

Industrial cooling solutions by Sumitomo

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Sumitomo(SHI) Cryogenics of Europe GmbH

23th & 24th of June 2021
11. Braunschweiger Energieseminaren

- Introduction Sumitomo
- MRI – „industrial“ cooling
- LPC - „cooling tool“ for large magnets
- Ecoswing – dry rotating SC magnet
- High-capacity Single-stage GM Cryocooler
– actual developement
- Service world wide

Sumitomo Company overview

SHI Corporate: 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 : 30,872 million Yen (as of March 31, 2021)

Employees: 24,050 (consolidated) (as of March 31, 2021)

Net Sales: 849,065 million Yen (as of March 31, 2021)

Head Office: Tokyo, Japan

President: Shinji Shimomura



Head Office (Osaki, Tokyo)

[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.

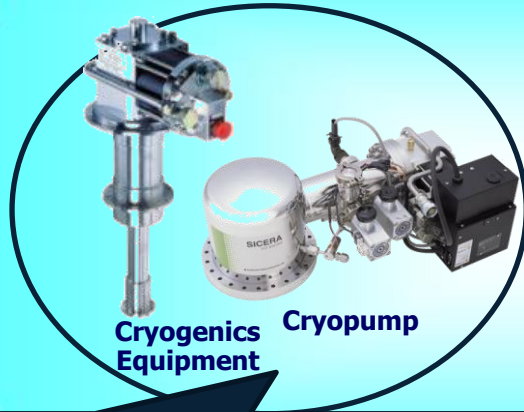
1. Sumitomo shall achieve strength and prosperity by placing prime importance on [integrity and sound management](#) in the conduct of its business.
2. Sumitomo shall manage its activities with foresight and flexibility in order to cope effectively with the changing times. [Under no circumstances, however,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



SHI Corporate: Product Introduction

<By Segment>

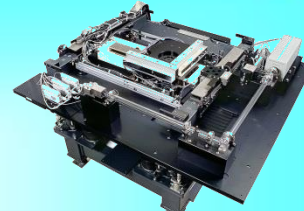
Precision Machinery



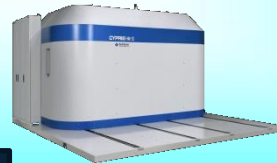
Cryocoolers for Superconductivity (MRI, R&D),
Vacuum application as incorporated into
Cryopumps (Semiconductor)



