>
<td>410 W + 1.1 g/s</td>
<td>1710 W</td>
</tr>
<tr>
<td>SHE Flow conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max 300 g/s, 4.5 K, 0.4 MPa Head 85 kPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHE Pump Load</td>
<td>330 W</td>
<td></td>
</tr>
<tr>
<td>Sub-cooler, Transfer Line b/w CB</td>
<td>150 W</td>
<td>250 W</td>
</tr>
<tr>
<td>Required Refrigeration</td>
<td>890 W + 1.1 g/s</td>
<td>1960 W</td>
</tr>
<tr>
<td>→ 1.0 kW</td>
<td></td>
<td>→ 2 kW</td>
</tr>
<tr>
<td>+ 20 % Margine</td>
<td>1.2 kW</td>
<td>2.4 kW</td>
</tr>
</tbody>
</table>

Taiyo-Nissan Co. in the business collaboration with LINDE won the bid.
5. Operation – Pre-cooling

- **CB&SC pre-cooling**
- **Gas Transfer**
- **Magnet Pre-cooling**
- **Shield Pre-cooling**
5. Operation – Magnet Excitation (Steady state)
5. Operation - Quench
5. Operation - Warming
6. Two in one structure cryostat

Feed Box
Mass flow rate: 20 g/sec ~ 40 g/sec
Coolant: SHE
Temperature 4.5
Pressure: 0.4 MPa

Quench protection heater
For calibration
2W, 3W, 4W

Cernox temperature censor
6. Results of Heat Load

- QPH is fired for calibration.
- Pure heat load & Removed QPH Power.
- Shield line forced cooling 100K→80K.

Total heat load to 4.5 K line 8.0W @Two in one structure cryostat
7. Quench simulation

This model is based on an assumption that flow is Two-dimensional. Numerical simulation is carried out involving four magnets, one relief valve, venting line and buffer tank.
7. Simulation Results at 4/4 Magnets Quench

- Pressure Profile
- Temperature Profile
- Density Profile

Quench relief valve
Magnet (Heat Input)
Baseline
8. States

- The cold Box is being manufactured by LINDE.
- The compressor is being manufactured by MYCOM.
- The sub-cooler design will be finalized by TN.
- SHE pump is made by Barber-Nichols.
- Tank foundation design, machine room design is in progress by KEK.
- A tender for the control system is being prepared.

- Heat load to 4.5 K level of two in one structure cryostat is 4.0W.

- Quench simulation involving 7 magnets is being prepared.