TECHNICAL SPECIFICATION

SPC-1
Stirling Process Cryogenerator

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Stirling Cryogenics is a registered trade name of DH Industries BV
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1. INTRODUCTION

This document contains detailed technical information and specifications for the SPC-1 gas liquefier. We trust that this information demonstrates that our Stirling Cryogenics cryogenerator will be a valuable asset in meeting your cryogenic demand.

The SPC-1 has two specific fields of application:

- *production* of liquid gas from a purified gas source to make it suitable for transport and/or storage
- *re-liquefaction* of evaporated gas to compensate for losses due to heat load into a cryogenic system.

In this document technical aspects of the above uses are given, together with different optional sub-systems to integrate the SPC-1 into the main system.

Typical characteristics of the SPC-1 are:
- a quick start up,
- low energy consumption
- reliable operation
- worldwide technical support and service

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

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2. (RE-) LIQUEFACTION OF GAS

In the SPC-1 heat exchanger, energy is extracted from the gas. This will be cooled and then liquefied. Extraction of energy is done using the renowned Stirling Cycle on which the functioning of our machines is based. Since these machines produce cryogenic cooling power they are named "cryogenerators".

Liquefaction

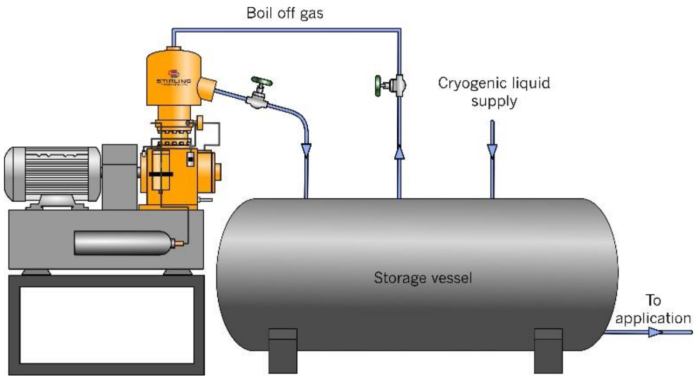
The gas to be liquefied shall be produced and purified by the main system of which the SPC-1 will be part. It is very important that the gas to be liquefied is within this specification. If contaminants are present in larger quantities, these will freeze in the liquefaction heat exchanger and gradually block it.

Re-liquefaction

This is usually either for compensation of boil-off or if the cryogenerator is part of a cooling system for an application generating heat load. The (re-) liquefaction quantity depends on the circumstances at which this is done.

Main influences on the (re-)liquefaction capacity of the cryogenerator are gas temperature and pressure.

The influence of gas inlet temperature is obvious; with lower temperature, the cryogenerator needs to extract less energy so the liquefaction rate increases.



Drawing 1: Re-liquefaction of liquid

Influence of pressure is more complicated. The pressure of the gas also determines the liquefaction temperature. With higher pressure, the liquefaction temperature goes up. Higher liquefaction temperature results in a higher liquefaction rate for two reasons:

- First, less energy needs to be extracted to cool the gas to reach liquefaction temperature.
- Second, at higher temperatures the Stirling Cycle will generate more cooling power, while also using less input power.

So, where possible within the total system it is beneficial to run a cryogenerator at high gas pressure. For the cooling power rate at different temperatures, refer to the graph of the SPC-1.

From these watts the liquefaction rate in kg/s or Nm3/h of the specific gas used can be calculated. After liquefaction, the liquefied gas drops out from the cryogenerator by gravity, usually into a vessel. Here the liquid gas is collected for further use. Further on in this quotation the different additional components that Stirling can include in here scope of supply are described.

