CRYOCOOLER (CCR) SOLUTIONS FOR R&D, MEDICAL AND INDUSTRIAL APPLICATIONS

16th of June 2015
Brief Introduction to SHI and Cryogenics Group

Applications and Cryocooler solutions

- R&D => Astronomy
- Medical => MRI
- Industrial => Windturbine (Concept)

Manufacturing
Company Profile

Sumitomo Heavy Industries, Ltd. (http://www.shi.co.jp)

Founded: November 20, 1888
Incorporated: November 1, 1934
Business: Manufacturing of industrial machinery
Capital: 30,871.65 million Yen (as of March 31, 2014)
Employees: 17,941 (consolidated) (as of March 31, 2014)
Net Sales: 615,270 million Yen (FY2013 ending March 2014)
Head Office: Tokyo, Japan
President: Shunsuke Betsukawa (from April 1, 2013)

[About Sumitomo]

Sumitomo's businesses originated from the Besshi copper mine. Other than SHI, the companies are spread over a diverse range of business categories. The “Sumitomo’s Business Philosophy” that has been inherited from the historical Sumitomo Family, is adhered to by these companies to this day.

1. Sumitomo shall achieve strength and prosperity by placing prime importance on integrity and sound management in the conduct of its business.
2. Sumitomo shall manage its activities with foresight and flexibility in order to cope effectively with the changing times. Under no circumstances, however, shall it pursue easy gains or act imprudently.
Product Introduction <By segment>

**Precision Machinery**
- Cryogenics Equipment
- Cryopump
- Cryocoolers for Superconductivity (MRI, R&D), Vacuum application as incorporated into Cryopumps (Semiconductor)

**Machinery Equipment**
- Power transmission equipment

**Construction Machinery**
- Hydraulic excavators

**Environmental Facilities & Plants**
- Water treatment system
- Energy-related system

**Industrial Machinery**
- Logistics & handling system
- Material handling system
- Automated parking system
- Turbines & pumps
- Forging press

**Ships**
- Ships

**Environmental Facilities & Plants**
- Water treatment system
- Energy-related system
Japan Domestic Network

Head Office
(Osaki, Tokyo)

Okayama Works

Chiba Works

Ehime Works (Niihama Factory)

Tanashi Works

Ehime Works (Saijo Factory)

Nagoya Works

Corporate R&D Center

Yokosuka Shipyard

8. Braunschweiger Supraleiterseminar

Sumitomo Heavy Industries, Ltd.
Sumitomo Cryogenics History

1983
Cryogenics business started at Tanashi for manufacturing 10K GM OEM

1995
Start manufacturing 4KGM for MRI at Tanashi

1999
Establish SCAI for sales and service in the US market

2000
Establish SCEG for sales and service in European market

2002
Acquired IGC-APD Cryogenics and SCAI & SCEL started

2004
Acquired Daikin cryogenics business and success their products and service business

2011
Establish SCGS & SCKL for Sales and Service in Chinese & Korean Market

2012~
Pulse Tube (1W)

SHI (Tokyo, JPN)

SCEG GERMANY

SCAI USA

IGC-APD

SCEL UK

DAIKIN Cryogenics

SICERA

SCGS China

SCKL Korea
## Product Portfolio

**Temperature (Kelvin)**

<table>
<thead>
<tr>
<th>Low</th>
<th>4.0</th>
<th>10</th>
<th>20</th>
<th>77</th>
<th>210</th>
<th>High</th>
<th>430</th>
</tr>
</thead>
</table>

### GM+JT Cryocooler
- Largest cooling capacity at 4K (only one manufacturer)
- Low vibration
- Low power consumption

### GM / Pulse Tube Cryocooler
- Compact 4K Cryocooler
- Stable performance
- Orientation-free
- High quality, reliability
- Selection of 4K lineup

