Tutorial Kältetechnik

ZIEHL VII
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Darmstadt

Übersicht

SHI Cryogenics Group

- Sumitomo (Cryogenics)
- Grundlagen
  - Temperaturskala
  - Thermodynamische Prozesse
  - Technische Umsetzung
- Anwendungen
  - Medizintechnik
  - Industrie
  - Forschung
- Überblick

Sumitomo Heavy Industries

SHI Cryogenics Group

Machinery Components

Power transmission and control equipment Inverters

Precision Machinery

Plastic injection molding machines
Cyclotrons
Plasma Coating System for FPD
Cryogenic Systems
Laser Processing Systems
XY Stages
Precision Forgings

Construction Machinery

Hydraulic excavators
Mobile cranes
Road machinery

Industrial Machinery

Forging machines
Material handling systems
Logistics & handling systems
Forklifts

Ships

Ships

Environmental Facilities/Plants

Industrial Wastewater Systems
Boilers for Power Generation
Turbines
Pumps
Clean Room System

- Net Sales: 8293 Mio. $ in 2018 (as of March 31, 2019)
- Capital: 284 Mio. $ (as of March 31, 2019)
- Emloyees: 21017 (consolidated) (as of March 31, 2019)

History of SHI Cryogenics Group

SHI Cryogenics Group

10K GM Cryocooler

4K GM Cryocooler

Chiller for Wafer test

Marathon Cryopump

GM-JT Cryocooler

SICERA Cryopump

4K PT Cryocooler

Vacuum Robot

Vacuum Component

1983 – 1995 – 1999 – 2000 – 2002 – 2004 – 2007 – 2012 – 2016 – 2017 – 2018 – Future

- **2017**: Start vacuum robot business by acquiring **PERSIMMON**
- **2016**: Establlish China company **SCSL**
- **2007**: Released **SICERA cryopump** for I/I and PVD tool
- **2004**: Enhance the product line by acquiring **DAIKIN** Cryogenics; Start the China service business SCGS
- **2002**: Enhance the US business by acquiring **IGC-APD**
- **2000**: Establish the UK company **SCEL** and in Germany **SCEG**
- **1999**: Establish the US company **SCAI**
- **1995**: **4K GM** Cryocooler for MRI
- **1983**: Cryogenics business Started, **10K GM** Cryocooler for Cryopump

Global Network

2	R&D, Applications, Mfg, Service and Sales	5	Applications, Service and Sales	2	Service And Sales	1	Mfg

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Temperaturskalen

- Grad Fahrenheit [°F]
  1,8°F entsprechen 1K
  T_{min} über Wasser/Eis/Salmiak Mischung
  T_{max} über Körpertemperatur
- Grad Celsius [°C]
  1°C entsprecht 1K
  T_{min} über Gefrierpunkt Wasser
  T_{max} über Siedepunkt Wasser
- Kelvin [K]
  T_{min} = 0 K, kein T_{max}

Typische Temperaturen

°C	Kelvin
27	300
10	
0	273
-20	
-40	
-70	
-100	
-140	
-162	
-196	77
-250	20.5
-269	4.2
-271	2.1
-272	1
-273	0

Ice (0°C)

Siberia Minimum observation temperature (-64.6°C)

Dry Ice (-78°C)

LN2 (-196°C)

LH2 (-253°C)

LHe (-269°C)

Low temperature

Very low temperature

Extremely low temperature

Typical temperature range of Cryocooler products

Absolute zero degree

Thermodynamische Prozesse

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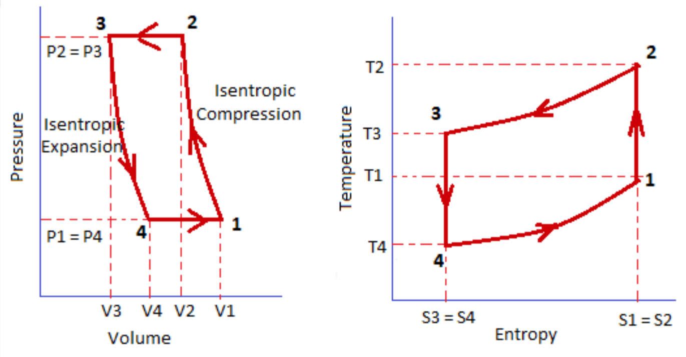
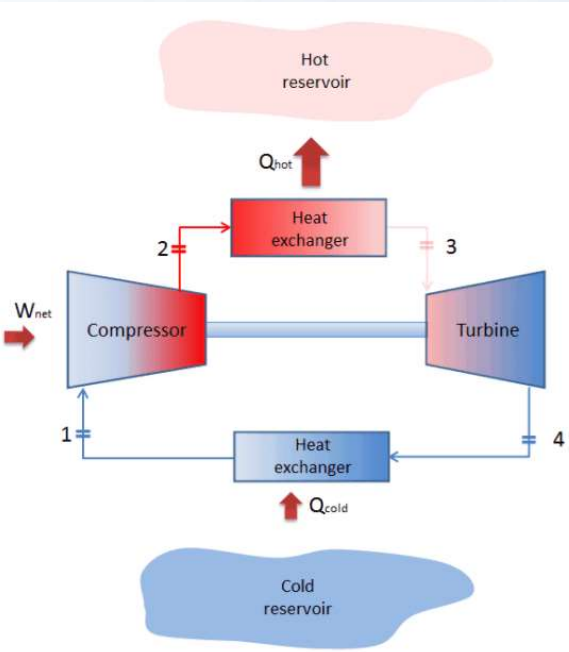
Ausgewählte thermodynamischer Kreisprozess

