Cryogenic system at Siam Photon Source

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Outline

» Background
» Installation and Commissioning
» Operation and Maintenance
» Problem and Solution
» Next project
» Safety
• **Cryogenics อดิศตศาสตร์, วิชาความเย็นยิ่งยวดยิ่ง**
• **Cryogenic refrigeration ภาวะเย็นยิ่งยวดยิ่ง**

การทำความเย็นให้ได้อุณหภูมิต่ำตั้งแต่ประมาณ -150 องศาเซลเซียสลงมา ส่วนใหญ่ใช้ในอุตสาหกรรมแก๊ส เช่น การทำให้แก๊สธรรมชาติเป็นของเหลว การทำไนโตรเจนเหลวเพื่อใช้ในวงการแพทย์ เทคโนโลยีอวกาศ และการทำความเย็นแก่อุปกรณ์อิเล็กทรอนิกส์ที่ทำงาน ณ อุณหภูมิต่ำ

Background

• To produce liquid helium (LHe) for the operation of the superconducting magnet as a part of the hard x-ray project.

In Thailand:

LHe cost ~800-1,000 Bath/Liter
Helium(N50) ~ 6,500 Bath/Cylinder
Size 150 barg (7m³)

• To supply LHe for cryogenic R&D activities at SLRI.

* LHe is produced and used in lab, the boiled-off He gas can be re-collected and recycled
Background

- The concept is similar to the cryogenic plant of the Taiwan Light Source (NSRRC)
- Brayton cycle & Joule-Thomson cycle
- Compressors installed outside the light source building
  (to reduce the vibration-related problems)
- Cold unit and main dewar installed in exp. Hall
- Recover the evaporated He gas
- Produce at least 20 l/h of LHe to the main LHe dewar
Simplified Liquid Helium system

- Compressor
- Cold box
- Liquid He
- LHe Dewar
- WLS Magnet
- Helium Gas
- Warm He
- Cold He
- 20 l/hr Liquefaction capacity
- 4.5 K
- Warm He gas
- Warm He gas
- 300 K
- 300 K

Helium Gas

300 K
### Liquid helium plant specification

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium Liquefier Model</td>
<td>Air Liquide HELIAL 1000</td>
</tr>
<tr>
<td>Liquefaction Mode</td>
<td>Claude Cycle</td>
</tr>
<tr>
<td></td>
<td>Two expansion turbines in series (Max. speed = 5500 Hz)</td>
</tr>
<tr>
<td>Liquefaction Capacity</td>
<td>20.0 liter/hr</td>
</tr>
<tr>
<td>without LN2 pre-cooling</td>
<td></td>
</tr>
<tr>
<td>Dewar Storage Capacity</td>
<td>450 liter (Min. capacity = 15% , 75 liter) &lt;1.8 bara</td>
</tr>
<tr>
<td>Compressor Station</td>
<td>Discharge pressure 12.00 bara (PT290&lt;12.4 bara)</td>
</tr>
<tr>
<td></td>
<td>Suction pressure 1.05 bara (PT275&lt;1.35 bara)</td>
</tr>
<tr>
<td></td>
<td>Water cooled</td>
</tr>
<tr>
<td></td>
<td>Kaeser CSD122 – Screw type</td>
</tr>
<tr>
<td>Helium Gas Buffer</td>
<td>10+10 m³ (upgrade to 40 m³) (PT286&lt;1.7bara)</td>
</tr>
<tr>
<td>Helium Gas Bag Volume</td>
<td>10+100 m³</td>
</tr>
<tr>
<td>Liquid Nitrogen Bulk Storage</td>
<td>6,000 liter</td>
</tr>
</tbody>
</table>
## Liquid helium plant (Fabrication procedure)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pipe shaping</td>
<td>Stainless Steel 304, Electro-polished</td>
</tr>
<tr>
<td>2. TIG Welding</td>
<td>Argon/N$_2$ shield</td>
</tr>
<tr>
<td>3. Chemical Cleaning</td>
<td>DI Water, Alkaline Degreaser, Ethanol 95%, N$_2$ Blow Dry</td>
</tr>
<tr>
<td>4. He Leak Test</td>
<td>leak rate &lt; $5 \times 10^{-9}$ mbar l/s</td>
</tr>
</tbody>
</table>
Commissioning and Start up

1. Compressor station - Helium condition (purity <15ppm)
   - Compressor (oil filling), ORS (regeneration), Buffer tank and transfer lines

2. Coldbox station
   - Adsorber (regeneration), Vacuum, FCV (cal.), HEXT (install-adjust) and Dewar
In operation since April 2009 @ >20L/hr
Location

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• 24 Hour Automatic Operation
• Liquid Helium Supply to User
Operation and Maintenance

- **COMPRESSOR MODULE**
  - Check of the operating parameters, check of the relief valves
  - Inspection of the electrical connections: once a year
  - Replacement of oil filters: once a year
  - Grease of the motor ball bearings: each 500 operating hours
  - Replace of the motor bearings: each 20,000 operating hours
  - Replace of the fan motor bearings: each 12,000 operating hours
Operation and Maintenance