Proton therapy system



Precision positioning
Equipment



Cyclotron PET



Plastics Injection
Molding Machinery

Machinery Equipment



Power transmission
equipment

Construction Machinery



Hydraulic excavators

Ships



Ships

Industrial Machinery



Logistics & handling
system



Material handling
system



Automated parking
system



Turbines & pumps



Forging press

Environmental Facilities & Plants

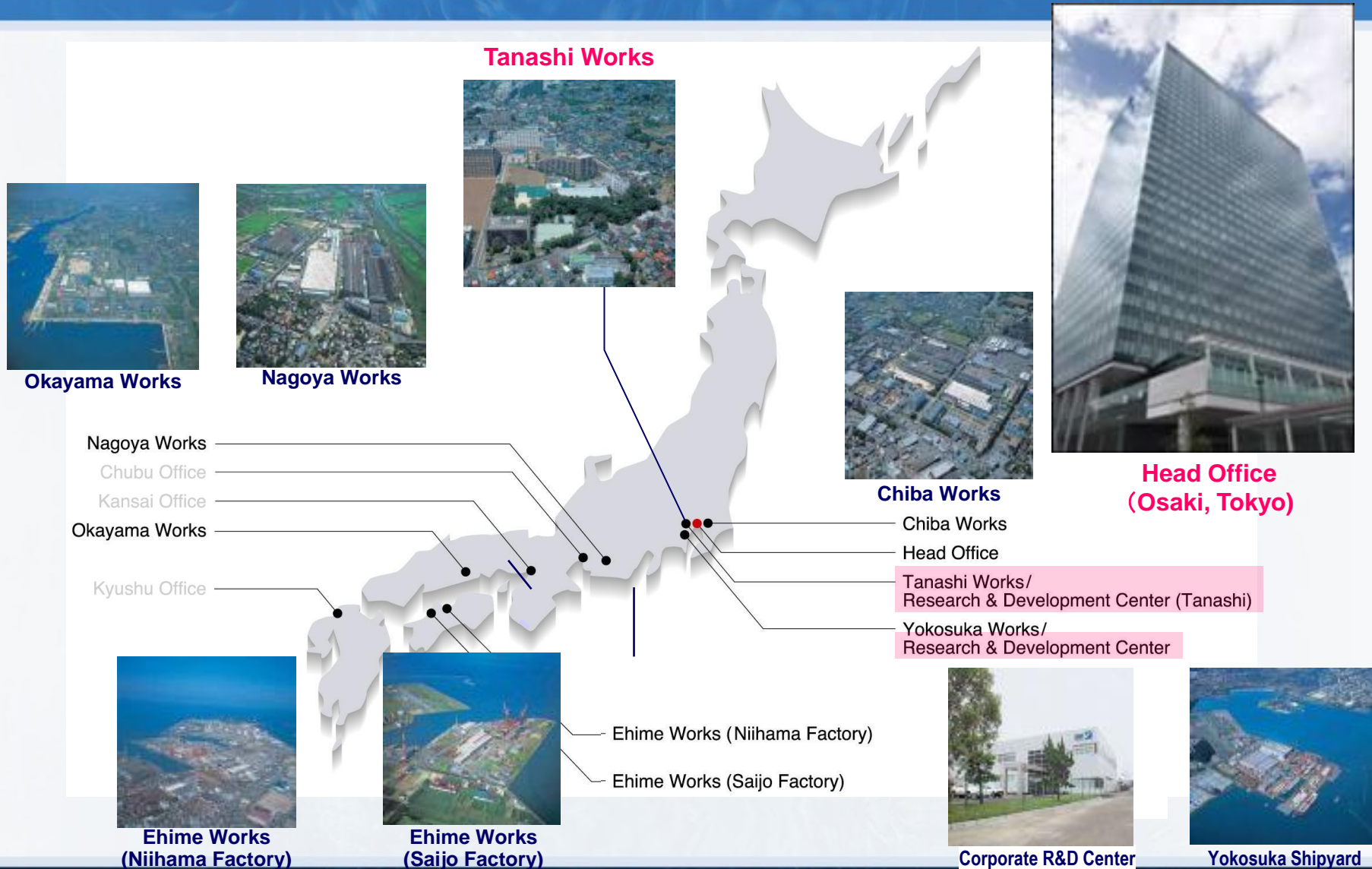


Water treatment
system

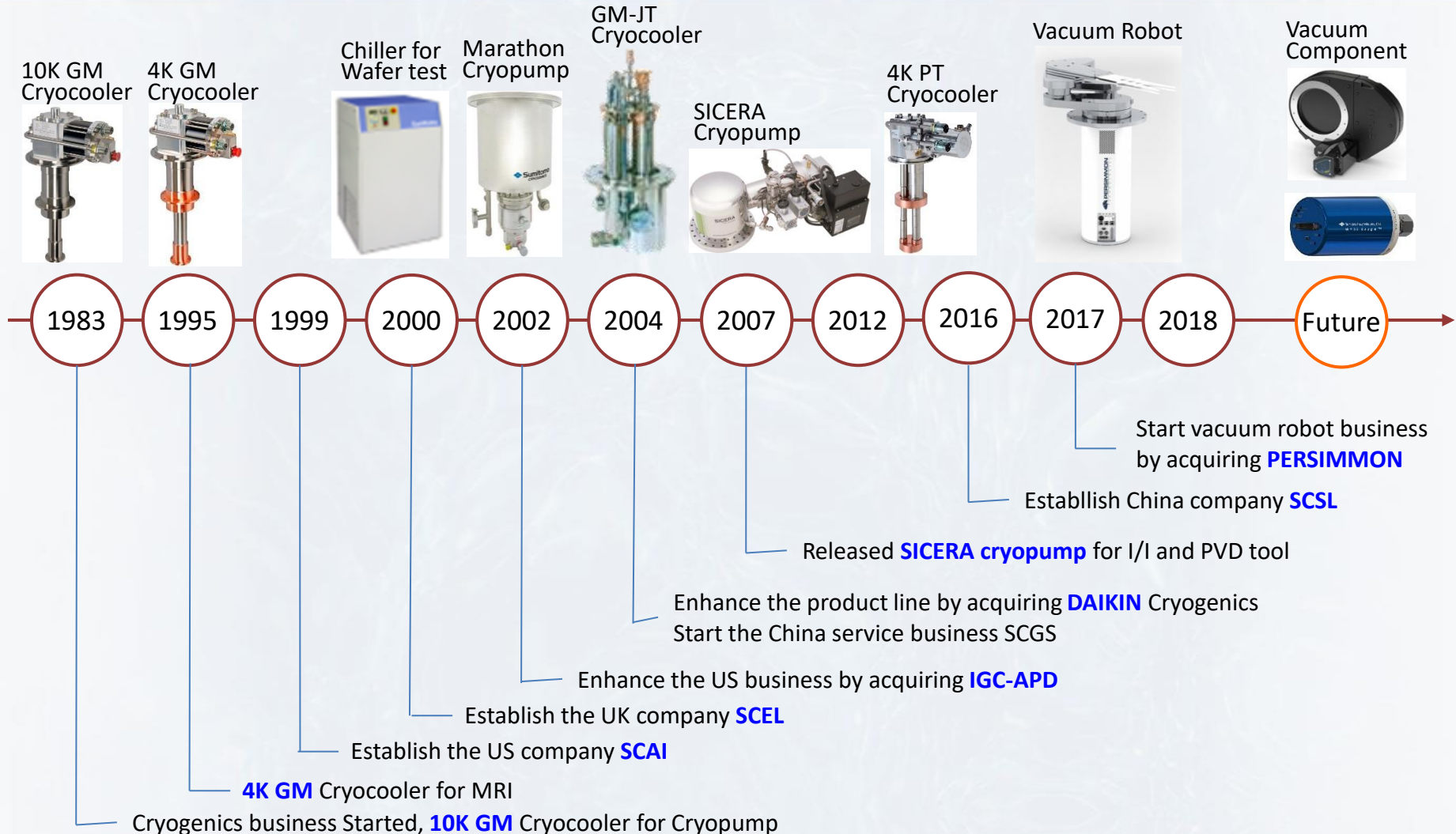


Energy-related
system

SHI Japan Domestic Network



History of SHI Cryogenics Group



Applications of Cryocoolers

【Vacuum】



Vapor Deposition



Ion Implanter
(SEN)



Sputtering