- Brayton
  - George Brayton, USA, 1830 – 1892
  - Kühlung => „reverse Brayton“ => Bell Coleman cycle
- Stirling
  - Robert Stirling, GB, 1790 – 1878
  - Philips(ab 1940 erste Produkte)
- Gifford-McMahon
  - W. Gifford & R. C. Longsworth, 1963
- Pulse tube

Brayton



(a) P-V Diagram (b) T-S Diagram



1-2: Isentropic Compression
The air drawn from the refrigerator to air compressor cylinder where it compressed isentropically (constant entropy). No heat transfer by the air. During compression, the volume decreases while the pressure and temperature of air increases.

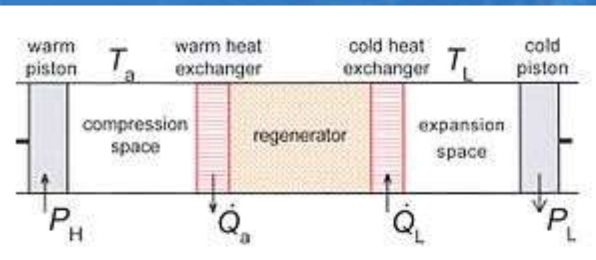
2-3: Constant pressure cooling process
The warm compressed air is then passed through cooler, where it cooled down at constant pressure.

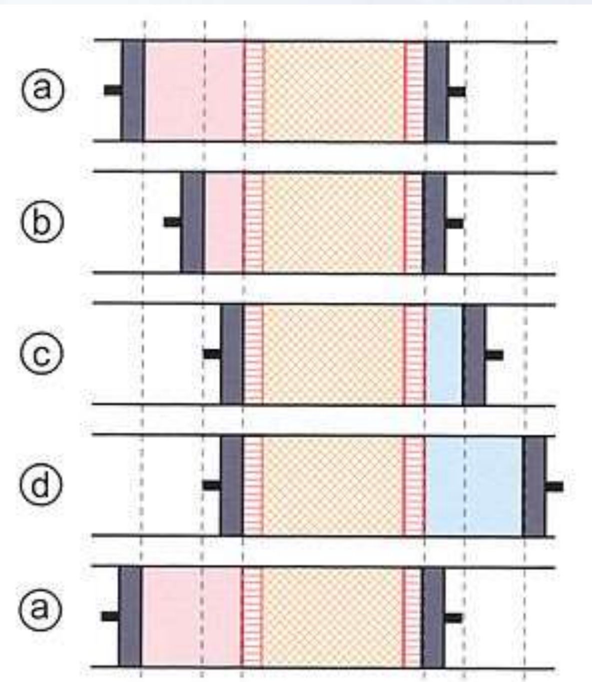
3-4: Isentropic expansion
No heat transfer takes place. The air expands isentropically in expander cylinder. During expansion, the volume increases, Pressure P3 reduces to P4. Temperature also falls during expansion from T3 to T4.

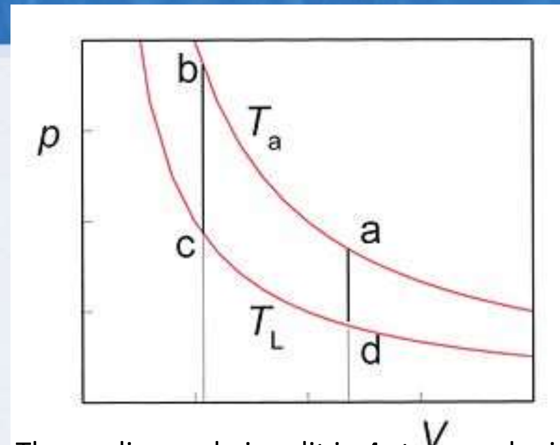
4-1: Constant pressure expansion
Heat transfer from the refrigerator to air. The temperature increases from T4 to T1. Volume increases to V1 due to heat transfer.