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3. SYSTEM OPTIONS

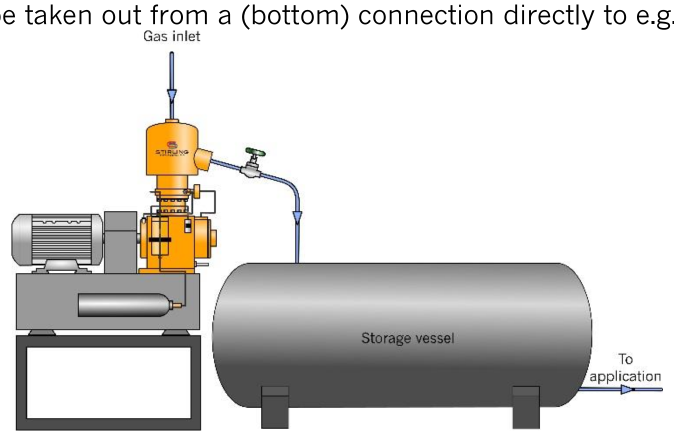
Earlier the production of liquid gas was described. The liquid produced then has to be stored. Below different options are given to do this.

Direct (re-) liquefaction into main storage

The simplest approach is to store the produced liquid in a storage vessel to which the cryogenerator is directly attached. Because the produced liquid drops into the vessel by gravity, the cryogenerator must be placed higher than the top of the vessel. Depending on plant room etc., this will limit vessel size. E.g. a large and high vertical vessel cannot be used.

From the storage vessel the liquid gas can be taken out from a (bottom) connection directly to e.g. a pumping station. To transfer the liquid, some pressure drop should be taken into account because a difference in pressure is needed between the gas, gas feed pressure and liquid output.

Stirling can offer various sizes of small storage vessels: 200, 300, 500 and 1000 liters. Other sizes are available upon request. The vessel will be placed in front of the liquefier, which is placed on a frame to obtain the required height.



Drawing 2: Liquefaction of gas

Vessel size is determined by the actual use of the liquid gas. A larger liquid gas production will need a larger vessel, but also the frequency of liquid supply is of influence. If liquid is taken out only a few times per week, the vessel needs to be larger than when this is several times per day.

(Re-) Liquefaction into transfer vessel

If the main storage vessel cannot be connected directly to the cryogenerator (e.g. due height, location), Stirling can supply a transfer vessel. This can be relatively small (200 up to 500 liters) and is only intended to store an amount of liquid until transfer.
Transferring is done when the transfer vessel is full. A cryogenic valve in the (bottom) connection is opened and feed gas pressure will push out the liquid into the actual main storage. When the transfer vessel is almost empty, this valve is closed and the transfer vessel will fill up again.

For re-liquefaction no feed gas pressure will exist and hence a pump will be required.

In the total system set-up a pressure drop between the transfer vessel and the main storage must be taken into account depending on required speed of transfer and main storage vessel height.

The transfer cycle will decrease the total liquefaction rate per day: during the transfer no liquid will be produced. The influence of this effect depends on the final total system set-up.

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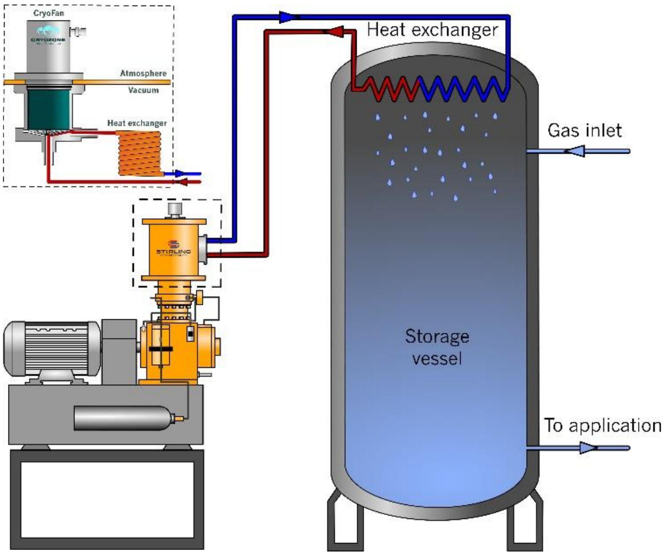
In-direct (re-) liquefaction using He

The process described so far was by direct liquefaction in the cryogenerator. However, other possibilities exist. Depending on site circumstances it might be beneficial to use a different liquefaction approach to move the liquefier to an adjacent area and to use an indirect method of liquefaction.