(for semiconductor)



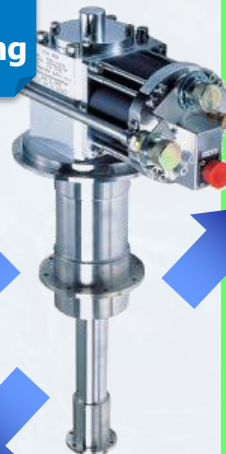
PET Cyclotron
(Quantum Div.)

**Creating 'clean'
ULTRA-high
vacuum
environment**



Cryopump
(UHV pump incorporating
Cryocooler)

**No.1 in
Energy Saving**



Cryocooler

【Cooling】



Gravity Meter
(Kamiokande)



Astronomy (ALMA in Chile)



NMR
(Nuclear Magnetic
Resonance)

•Improve sensitivity
•Environmental test

Cryocooler No.1! 【Superconductivity】



MRI



MCZ magnet
(for silicon wafer)



Magnet for accelerator
(SPRING-8)



Magnetic Separation

**Creating
Superconducting
environment
(-269°C)**



SMES
(Supercon. Magnet energy storage)

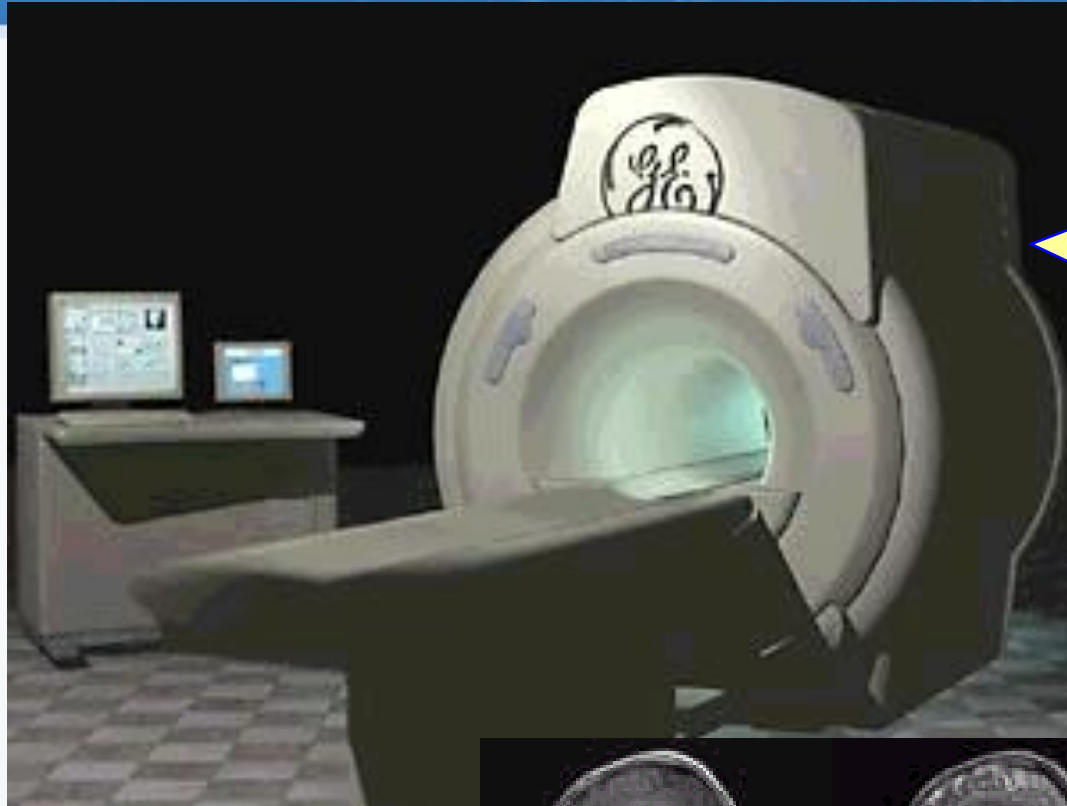
MRI

“industrial” cooling

Why MRI as „industrial“ cooling?

