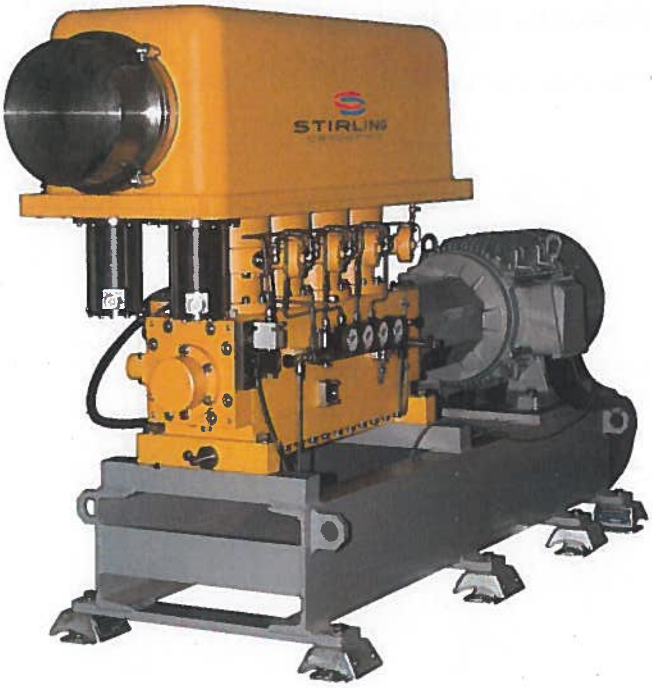
TECHNICAL SPECIFICATION

SPC-4T
Helium Refrigeration System



Reference	Technical Specification 20140891_02
Issue Date	June 1, 2015
Customer	RID Oyster

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1. INTRODUCTION

Since more than sixty years Stirling Cryogenics has designed and manufactured gas liquefaction and refrigeration systems, serving customers all over the world.

In this technical specification the Helium Refrigeration System (HRS) for the RID Oyster project has been described, based on the SPC-4T as refrigerator.

The HRS set-up has been specifically designed for RID Oyster, based on the several discussions and meetings during the last 6 months.

We trust that this information demonstrates that our system will be a valuable asset in meeting your refrigeration demands for your application.

Thank you for your interest in our company and our products, we look forward to your valuable response.

Yours faithfully,

Area Sales Manager

Tel
Fax
E-mail

2. WORKING OF THE COOLING SYSTEM

2.1 Creation of cooling power

Creation of cooling power by the SPC-4T is done by the so called reversed Stirling cycle which is based on the compression and expansion of helium gas in a closed cycle. The Stirling cycle efficiently produces cooling power at cryogenic temperatures by input of shaft power from an electric motor.
For detailed information on this creation of cooling power we refer to our leaflet "The Stirling Cycle" available on our website.

2.2 Cooling power to the IPA

One main advantage of the SPC-4T is that the helium transporting the cooling power to the IPA is not part of the cycle to create the cold. The He gas will just flow through a cold heat exchanger in the SPC-4T, where energy is extracted so the helium flow will cool down. This helium flow will transport the cooling power to the IPA.

Flow of helium is created by our CryoFans which are especially design to provide helium flow at minimal losses.

The cooling capacity of the SPC-4T depends on the process conditions. Main parameters are the required inlet and outlet temperature of the IPA. These conditions will determine at which temperature the cold head will operate and therefore, how much energy will be extracted. The lower the temperature the less energy will be extracted from the fluid.

Further, these parameters determine the required volume flow and the consequential losses by flow resistance due to the dimensional design of the VJ lines and the IPA.
These losses as well as the thermal heat leak of the VJ lines will affect the final cooling power available to the IPA.

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2.3. Flexibility and redundancy

Due to its modular set-up, the HRS has a fast flexibility in cooling power as well as redundancy.

Each SPC-4T will have its own CryoFan and local Cryogenerator Control Unit, making it an independently functional unit. The total system will comprise of 6 of these SPC-4T units, of which the helium flows and cooling powers are combined using a header to combine the helium gas flow towards the IPA. A second header will distribute the return gas from the IPA over the 6 units.

The headers will have automatic valves at their connections to the SPC-4T's, separating them from the total system when turned off. Standstill of one of the SPC-4T's will thus not affect the others in any way, securing as much as possible cooling power in case of failure.

In the same way cooling power can be turned down and up easily depending IPA functionality by switching off or on SPC-4T units. The SPC-4T will reach full cooling power within 20 minutes from a warm start, allowing a high response time to changes in cooling power requirement by the IPA.

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3. TECHNICAL SPECIFICATIONS

3.1 Functional specifications SPC-4T (per unit)

This paragraph describes the functional specifications per SPC-4T Cryogenerator.