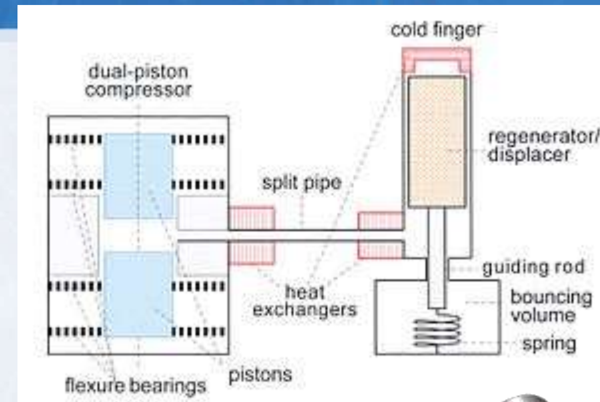
Source: www.ques10.com article “bell-coleman-cycle”

Stirling









The cooling cycle is split in 4 steps as depicted in Fig. left.
The cycle starts when the two pistons are in their most left positions:

From a to b. The warm piston moves to the right while the cold piston is fixed. The compression at the hot end is isothermal (by definition), so heat Qa is given off to the surroundings at ambient temperature Ta.

From b to c. The two pistons move to the right. The volume between the two pistons is kept constant. The hot gas enters the regenerator with temperature Ta and leaves it with temperature TL. The gas gives off heat to the regenerator material.

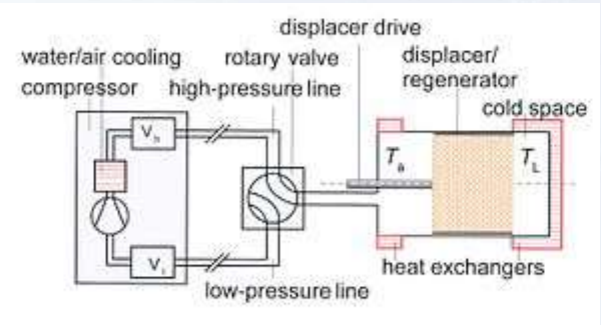
From c to d. The cold piston moves to the right while the warm piston is fixed. The expansion is isothermal and heat QL is taken up. This is the useful cooling power.

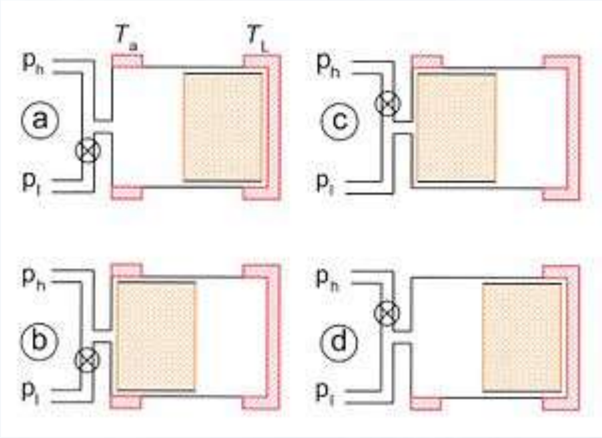
From d to a. The two pistons move to the left while the total volume remains constant. The gas enters the regenerator with low temperature TL and leaves it with high temperature Ta so heat is taken up from the regenerator material.

At the end of this step the state of the cooler is the same as in the beginning.

Source: Wikipedia, Article Cryocoolers

Gifford-McMahon





The cycle starts with the low-pressure (lp) valve closed, the high-pressure (hp) valve open, and the displacer all the way to the right (so in the cold region). All the gas is at room temperature.

From a to b. The displacer moves to the left while the cold head is connected to the hp side of the compressor. The gas passes the regenerator entering the regenerator at ambient temperature Ta and leaving it with temperature TL. Heat is released by the gas to the regenerator material.