- The MRI systems are mass production
- End-User has no technical background and is just „using“ the systems
- MRI as medical device is planned similar to industrial production -> „uptime“, „throughput“
- Hospitals are like companies profit-orientated -> cost of ownership?

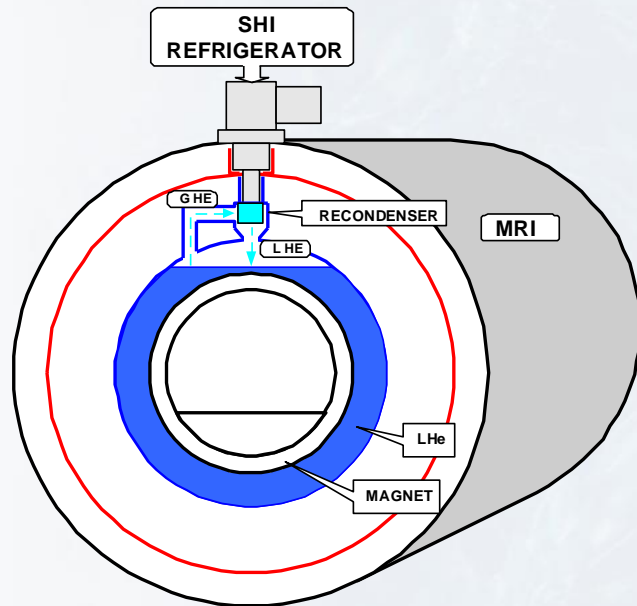
MRI - pictures



4K GM



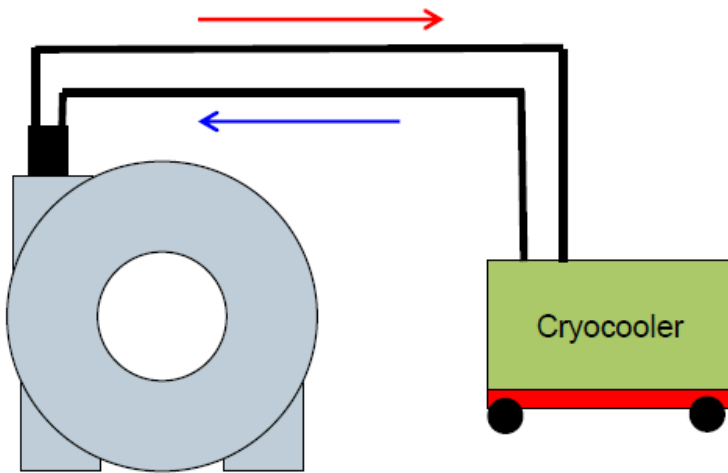
MRI – use of cryocooler



Cold Head Unit (Model: RDK-408D2)

Cooling Cycle	Modified Gifford-McMahon (2-Stage)		
Site Condition	Indoor		
Cooling Capacity (Vertical Position)	1st	40/50W	at 43K (50/60Hz)
	(1st	34/44W	at 40K (50/60Hz))*
	2nd	1.0 W	at 4.2K (50/60Hz)
	* for reference only		
Lowest Temperature	< 3.5 K	-- for reference only	
Cool Down Time (300K to 4.2K, 2nd Stage)	< 60 min.	-- for reference only	
Cooling Capacity Degradation (10,000Hrs.)	< 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%)	

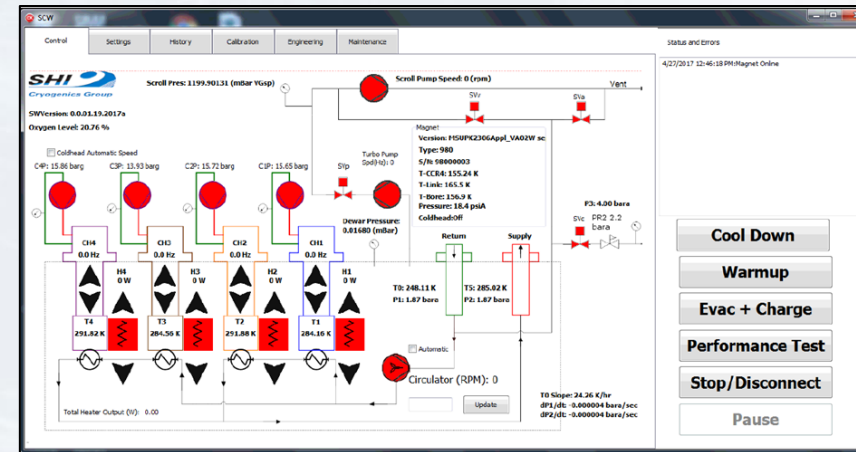
LPC - Low Pressure Cooler



Picture taken from MT25 conference talk presentation:
https://indico.cern.ch/event/445667/contributions/2562070/attachments/1513165/2360399/A_Mortensen_MT25_presentation.pdf