Cooling power	Refer to paragraph 3.2 for cooling power of the total system
Power consumption	approx. 45 kW @ 20K
Helium pressure	28 bar(g) when at ambient temperature
of the loop	19 bar(g) when at working temperature
Helium flow	1.5 – 2.5 m^3/h, adjustable by rpm of the CryoFan
	the optimal flow is given in 3.2
Electricity supply	3 Ph 400 V (+/- 5%), 50 Hz (+/- 2%),
Ambient operating conditions	Between 5°C and 45°C
Ambient humidity	20 – 95%
Required cooling water flow	4.000 L/hr @15ºC per SPC-4T
	(containing 20% glycol, cooled by chillers)

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3.2 Functional specifications HRS

This paragraph describes the functional specifications of the total HRS, based on the following parameters as discussed.

Helium system pressure, cold	19 barg
He outlet temperature at HRS boundary	19.65 K
He inlet temperature at HRS boundary	20.83K
Helium flow	11.2 m³/h, at outlet of IPA (2)
Available dP	5000 Pa
Cooling capacity at boundary	981 W (1)

1) This will be the heat load to be proven during the SAT using the test system at the HRS system boundary, while creating this given flow and pressure drop, resulting in the given temperatures.
2) Mass flow of 141.7 g/s will be constant throughout the system, however volume flow will vary depending temperature at a certain location. This volume flow is based on the conditions at the outlet of the IPA.

Based on the available budgets for thermal and flow loss, ***which values need to be confirmed by KHC and be met by the VJ lines and IPA specifications,*** the resulting system behavior and net capacity at the IPA will be as follows.

Important remark:
Other values for thermal heat loss and pressure drop will result in a different cooling capacity at HRS system boundary, net available cooling power to the IPA and different dT over the IPA.

Note: Resistance of the VJ line is based on 34.8 mm ID with 27 m of length.
Resistance of IPA is based on information provided by KHC.

Budget for thermal heat* loss VJ lines outside of HRS boundary, per direction:	25	W
Budget for dP of VJ lines*, per direction, @ 11.2 m3/h at outlet of IPA	1800	Pa
Resulting in a temperature raise over the line length per direction	0.03	K
Resulting IPA helium inlet temperature	19,69	K
Budget for dP of IPA heat-exchanger @ 11.2 m3/h	3400	Pa
Resulting friction loss in the IPA	13	W
Net available heat load, if these budgets are met	**920**	**W**
Resulting temperature raise over the IPA	1.15	K
Resulting IPA helium outlet temperature	20.79	K
Resulting helium inlet temperature to HRS	20.83	K

* These shall include all heat and dP losses by all components such as valves, connections, bayonets, bends etc etc.

3.3 Functional test of HRS

To functionally test the HRS, a test system will be provided of which the components will be integrated in the HRS.

The test system will comprise o.a. of the following components. The final concept of how to determine the cooling capacity and which components are required is not determined yet and will be worked out in the Basic Design during the pre-order phase.

- Temperatures sensors at in and outlet of the HRS
- dP sensor between in and outlet of the HRS
- a variable heater of up to 1200 W to simulate heat losses in the VJ lines and IPA heat load this heater can also be used for fine-tuning of the cooling capacity.
- a variable hand valve to mimic the VJ lines and IPA pressure drop.

By combining these data, the available cooling power at the in/outlet of the HRS can be determined and checked against the values in paragraph 3.2.

The test system components can also be used by RID and KHC to connect to determine the behavior of the VJ lines and IPA. To do this, the components to measure temperature and dP must be repeated close to the in/outlet of the IPA.

3.4 Further remarks and specifications of the SPC-4T and HRS

- System boundary of the HRS is defined as the in- and outlet bayonet connections to the headers.
- All HRS equipment delivered by DH Industries will meet CE Directive / PED requirements.
- Service interval for the SPC-4T is 6,000 operating hours.
- Due to power supply restrictions at our factory, the HRS will not be tested as total system at DH Industries. Each individual SPC-4T will be tested. The total HRS will be tested at RID at the SAT using a test system, refer to 3.3.

3.5 System Control

In our standard supply as per this offer, each SPC-4T is equipped with its own Cryogenerator Control Unit and (optional) frequency convertor. This assures that failure of one component will affect only a part of refrigeration capacity. Each Cryogenerator Control Unit will safeguard its Cryogenerator from internal and external failures, ensuring proper start and stop.

This will be done by the HRS overall system control, based on a signal from the KHC control. The KHC PID shall provide a signal to the HRS indicating to change its cooling power and how much. This PID output shall be based on internal KHC system data such as IPA H_2 pressure.

Capacity control will be done by a combination of switching on or off units, regulation of capacity by frequency control and fine-tuning by use of the heater.
This capacity control concept is not determined yet and will be worked out in the Basic Design during the pre-order phase.