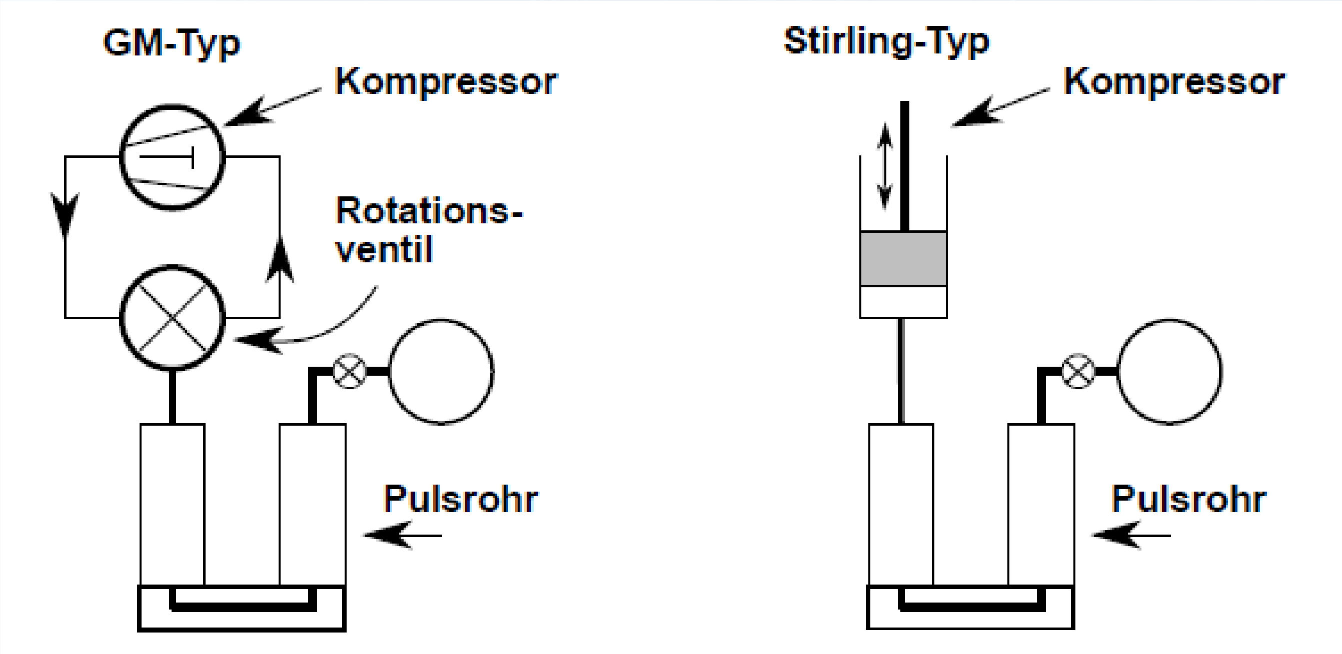
From b to c. The hp valve is closed and the lp valve opened with fixed position of the displacer. Part of the gas flows through the regenerator to the lp side of the compressor. The gas expands. The expansion is isothermal so heat is taken up from the application. This is where the useful cooling power is produced.

From c to d. The displacer moves to the right with the cold head connected to the lp side of the compressor forcing the cold gas to pass the regenerator, while taking up heat from the regenerator.

From d to a. The lp valve is closed and the hp valve opened with fixed position of the displacer. The gas, now in the hot end of the cold head, is compressed and heat is released to the surroundings. In the end of this step we are back in position a.

Source: Wikipedia, Article Cryocoolers

Pulsrohrkühler



- Keine bewegten Teile im Kaltkopf
- Geringerer Verschleiß
- Längere Wartungszyklen

Technische Realisierung Brayton

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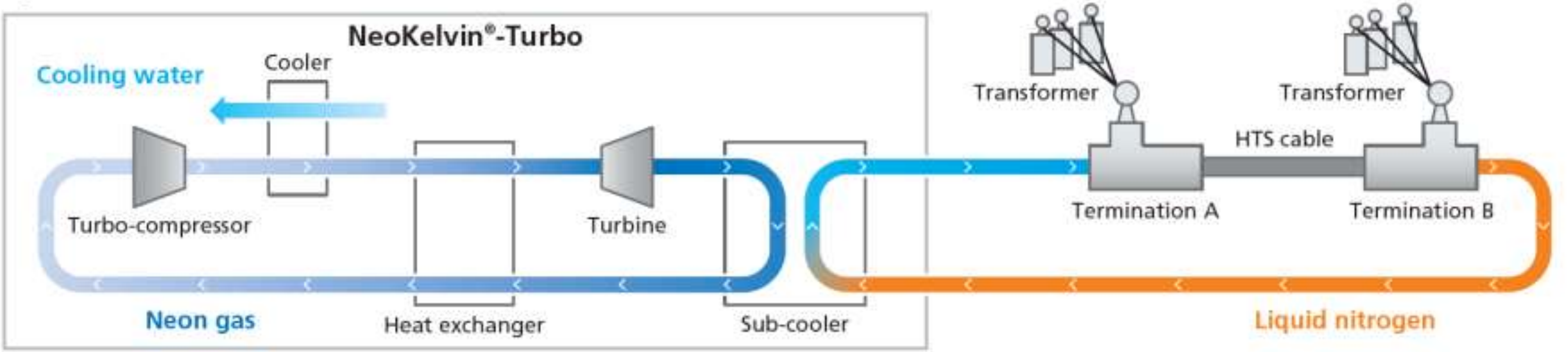
System Flow



NeoKelvin®-Turbo 10kW

For commercial scale of HTS application

Cooling Capacity	10 kW
Cooling Temperature	70 K
Power Supply	φ3, AC 400 or 380V
Input Power	170 kW
Cooling Water	750 L/min
Size	W:7.0 H:3.0 D:4.0 (m)