- Pre-cool a SC magnet (like a MRI) without LN₂ just with cold Helium gas
- Save LHe
- Avoid Nitrogen contamination due to LN₂ pre-cooling
- Transportable for multiple use cases

LPC – pictures and description

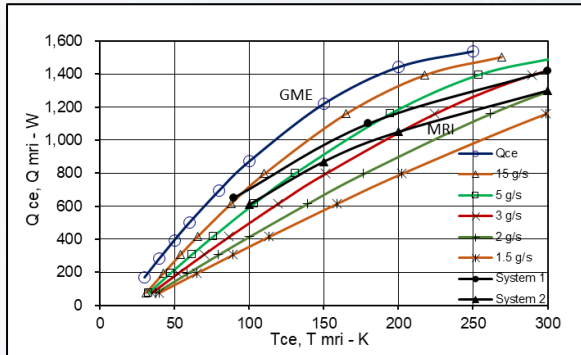


Mobile Cryogenic System Benefits:

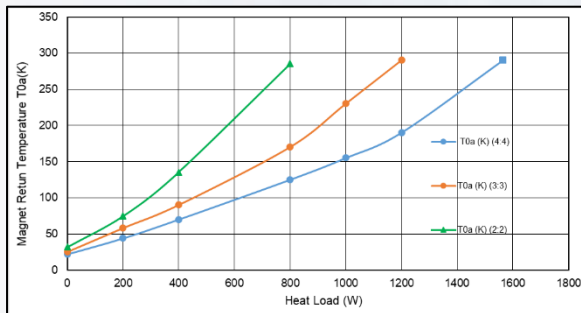
- Conservation of helium
- Warm shipment of MRI magnets
- Reduce cryogen expense
- Reduce cryogen handling on site
- Onsite maintenance
- Reusable shipping containers
- Ergonomically designed for ease of handling
- Control console with automatic and manual controls

For more information refer to Gandla S K, Longworth R C, "Mobile refrigeration system for precool and warm up of superconducting magnets", *Advances in Cryogenic Engineering: Proceedings of the Cryogenic Engineering Conference (CEC) 2017*, Vol. 278, 012179
[MT25 Conference 2017 - Timetable, Abstracts, Orals and Posters \(27 August 2017 - 1 September 2017\): Hub- and Site-cooling of MRI magnets using a mobile cryogenic system - Indico \(cern.ch\)](#)

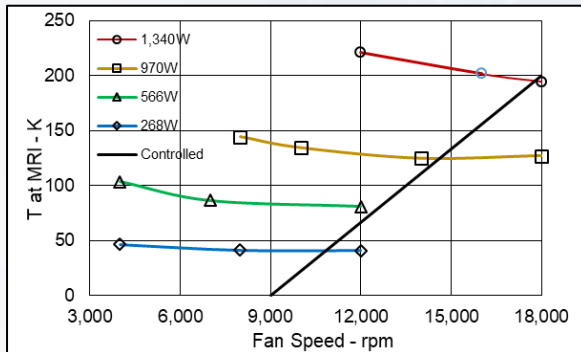
LPC – technical data



- The figure depicts capacity at the expander (GME) and capacity at the MRI cryostat for different circulation flow rates. The capacity with 2 g/s and 3 g/s initial flow rates at constant circulator speed are superimposed.
- The current system design has prioritized lower temperatures over reduced cool down cycle time.
- Circulating gas to cool the device results in less cooling available at the device cryostat when compared to refrigeration produced by expanders
- Refrigeration reduction: temperature change in gas, heat input from circulator, thermal losses in piping and transfer lines



- Minimum temperatures
 - 4 expanders = 22K
 - 3 expanders = 25K
 - 2 expanders = 32K
- System redundancy with multiple expanders
- Exact Configurations based on application requirements



- The figure depicts tests at constant heat loads, variable fan speeds, 220 kPa absolute pressure
- High fan speeds circulate gas at higher rate, and add more heat of compression than lower speeds
- Minimum temperature for given load at optimum fan speed
- User adjustable program based on application requirements

EcoSwing

EcoSwing - overview



Official EU homepage: <https://ec.europa.eu/inea/en/horizon-2020/projects/H2020-Energy/Wind/EcoSwing>

- Make SC turbine to reduce size and weight
- Exchange at existing turbine
- Direct cooled coils – no liquid
- Field experience with real operation (~6 month) at 3+ MW

EcoSwing - cooling



Power Supply	50 Hz	60 Hz
1st Stage Capacity	40 W @ 20 K	45 W @ 20 K
	80 W @ 30 K	94 W @ 30 K
Minimum Temperature¹	<14 K	
Cooldown Time to 40 K¹	<70 Minutes	
Weight	25.0 kg (55.1 lbs.)	
Dimensions (HxWxD)	570 x 180 x 325 mm (22.4 x 7.1 x 12.8 in.)	
Maintenance	8,760 Hours	
Regulatory Compliance	CE, UL/cUL	

Ecoswing used nine RDK-500B supplied via one rotory joint assembly bundling the nine F-70H compressors – gas distributed again within the turbine to each cryocooler.