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4. SCOPE OF SUPPLY

We offer the following scope of supply :

1) **6 SPC-4T Cryogenerators, each consisting of**
   - SPC-4T, 4-cylinder 2-stage cryogenerator
   - 4 Cold head heat exchangers suitable for He gas cooling
   - Vacuum insulation of the cold heads.
   - Standard 45 kW electrical motor
   - Frequency convertor to allow partial cooling capacity and soft start
   - Mounting skid to support the cryogenerator, to keep it at proper height for servicing connections at approximately 1740 mm height from the floor.
   - Internal helium gas and water lines with their connections
   - Helium buffer for the Stirling Cycle.
   - Sensors, valves and switches for status monitoring and cryogenerator control
   - Böhmwind CryoFan, integrated in the vacuum space of the cold head.
   - Cryogenerator Control Unit to safeguard the SPC-4T and display measured values. These can be communicated to the main KHC control system.
   - Control cable between control unit and SPC-4T

2) **2 pieces He gas distribution headers**
   - One to distribute return gas from the KHC VJ line over the 6 SPC-4T cold heads.
   - The second to collect the cooled gas and return to the KHC VJ line.
   - Both prepared with two additional blinded connections for future extension.
   - Integrated test components as per 3.3
   - Materials to hang or support the headers

3) **Main control cabinet**
   - System control based on PID output by KHC, deciding how many and which SPC-4T need to be running. Refer to Paragraph 3.5.

4) **Chillers**
   - Water chillers to supply cooling water to 6x SPC-4T. 3 or 6 units, TBD
     Suitable for outdoor placement, to be put on the roof top.

5) **Test system**
   Components as per 3.3.
   Read out of these signals in the Main Control Cabinet 3).

6) **Consumable parts and tools**
   - Consumable parts for 18,000 hrs (2 years) hours of operation + required tools.

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7) Engineering and project management

Man hours for the basic and detailed engineering as well as project management, divided in 3 phases:

1. Basic design and project management during the pre-order phase. Support of RID and KHC with information for the design of the process, building and infrastructure.
2. Detailed and final design of the HRS and project management after the order by RID.
3. Project management during the testing and FAT stage as well as installation and SAT, refer to item 10.

8) Preparation for future extension

Provisions will be made to enable extension of the system at a later stage with another 2 SPC-4T cryogenerators.

9) Factory acceptance

The customer is invited for a factory acceptance to witness the testing of the last SPC-4T.

10) Supervision of site installation & site acceptance test

- Supervision of the installation of the SPC-4T's, He distribution headers, chillers and control units. Customer to supply workforce and handling equipment.
- Testing of the system and its components
- Site acceptance of the HRC together with RID using the testing tool.
  This is **excluding** the testing at the IPA connections, which is not part of this scope.
- Operator training on site on daily use of the HRC system and the Cryogenerators.

11) Documentation (in English)

- 1x Paper Manuals
- 1x DVD with Manuals

12) Transport and packing

Suitable packing of the equipment and transport to RID

Not included in the delivery are:

- Housing/enclosure for the Cryogenerators
- VJ lines from HRS system boundary to the application
- He gas buffers for helium loop sections
- All infrastructure for facilities:
  - Electrical distribution panels and fuses and their power supply cables to and inside the HRS room and roof top chillers
  - Power cables to the SPC-4T electric motors
  - Water lines from the SPC-4T's to the chillers on the roof top
  - Power cables to the different Cryogenerator Control Units and Main Control Cabinet
  - Signal cables from the Main Control Cabinet to RID and KHC control room
  - Operator work station
  - All helium lines between the different elements like SPC-4T's, helium buffers, VJ lines and helium gas supply.
- Helium gas min. purity of 99,99% to fill the Cryogenerators and helium loop during installation, operation and maintenance of the system.
- Unloading and transport/lifting to the HRC installation room.
- Support for testing the VJ lines using the test unit at IPA side.
- Support for putting IPA into service and optimizing control settings.

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5. INSTALLATION AND MAINTENANCE

Installation of a Cryogenerator is relatively straight forward due to the preassembled systems on skids.

It involves placing the skids at its position and connecting it to the several interfaces.

- VJ line headers
- Cooling water lines
- Signal cables to the Cryogenerator Control Unit and Main Control Cabinet.
- Power cables between motor and (optional) frequency convertor and to mains
- Installing and alignment of the electrical motor

Installation, commissioning and maintenance of the plant must be done by a Stirling Cryogenics service engineer or by our certified representative to qualify for the warranty. The plant room must be prepared by the customer according to Stirling Cryogenics Site Preparation Instructions and must comply with local legislation. Local, qualified technicians, made available by and on account of the customer, will carry out electrical and plumbing work, as well as construction/civil work prior and during installation.
Equipment for placement of the system is to be provided by the customer (i.e. cranes, trolleys, lifts etc)

Stirling Cryogenics also offers training courses at our facilities in Son, The Netherlands, to improve the knowledge of plant operators and technicians.

During the warranty period, maintenance must be performed by a technician trained by Stirling Cryogenics at Son or by a Stirling Cryogenics engineer. If non-qualified personnel carry out maintenance or repair, the warranty will be null and void.

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