• OIL REMOVAL MODULE
  – Adsorber: the activated charcoal: every 8,000 operating hours
  – Check and adjust the control valves: once a year

• COLD BOX MODULE
  – Check and adjustment of automatic valves, pressure regulators, pressure safety valves, pressure transmitters and switches: once a year
  – Cleaning of the electrical/PLC cabinet: every 2 years
  – Check of oil level and quality of the vacuum pumps: regularly
  – Change of the oil of the vacuum pumps: every year
Oil Removal System Condition

Flow meter

Thermometer

Flow rate = 160 l/min
Temp. = 60-80 °C
Drying operation = 60 Hr
Dewpoint = -50 °C

Charcoal Filling

Heater

Temp. monitor

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**Main compressor PM procedure**

1. **Stop Compressor**
   - Draining Oil from:
     1. Oil separator tank
     2. Oil cooler
     3. Oil tank
     4. Airend
   - 2 minute & Built-up pressure to 5 bar

2. **Vacuum ≤ 1 mbar & Filling Helium (N50)**
   - 3 times
   - Helium Leak Test

3. **Renew**:
   - 1. Oil filter
   - 2. Oil separator cartridge

4. **Filling Cooling Oil**

5. **Re-Start Compressor**
Main compressor Yearly PM

- Draining
- Oil filter
- Oil separator cartridge
- Re-new
- Helium leak test
- Breox oil B35
- Re-filling
Main compressor Yearly PM
### On-site inspection by AL (France) June 2015

<table>
<thead>
<tr>
<th>Component</th>
<th>Maintenance Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 200 Oil Removal system</td>
<td>- Control valves strokes verification and adjustment</td>
</tr>
<tr>
<td>Module 400 Cold box</td>
<td>- Cryogenic valves stroke verification and adjustment</td>
</tr>
<tr>
<td></td>
<td>- A420 Cold adsorber regeneration</td>
</tr>
<tr>
<td>Module 800 Purifier</td>
<td>- Cryogenic valves stroke verification and adjustment</td>
</tr>
<tr>
<td>HELIAL 1000 Restart</td>
<td>- Cooling down of the Cold box, connected to the main Dewar (Ambient temperature)</td>
</tr>
</tbody>
</table>
Problem (6.5T SWLS Operation on August 2013)

- **Voluntary stop** (32) 74%
  - Coldbox (18)
  - Compressor (12)
  - Dewar (2)
- **Utility** 21%
  - Electricity
  - Water cooling
  - Air instrument
- **Human error** 5%
- **Miscellaneous** 0%

- After supply to SWLS (3 times)
  - LN2 low
  - SWLS PS fault
  - Coldbox stop (Turbine fault)
## Problem and solution

<table>
<thead>
<tr>
<th>Failure event</th>
<th>Cause</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of main compressor too high (110°C) and TT220 &gt; 323K</td>
<td>Dust/scale inside water cooling system</td>
<td>Cleaning oil HEX (Phosphoric acid)</td>
</tr>
<tr>
<td>Low production capacity of LHe to Dewar</td>
<td>Adsorber have a moisture</td>
<td>A420 Slow regeneration</td>
</tr>
<tr>
<td>LT607 cannot reading</td>
<td>Unknow</td>
<td>Remove/Replace</td>
</tr>
<tr>
<td>FCV469 open 100% all the time</td>
<td>Unknow</td>
<td>A420 hot regeneration</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Hard X-ray project time line

- Start of the hard X-ray project: June 2005
- 1\textsuperscript{st} Modification of 6.4T WLS (Cover plate): 2006-2008
- Damage on WLS cryostat: March 2009
- First Helium liquefaction: April 2009
- 2\textsuperscript{nd} Modification of 6.4T WLS (Bellow): 2009-July 2010
- 6.4T WLS Cold test with cryogenic plant: August 2010
- Design of new cryostat: September 2010-2011
- 6.5T SWLS project: 2012-2013
- New 3.5T SMW for ASEAN Beamline: 2016-2018
6.4T WLS cold test

1. The superconducting magnet
2. Vacuum shield
3. LHe consumption rate (>20 l/hr).
4. Current feedthroughs (HTS)
5. More safety devices
# New Cryostat design parameter