kagaku.com

Technische Realisierung Stirling

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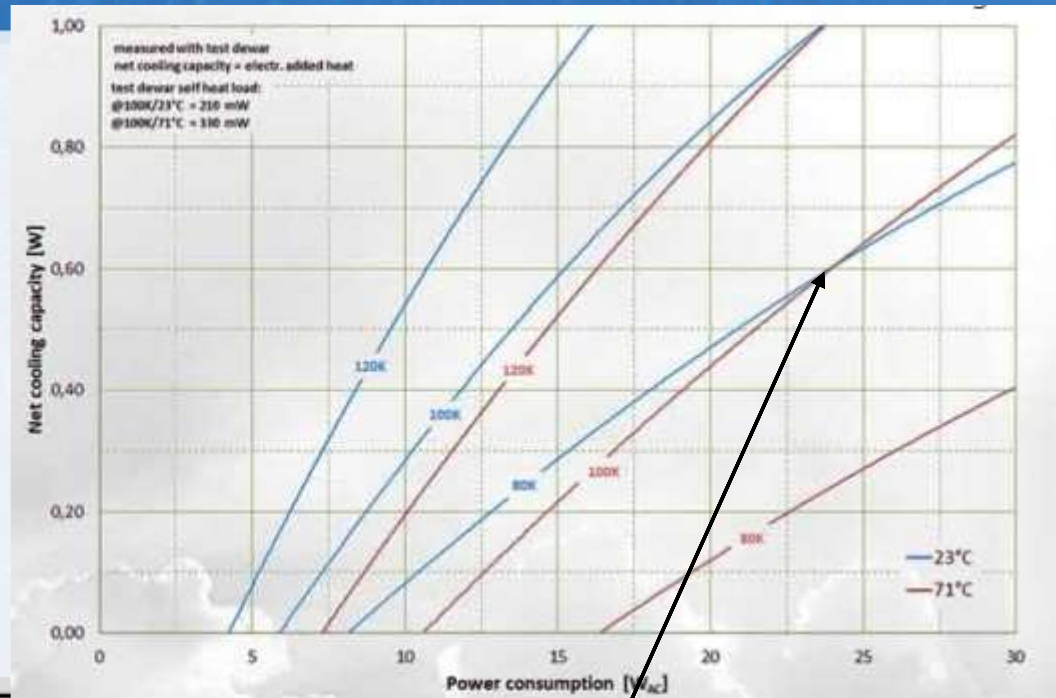

Typical power 0.6W@80K

	SF070
Compressor diameter [mm/in]	44 / 1.73
Compressor length [mm/in]	113 / 4.45
Compressor weight [g/lb]	850 / 1.87
Supply voltage [V_{AC}]	5 - 15
Cooler Controller	µDCE050 / DCE100
Ambient temperature range [°C]	-54 to +80
Suitable coldfinger / dewar diameter	6mm, 8mm, 9mm

www.aim-ir.com

Technische Realisierung GM

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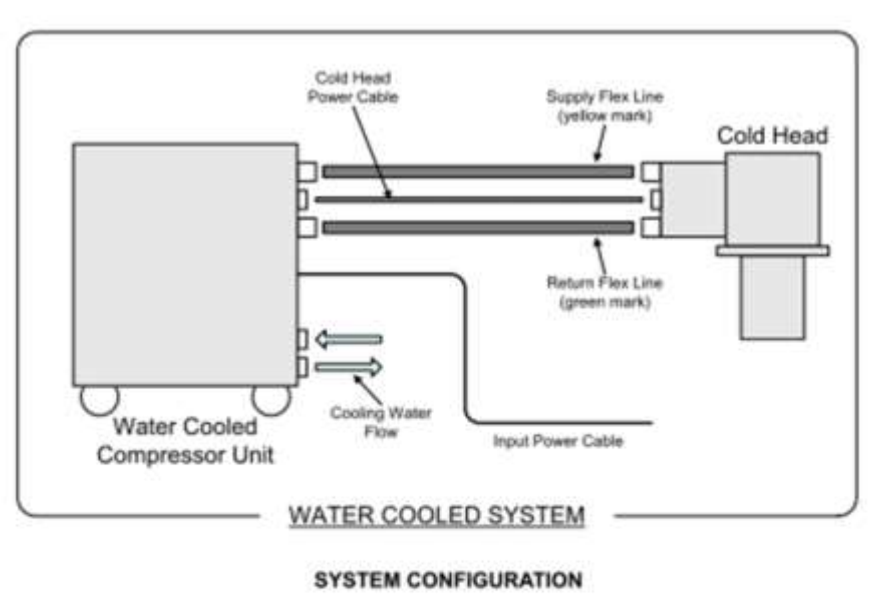

Cryocooler	CH-110
Cooling Capacity (50/60Hz)	170/180W@70K 180/205W@80K
Power consumption (50/60Hz)	6.8/7.8kW

F-70LP Compressor
(443W x 588D x 532H, 120kg)

CH-110 Coldhead
(13.7kg)

