Introduction

German representative
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Product range

SPC-1(T) Cryogenerator

- **SPC-1**
  - 1000 W @ 77K
  - 700 W @ 67K
  - Power consumption: 12kW

- **SPC-1T**
  - 75W @ 20K
  - 130W @ 30K
  - Power consumption: 12kW
Product range

SPC-4(T) Cryogenerator

- SPC-4
  - 4000 W @ 77K
  - 2800 W @ 67K
  - Power consumption: 48kW

- SPC-4T
  - 300W @ 20K
  - 550W @ 30K
  - Power consumption: 48kW
Stirling thermodynamic cycle

- Gas in
- Condenser head (cold)
- Regenerator
- Gas cooler
- Compression space
- Liquid out
- Displacer
- Expansion space
- Non-condensables
- Piston
Stirling thermodynamic cycle
HTS Cooling concepts
Re-liquefaction (1)

- The application is immersed in boiling liquid
- For applications where:
  - there is sufficient cooling by natural flow
  - the boil-off gas will easily collect at the top of the application cryostat
  - E.g. FCL, transformers, test cryostats
HTS Cooling concepts
Re-liquefaction (2)

- The Cryogenerator re-liquefies the boiling gas, which drains back into the cryostat

- By controlling the pressure (capacity control on the cryo) the temperature can be set
HTS Cooling concepts
Re-liquefaction (2)

Boiling point of cryogenic Nitrogen

\[ P \text{ (Bar)} \]

\[ T \text{ (K)} \]
HTS Cooling concepts
Sub-cooled LN$_2$ / Forced flow (1)

For applications where:
- Sub-cooled LN$_2$ needed
- Not sufficient cooling by natural flow

E.g.:
- Cables
- Instrumentation
HTS Cooling concepts
Sub-cooled LN2 / Forced flow (2)

System consist of 2 loops:
- Low pressure loop of boiling LN$_2$ re-liquefaction through the cryogenerator
- High pressure loop of sub-cooled LN$_2$ through the cable, pump and pressure build up system
HTS Cooling concepts
Helium gas circulation (1)

- Circulation of He(g) to transport the cold from the cryogenerator to the application

- For applications where:
  - Low temperature (20/30K) and/or He is needed
  - Heat transfer by direct contact to a cold head is not an option or not preferred (vibration)
  - Cryocooler can not be near the application.

- E.g. motors & generators
HTS Cooling concepts
Helium gas circulation (2)

System can also provide a second loop (1\textsuperscript{st} stage) of 80K gas for shielding

Cryogenic Helium gas fan
Reliability/Maintenance
Stirling Cryogenerator

- Proven technology
- Highly reliable
- MTBM: 6,000 hours
- Takes 0.5 – 1 day of (trained) own people
- Stirling systems have been operating since the 1950’s, some still in operation
Reliability/Maintenance
Stirling Cryogenerator

- Uptime around 99%
- Back up can/will be provided by redundancy and/or smart design (modular build up)
- Assume that everything can/will breakdown
Reliability/Maintenance
Stirling Cryogenerator

- Make sure that there is always redundancy or “a way out”
- This also applies to the five Euro fuse (design the system in such a way that it does not need to depend on it!)
- This does not necessarily mean that everything has to be double/triple!
Reliability/Maintenance
Smart design / redundancy

20-32kW cooling system for the INFR Icarus project:
- (smart) redundancy
- 100% uptime for 10 years

1st line of technical support, service and maintenance is provided by customer’s own engineers
Scientific: ICARUS
Developments
HTS Market demand

New generation cryo coolers
- Low or Zero maintenance
- 100% uptime
- High efficiency
- Low vibration
- Orientation independent
CryoSphere™

- Under development (~2011/2012)
- Initial 200W @ 77K
- Also a 20K Version
- Oil free – Maintenance free
Introduction to CryoZone

- Founded in 2005 as split off from Stirling Cryogenics
- Subsidiary of DH Industries
- Based near Eindhoven, in the main High Tech region of the Netherlands
Introduction to CryoZone

- Not a cryo cooler manufacturer; CryoZone can integrate any brand and type depending on customers’ choice.

- Main products:
  - Insulation cryostats for applications
  - Process control cryostats
  - CryoFans
  - Heat exchangers for any type of cryocooler
Vacuum test cryostat

- Test objects of 15 tons
- Diameter 2650 mm
- Height 2500 mm
Process control cryostats

- To connect application and cold source
  - Controlling cool-down and set temperature etc
  - Housing system elements (valves, pumps, heaters)
  - and instrumentation (flow, T, P sensors)
Process control cryostats
Thermal cycling cryostat

- Closed loop gas cooling system
- To cycle the target between 150 and 400K
- Control for ramp and set temperature
- Cooling by LN$_2$ in liquid/gas HX
- Heating by electric heater
Liquid nitrogen pumps for closed loop cooling systems

- Large impeller diameter up to 100 mm
- Capacity up to 100 litres/min; 3.5 bar dP
- > 50% efficiency
- Up to 6000 rpm
- Disassembly without breaking vacuum
- No rotating seal: assembly within pressure housing
- No cold bearing: 5 years of MTBM
CryoFans & HX

- To thermally connect any cryocooler or cold source to an application
- Features:
  - CryoFan adapted to application closed circuit
  - Highly efficient heat exchanger to tap off cold from cooler into helium or nitrogen gas flow. Adaptable to all types of cryocoolers.
CryoFans
CryoFans
Heat eXchangers
CryoFans & HX

CryoFan operation vs. average hydraulic efficiency

- CryoFan curve (volume flow rate Q vs. head H)
- Efficiency $\eta = f(Q, H, N)$, N rotation speed

Efficient working area
CryoFans & HX

CryoFan models with 20 - 42 mm impeller diameter

- Böhmwind 42 mm
- Noordenwind 31 mm
- Mistral 20 mm

Pressure rise head (m)

Volume flow rate (m³/hr)
CryoFans & HX

CryoFan models with 42 - 75 mm impeller diameter

Pressure rise head (m)

Volume flow rate (m³/hr)

Böhlmwind 42 mm
Bise 56 mm
Neyol 75 mm
CryoFans & HX

CryoFan models with 75 - 125 mm impeller diameter

Pressure rise head (m)

Volume flow rate (m³/hr)

Tramontana 125 mm

Nodin 85 mm

Neyol 75 mm
INDEPENDENT BUT CONNECTED
TO STIRLING CRYOGENICS
Examples
Example concept RL
HTS Fault Current limiter

CURL 10, Germany, LPC-2 RL 1400W, 65K
Example concept FF
HTS Power cable

- Albany, USA, 2006 – 2009
- 350 mtr HTS Cable
- ~4kW @ 67K cooling
Example concept FF
HTS Power cable
Example concept FF
HTS Power cable

- Test for HTS Cable at R&D Center in Moscow, Russia
- Cooling provided by one LPC-4 FF Cryogenator with pump cryostat.
- Extendible with additional cryogenerator

Cable:
3 Phase 30 m.
30 kV, 2 kA
Future length of 200 m.

Cryogenic system:
1-7,5 kW @77K
Pressure: 1-5 Barg
Flow: max. 100 ltr/min.
Example concept FF
HTS Power cable
Example concept GPC
HTS Power Generator

Hydrogenie (Germany),
HTS hydropower plant, 1.7 MW

Cooled with two SPC-1T
cryogenerators and CryoFans
with GHe @ 30K and ferrofluid
sealed rotating coupling
STRONG BELOW ZERO