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Type</td>
<td>Bath cooling</td>
</tr>
<tr>
<td>Liquid Helium Consumption Rate</td>
<td>5 liter/hr</td>
</tr>
<tr>
<td>Liquid Helium Vessel</td>
<td>Material SUS 304/SUS316</td>
</tr>
<tr>
<td></td>
<td>Multilayer insulation (MLI) 30 Layers</td>
</tr>
<tr>
<td>Thermal Shield</td>
<td>Material OFHC Copper blanket with Liquid Nitrogen cooling tubes</td>
</tr>
<tr>
<td></td>
<td>Multilayer insulation (MLI) 50 Layers</td>
</tr>
<tr>
<td>Vacuum Vessel</td>
<td>Material SUS 304/SUS316</td>
</tr>
<tr>
<td></td>
<td>Vacuum pressure $\leq 10^{-6}$ mbar Sputtered (Ion pump)</td>
</tr>
<tr>
<td>Mechanical Support</td>
<td>8 - G10 straps (NSRRC Type)</td>
</tr>
<tr>
<td></td>
<td>Material S-glass fiber reinforced epoxy resin (G10)</td>
</tr>
<tr>
<td></td>
<td>Stainless steel 316 – Rod ends</td>
</tr>
<tr>
<td></td>
<td>Inconel 718 – Pin</td>
</tr>
<tr>
<td>Thermal Interception</td>
<td>Material OFHC Copper</td>
</tr>
<tr>
<td>Beam Duct</td>
<td>Material OFHC Copper</td>
</tr>
<tr>
<td>Cryostat Pressure</td>
<td>Operating Pressure 1.20 bara</td>
</tr>
<tr>
<td></td>
<td>Maximum allowable working pressure 1.50 bara</td>
</tr>
<tr>
<td></td>
<td>Design pressure 3.0 bara</td>
</tr>
<tr>
<td>Liquid Helium Volume</td>
<td>217 Liter</td>
</tr>
</tbody>
</table>
Operating in normal LHe = 4.5 K
Total mass of cold mass = 720 kg (OD 0.8m X L 0.6m)
Max. heat loss budget @ 4.5 K = 3.35 W (~5 l/h)

New cryostat (Design concept)

A conceptual sketch of WLS cryostat transverse cross section

Thermal flow diagram
New Cryostat design

Service Tower

80K thermal shield

SC Magnet

4.5K LHe vessel
### 6.5T SLWS Preparation for Hard X-ray project

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superconducting wire</td>
<td>NbTi</td>
</tr>
<tr>
<td>Main current (A)</td>
<td>308</td>
</tr>
<tr>
<td>Peak field (Tesla)</td>
<td>6.5</td>
</tr>
<tr>
<td>Number of pole</td>
<td>3</td>
</tr>
<tr>
<td>Physical length (cm)</td>
<td>85</td>
</tr>
<tr>
<td>Horizontal aperture of vacuum chamber (cm)</td>
<td>10</td>
</tr>
<tr>
<td>Vertical aperture of vacuum chamber (cm)</td>
<td>2</td>
</tr>
<tr>
<td>Pole gap (mm)</td>
<td>50</td>
</tr>
<tr>
<td>Beam duct temperature (K)</td>
<td>300</td>
</tr>
<tr>
<td>Total energy @ 6.5T (kJ)</td>
<td>450</td>
</tr>
<tr>
<td>LHe boiling off (L/hr)</td>
<td>&lt;2</td>
</tr>
<tr>
<td>LN2 boiling off (L/hr)</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

![Diagram of 6.5T SLWS Preparation for Hard X-ray project](image)
6.5T SLWS Project August 2013

- Helium transfer system (LHe transfer line and Helium gas return)
- Nitrogen transfer system (LN2 phase separator and transfer line)
- Integration to Cryogenic plant
- Helium Condition and Safety devices
- Utility
Helium Diagram

Recovery system

Gag Bag

Gas Warmer

LHe Plant

Valvebox

SWLS

Interface

LHe Plant

LHe

10L/hr

Valvebox

LHe

>5L/hr

SWLS

T<sub>SWLS</sub> < 77K

Gas Warmer

GHe

GHe

GHe

GHe

LHe

65L/min

T = 300K

T = 77K

GHe

LHe

>5L/hr

T = 300K

LHe

10L/hr

LHe

>5L/hr
3.5T SMW Project - 02

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สถาบันวิจัยแสงซินโครตรอน (องค์การมหาชน)
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Safety equipment

- Oxygen Detector
- Portable Oxygen Detector
- Smoke Detector & Fire Alarm
Physiological Hazards

-Cold Burns-

• Effects:
Similar to burns

• First Aid:
– rinse injured part with warm water
– cover injured skin with sterile gaze
– do not apply powder or creams

Protection:
– eye protection
– gloves of insulating and non combustible material which can be easily removed
– high, tight-fitting shoes
– trousers which overlap the shoes

อ้างอิง: http://www.slac.stanford.edu/econf/C0605091/present/CERN.PDF
Physiological Hazards

-Asphyxiation-

• Effect:
  – 19% - 15% pronounced reduction of reaction speed
  – 15% - 12% deep breaths, fast pulse, co-ordination difficulties
  – 12% - 10% vertigo, false judgment, lips slightly blue
  – 10% - 8% nausea, vomiting, unconsciousness
  – 8% - 6% death within 8 minutes, from 4-8 minutes brain damages
  – 4% coma within 40 seconds, no breathing, death

• First Aid:
In case of indisposition - remove person from the danger area.

• Protection / Prevention:
– ensure sufficient ventilation + oxygen monitors

อ้างอิง: http://www.slac.stanford.edu/econf/C0605091/present/CERN.PDF
Thank you for your attention