Technische Realisierung PTR

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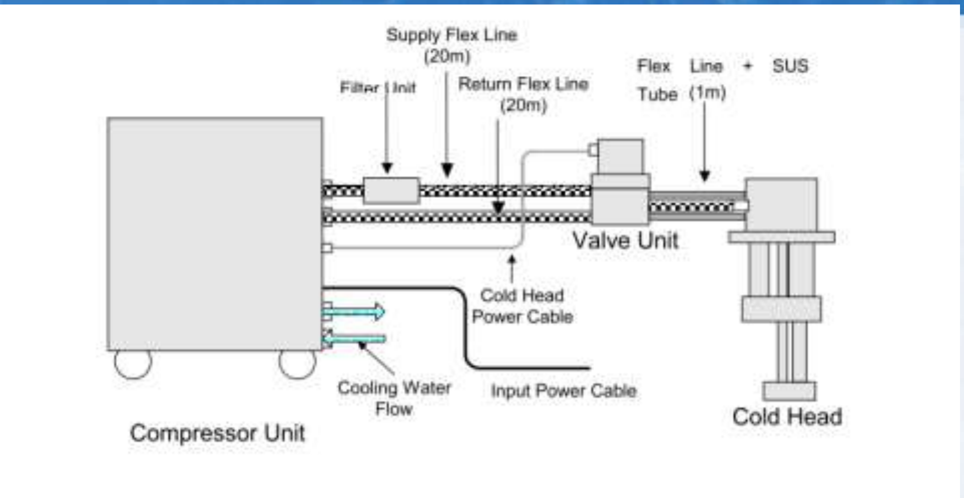

Figure 1.1 SRP-082B2S (VU Separate Type) CRYOCOOLER SYSTEM


RP-082B2S Coldhead
(13.7kg)

F-70LP Compressor
(443W x 588D x 532H, 120kg)

Cryocooler	SRP-082B2S
Cooling Capacity (50Hz)	1st: 35W@45K 2nd: 0.9W@4.2K
Power consumption (50Hz)	6.8kW