### Cryopump
- Energy saving (multiple operation)
- Stable performance
- Shorten down time (large pumping capacity)

### GM Cryocooler
- Large capacity, wide temperature range (improving throughput)
- Energy saving
- Small footprint

### Stirling Cryocooler
- Small, compact (integrated)
- Low power consumption

### Superconducting
- Single crystal silicon grower for wafer production
- SMES

### Superconducting
- MRI application (share >95%)
- Other superconducting application (industrial & research)

### Vacuum
- Sputtering Equipment
- Ion Implanting Equipment (for semiconductor production)

### Superconducting
- HTS application (Motor, Generator, FCL)
- Pre-cooling magnet

### Cooling
- Dew point meter
- Infrared Camera
Sumitomo Cryogenics group in Europe

Sumitomo (SHI) Cryogenics of Europe, Ltd.
Basingstoke, UK

Sumitomo (SHI) Cryogenics of Europe GmbH
Darmstadt, Germany
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Manufacturing
Applications of Cryocoolers

[Vacuum]
- Vapor Deposition
- PET Cyclotron (Quantum Div.)
- Cryopump (UHV pump incorporating Cryocooler)
- Ion Implanter (SEN)
- Sputtering (for semiconductor)

Creating ‘clean’ ultra-high vacuum environment

No.1 in Energy Saving

[Cooling]
- Astronomy (ALMA in Chile)
- NMR (Nuclear Magnetic Resonance)
- Magnetic Separation
- Magnet for accelerator (SPRING-8)
- Creating Superconducting environment (°C)

[Superconductivity]
- MCZ magnet (for silicon wafer)
- MRI
- SMES (Supercon. Magnet energy storage)

Creating Superconducting environment (°C)

• Improve sensitivity
• Environmental test
High on the Chajnantor Plateau in the Chilean Andes, the European Southern Observatory (ESO), together with its international partners, is building and operating the most complex ground-based astronomical project in existence. The Atacama Large Millimeter/submillimeter Array, ALMA, is a state-of-the-art, revolutionary telescope which captures light from some of the coldest objects in the Universe. This light has a typical wavelength of around a millimetre, lying between infrared radiation and radio waves in the electromagnetic spectrum, and is therefore known as millimetre and submillimetre radiation. ALMA is composed of 66 high-precision antennas, operating at wavelengths of 0.32 to 3.6 millimetres.

Source: ESO, ALMA Handout
Cold Head Unit (Model: RDK-3ST)

<table>
<thead>
<tr>
<th>Cooling Cycle</th>
<th>3-Stage Modified Gifford-McMahon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Condition</td>
<td>Indoor</td>
</tr>
<tr>
<td>Cooling Capacity</td>
<td></td>
</tr>
<tr>
<td>(Vertical Position, 50Hz)</td>
<td>1st stage</td>
</tr>
<tr>
<td></td>
<td>2nd stage</td>
</tr>
<tr>
<td></td>
<td>3rd stage</td>
</tr>
<tr>
<td>Lowest Temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1st</td>
</tr>
<tr>
<td></td>
<td>2nd</td>
</tr>
<tr>
<td></td>
<td>3rd</td>
</tr>
<tr>
<td>1.0Hz Temperature Fluctuation</td>
<td>1st</td>
</tr>
<tr>
<td>(@50Hz mains frequency)</td>
<td>2nd</td>
</tr>
<tr>
<td></td>
<td>3rd (He-Pot)</td>
</tr>
<tr>
<td>Cool-Down Time</td>
<td></td>
</tr>
<tr>
<td>(300K to 40K, 1st stage)</td>
<td>&lt; 4 hours.</td>
</tr>
<tr>
<td>Cooling Capacity Degradation</td>
<td></td>
</tr>
<tr>
<td>(at vertical, cold end downward)</td>
<td>&lt; 10 % per 10,000 Hrs</td>
</tr>
<tr>
<td>Orientation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free</td>
</tr>
<tr>
<td></td>
<td>(Cooling Capacity Loss: max. 15 %)</td>
</tr>
<tr>
<td>Ambient Temperature Range</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 to 35 deg.C</td>
</tr>
<tr>
<td></td>
<td>(28 to 35 deg.C with cooling capacity loss max. 5%)</td>
</tr>
<tr>
<td>Dimension</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H: 758 x W: 180 x L: 298 mm</td>
</tr>
<tr>
<td></td>
<td>-- approx.</td>
</tr>
<tr>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28 kg</td>
</tr>
<tr>
<td></td>
<td>-- approx.</td>
</tr>
</tbody>
</table>