High-capacity Single-stage GM Cryocooler – actual developement

Large single stage GM - Conceptual Design

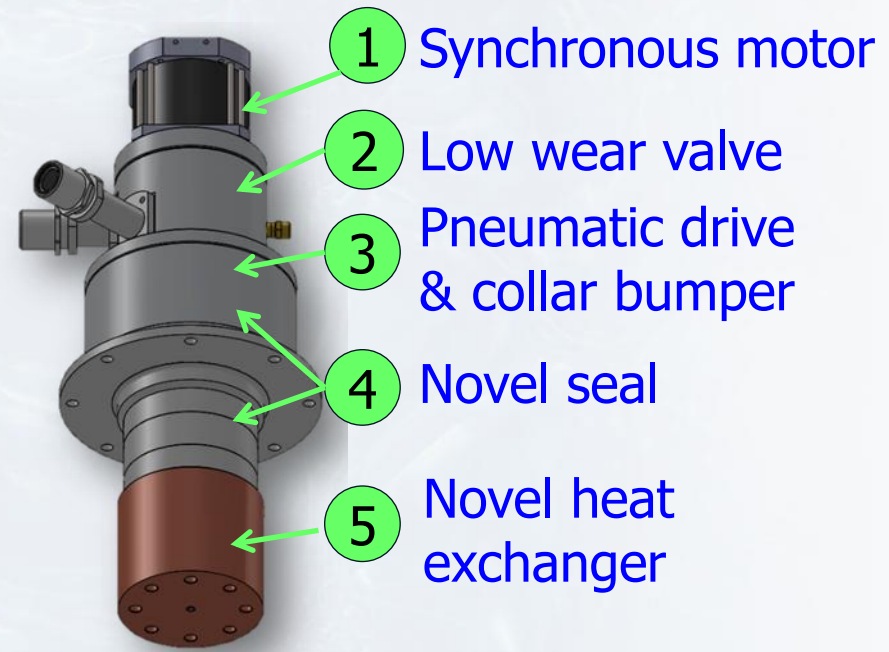
1 Synchronous motor like SHI RDE-412 1.2 W 4 K G-M cryocooler to reduce noise

2 Novel gas balanced low wear valve to extend maintenance interval

3 Novel pneumatic drive and large collar bumper to reduce vibration and knocking noise

4 Novel seal structure to extend maintenance interval

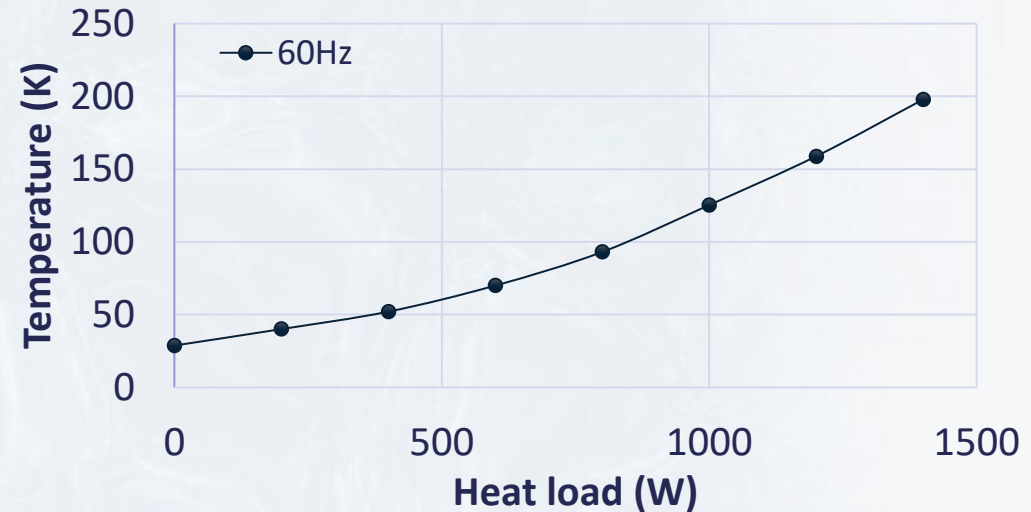
5 Novel heat exchanger to improve the efficiency