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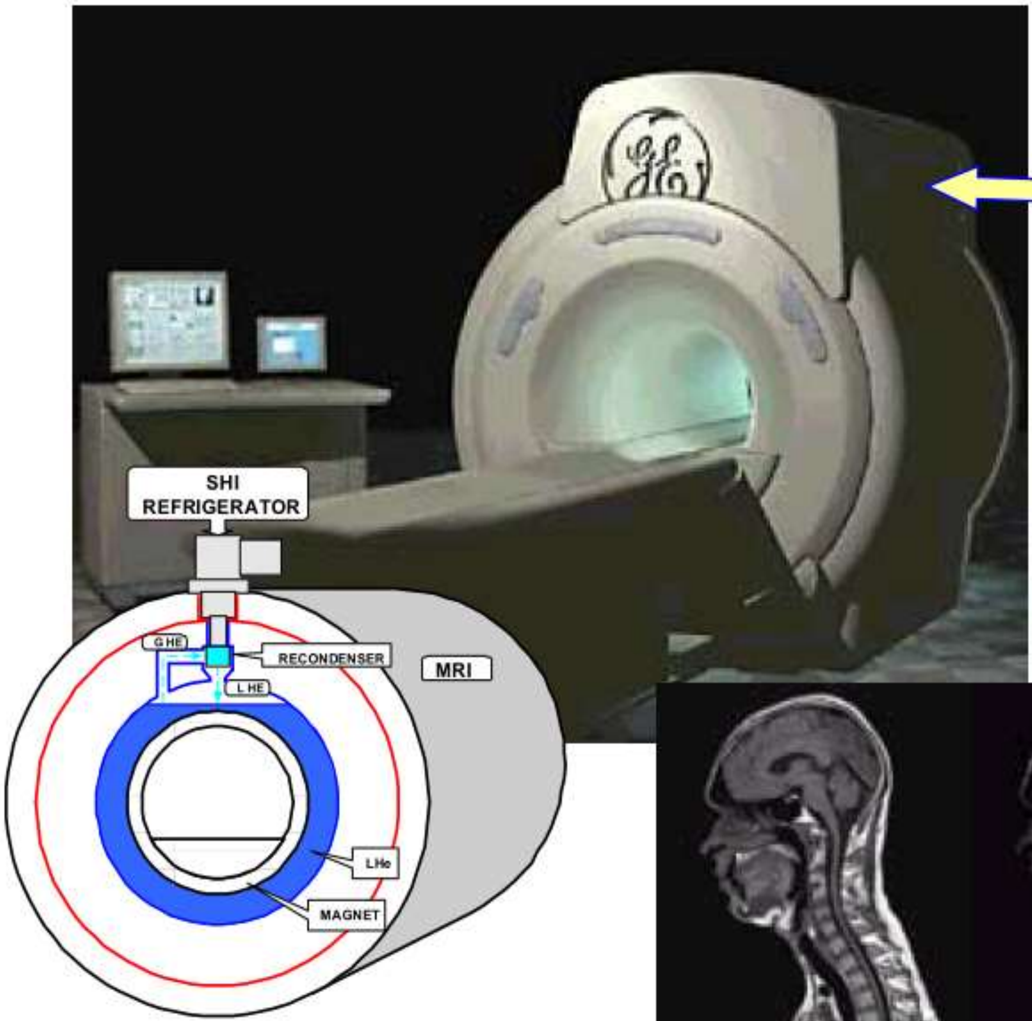
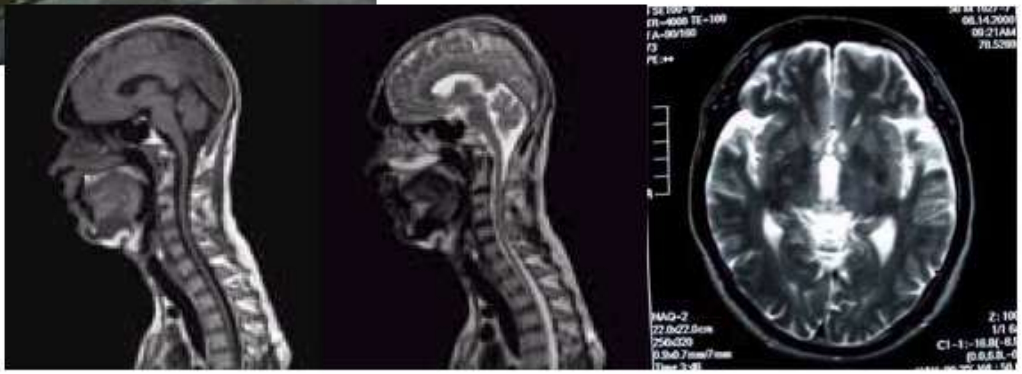
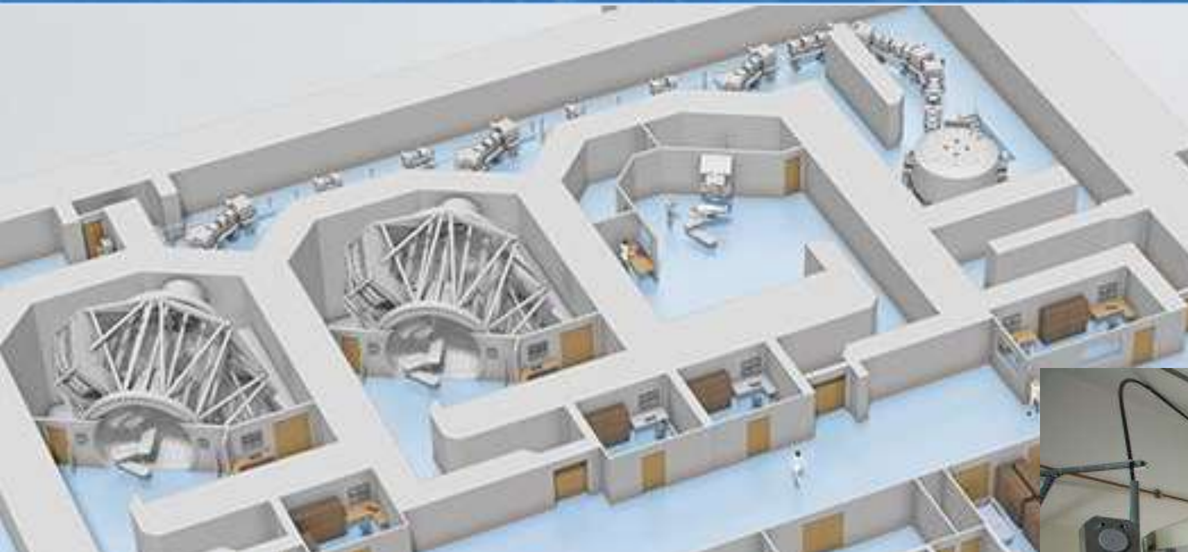
MRI



4KGM cryocooler



Proton Therapy



Proton therapy complex with one cylotron and two treatment rooms.