CCR = Closed Cycle Refrigerator
3-Stage Cold Head + He-pot on the 4K stage
Air Cooled He-Compressors (Indoor/Outdoor)
Low noise receiver are cooled to less then 4K
Temperature Stability shall be better than ± 5mK
Medical => MRI

4K GM
**Cold Head Unit (Model: RDK-408D2)**

- **Cooling Cycle**: Modified Gifford-McMahon (2-Stage)
- **Site Condition**: Indoor

<table>
<thead>
<tr>
<th>Cooling Capacity</th>
<th>1st 40/50W at 43K (50/60Hz)</th>
<th>(1st 34/44W at 40K (50/60Hz)) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Vertical Position)</td>
<td>2nd 1.0 W at 4.2K (50/60Hz)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* for reference only</td>
<td></td>
</tr>
</tbody>
</table>

- **Lowest Temperature**: < 3.5 K -- for reference only
- **Cool Down Time**: < 60 min. -- for reference only
- **Cooling Capacity Degradation**: < 10 % -- for reference only
- **Orientation**: Free (Cooling Capacity Loss: max. 15 %)
- **Ambient Temperature Range**: 5 to 35 deg C (28 to 35 deg C with cooling capacity loss max. 5 %)

**CCR** = Closed Cycle Refrigerator
Industrial => Windturbine

Concept

Rotor

Rotorspulen

Dämpfer

30 Kelvin

Vakuumraum

Rotoreisen

Supraleiter

Rotor

Courtesy Dr. Bührer, ECO 5 (Bonn)
von Molgreen (Eigenes Werk) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons
<table>
<thead>
<tr>
<th></th>
<th>20K</th>
<th>77K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>500B</td>
<td>CH-110</td>
</tr>
<tr>
<td><strong>20K</strong></td>
<td>40/50W</td>
<td>-</td>
</tr>
<tr>
<td><strong>30K</strong></td>
<td>80/95W</td>
<td>-</td>
</tr>
<tr>
<td><strong>70K</strong></td>
<td>-</td>
<td>170/180W</td>
</tr>
<tr>
<td><strong>80K</strong></td>
<td>-</td>
<td>180/205W</td>
</tr>
<tr>
<td><strong>Coldhead Dimension</strong></td>
<td>φ108</td>
<td>Φ105</td>
</tr>
<tr>
<td></td>
<td>379</td>
<td>233.1</td>
</tr>
<tr>
<td></td>
<td>25 kg</td>
<td>13.7kg</td>
</tr>
<tr>
<td><strong>Compressor</strong></td>
<td>F70LP</td>
<td>HC-4E1</td>
</tr>
<tr>
<td></td>
<td>(RP-082B)</td>
<td>F-70</td>
</tr>
<tr>
<td><strong>Power (50/60Hz)</strong></td>
<td>7.5/9.0KW</td>
<td>6.8/7.8KW</td>
</tr>
<tr>
<td><strong>COP</strong></td>
<td>0.0056(20K)</td>
<td>0.023(80K)</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>1 year</td>
<td>30,000 hrs.</td>
</tr>
<tr>
<td><strong>Orientation Dependence</strong></td>
<td>Max. 30%</td>
<td></td>
</tr>
<tr>
<td><strong>Regulatory</strong></td>
<td>UL/CE</td>
<td>UL/CE</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>70dBA</td>
<td>70dBA</td>
</tr>
</tbody>
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Manufacturing
Manufacturing Locations

- Manila, Philippines
- Tanashi, Japan
- Allentown, USA
Thank you

Committed to providing the best in Cryogenic Products and Services .... The World`s Leading Supplier of Cryogenic Cooling and Cryogenically Cooled Solutions