Dimension

Housing/Motor	358.2
Cylinder	229.0
Total	587.2

Large single stage GM - Results

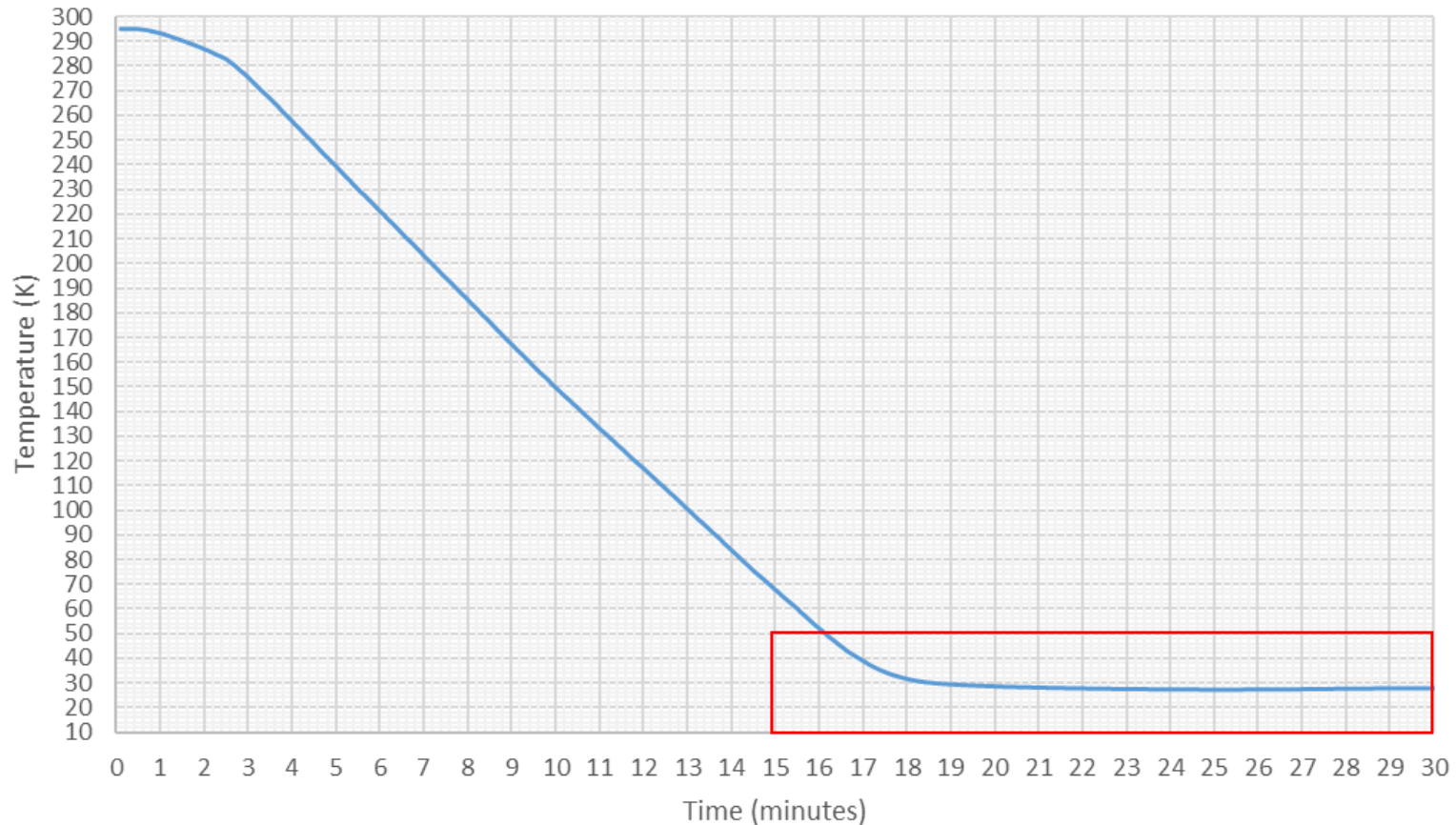


Results

- Designed, built and tested prototype units
- Achieved a no load temperature of <30 K and a typical cooling capacity of **600W at 71 K** with an input power of <14 kW (60Hz)