Source: iba-worldwide.com/proton-therapy

Measurement systems

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Application

NMR/EPR, Optical Spectroscopy

Optical Microscopy, Resistivity

X-Ray Diffraction, Large Samples

Ultra High Vacuum, Magnetic Susceptibility

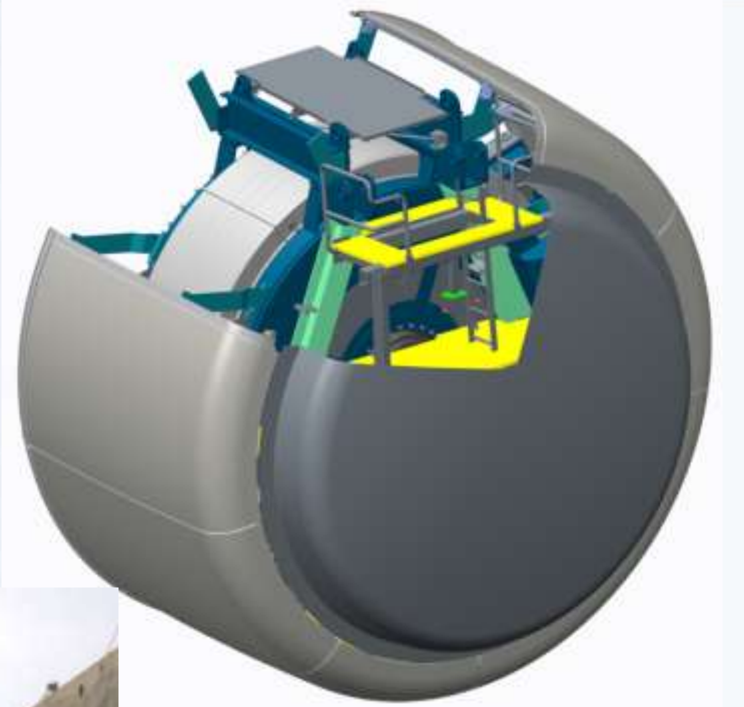
UHV Manipulators, Mossbauer

CryoProbe™500-600

Courtesy by Bruker Japan

900 MHz TXI CryoProbe™

HTS generator (ECOSWING)



Sourse:
ICEC 2018 Oxford
plenary talk 5
(Markus Bauer)

Astronomy

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SUBARU Telescope – NAOJ

Mauna Kea, HAWAII

(Optical IR Telescope)

Courtesy by NAOJ

Large Research Facilities

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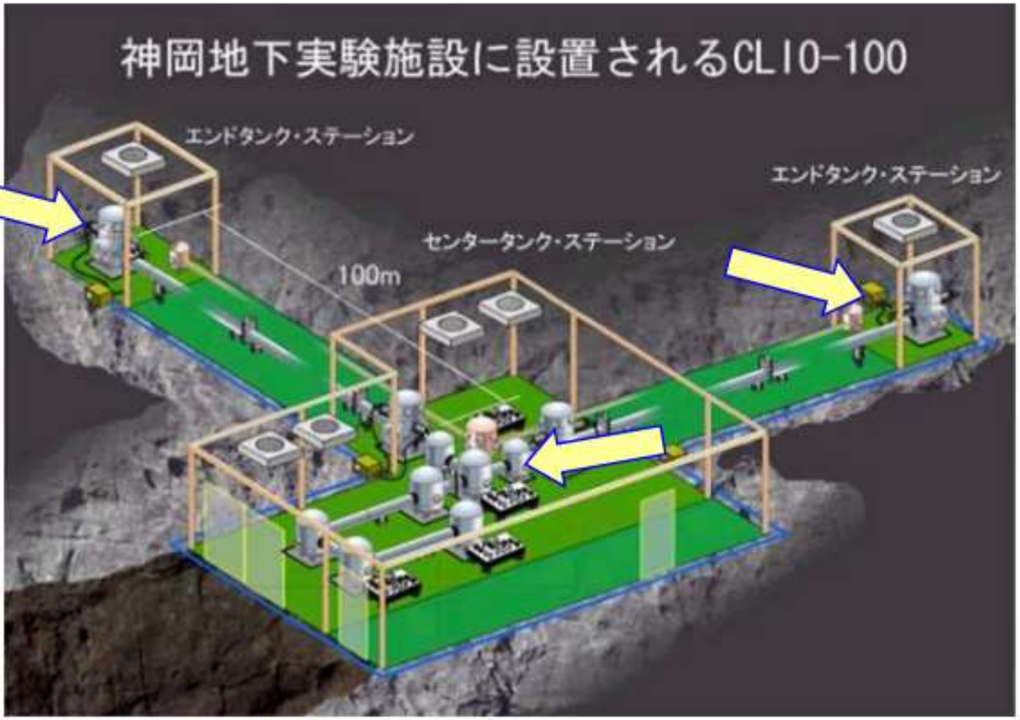
Pulsetube Cryocooler



Gravitational Wave Telescope
(Kamiokande)

Customized Cryostats

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Cryocoolers: typical install fields

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【Vacuum】

Vapor Deposition

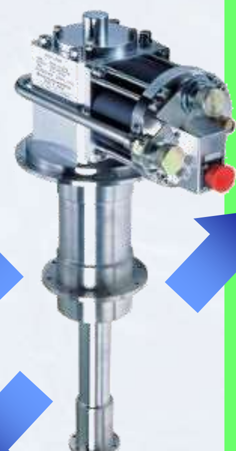
Ion Implanter
(SEN)

Sputtering
(for semiconductor)

PET Cyclotron
(Quantum Div.)

Cryopump
(UHV pump incorporating Cryocooler)

Creating 'clean' ULTRA-high vacuum environment



Cryocooelr

【Superconductivity】

MRI

MCZ magnet
(for silicon wafer)

Magnet for accelerator
(SPring-8)

Magnetic Separation

Creating Superconducting environment (※-269°C)

SMES
(Supercon. Magnet energy storage)

【Cooling】

Gravity Meter
(Kamiokande)

Astronomy (ALMA in Chile)

NMR
(Nuclear Magnetic Resonance)

- **Improve sensitivity**
- **Environmental test**

THANK YOU