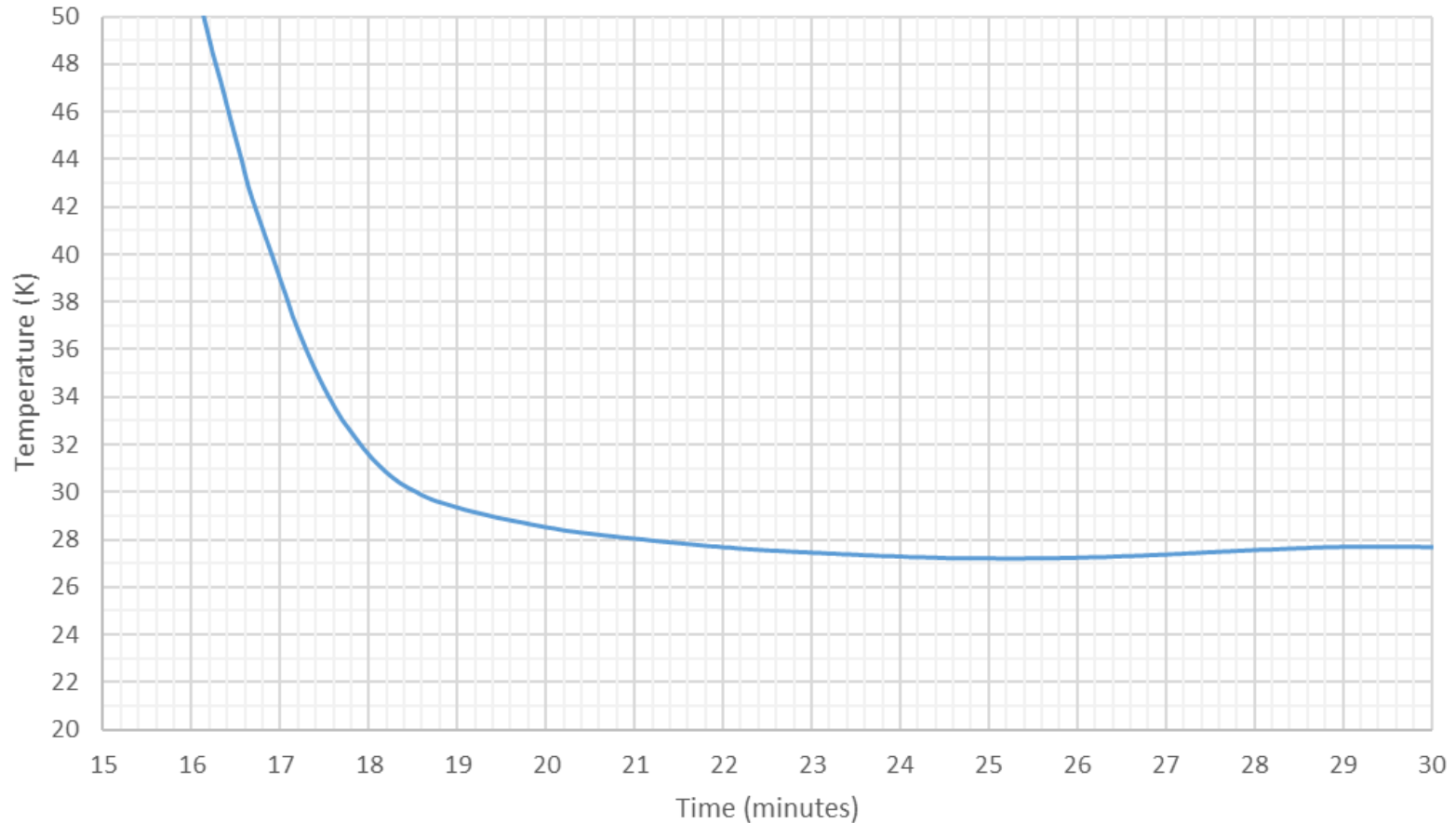
Large single stage GM - Results

Typical Cooldown of 600W High Capacity GM



Large single stage GM - Results

Typical Cooldown of 600W High Capacity GM



Large single stage GM ->Future Development

- Low Pressure Cooler Consolidation
 - Utilize High Capacity Single-Stage G-M Cryocooler to consolidate required number of compressors and coldheads needed to support LPC operation.
 - Coldhead/compressor reduction should reduce from 6 carts to 1-2 carts, greatly reducing tool footprint
- Low Temperature (LT) Single-stage G-M Cryocooler
 - Develop G-M cryocoolers having a capacity of >100 W at 20 K for HTS
 - Continue to improve the process capability and reliability
- Rapid Cooldown System
 - Combine LPC & LT Single-stage G-M cryocooler technology to aid in rapid cooldown of high-pressure, high thermal mass systems.

Service world wide

Synergy in global footprint



SHI: *Serving global customers in semiconductor* and other applications (medical, research, etc.)

- Japan: *Center of all functions* (R&D, Manufacturing, etc.)
- US: Coverage *major semi. customers* (Santa Clara, San Diego, Austin, Allentown and Malta)
- Taiwan, Korea: Supporting one of the *largest semi. end users*
- China: Based in *Shanghai* to support emerging market in all industries.
- Europe: Based in *UK and Germany* to support entire European market
- Philippines: Center of *low cost manufacturing*
- Boston: *Newly joined to provide vacuum robotics in semiconductor market utilizing all the existing network*

4

R&D, Applications, Mfg,
Service and Sales

10

Sales and Service
(Tech. support)

1

Manufacturing



Sumitomo Heavy Industries, Ltd.

**Thank you to the engineering team in
Allentown and Tanashi for their input for this
presentation.**

Thank you



**Committed to providing the best in
Cryogenic Products and Services The
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Cooling and Cryogenically Cooled Solutions**