One possibility is to pump around helium gas as a cooling medium.
The cryogenerator can be placed anywhere: relatively far away and even under the liquid gas storage vessel because the helium gas pump will overcome distance and height.
The liquefaction heat exchanger can directly be placed inside a large liquid gas storage vessel so a transfer vessel (and its losses) can be avoided.



Drawing 3: In-direct (re-)liquefaction

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4. TECHNICAL SPECIFICATION SPC-1

Feed gas specifications to the SPC-1:

- Main stream: N_2, O_2, Ar, other cryogenic gases
- CO_2: < 50 ppm
- H_2O: < -70°C dew point
- H_2S: < 1 ppm
- C_xH_y (C_2 to C_4): < 5%
- C_xH_y (C_5^+): < 1 ppm
- Oil content: < 0,01 mg/m3
- Particles: < 0,1 micron

Cooling power	Depending on liquefaction pressure and resulting temperature, refer to graph
Power consumption	Depending working temperature, refer to graph
Maximum system pressure	20 bar(g)
Electricity supply	3 Ph 400 V (+/- 5%), 50 Hz (+/- 2%)
Ambient temperature	between 5 °C and 45 °C
Ambient humidity	20 – 95%
Required cooling water flow	1.000 L/hr @ 15 °C
Required cooling water cooling power	Sum of cryogenerator cooling power + input power depending on liquefaction temperature, refer to graph
Sound level cryogenerator	70 dB
Sound level chiller (optional)	60 dB
Size and installation space	Refer to lay-out drawing

NOTE:

A transfer vessel or indirect liquefaction of gas will have a decreasing effect on the liquefaction rates stated. This effect will depend on actual set-up of the total system and can be determined in a technical system discussion.

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5. SCOPE OF SUPPLY

Stirling offers the following scope of supply of the liquefier and its system options.

SPC-1

The SPC-1 for direct gas liquefaction consists of the following components:

- One basic 1-cylinder cryogenerator, model SPC-1
- Electric motor
- Mounting frames
- Gas inlet coupling from gas feed including non-insulated service valve, suitable for cryogenic use
- Liquid outlet coupling to vessel including non-insulated service valve, suitable for cryogenic use
- Internal helium gas and water lines
- Connections for power, water and helium supply
- System control box including star/delta switch. Non-ATEX: to be placed in separate room.
- Documentation including operating and maintenance instructions
- One cylinder Helium 99.99% purity with pressure reducer

Not included in the delivery are:

- Housing
- Lines/cables to the module for gas and power
- Main power box and fuses
- Chiller (quoted as an option)
- Installation and commissioning at site during a period of approx. 4 days (quoted as an option)

Transfer and main storage vessels

All vessels supplied by Stirling Cryogenics have the following specifications:

- Size: 200, 300, 500, 1.000, 2.000 or 3.000 liters. Other sizes available on request.
- Top connections for 2 – 4 cryogenerators, depending vessel size.
- (Bottom) liquid connection. This is a vacuum jacketed bayonet connection to which the main system constructor must connect a transfer line.
- Measuring devices with 4-20 mA output to Stirling control box:
    - Liquid level indicator
    - Pressure indicator
- *Extra in case of transfer vessel:*
  cryogenic valve at liquid connection.

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Indirect liquefaction by helium gas

Additionally to the scope of supply described for the SPC-1 , the following items will be added for a system based on indirect liquefaction by a helium gas loop.

- Adapted cryogenerator with:
  - Pump for helium gas
  - Connections in/out for helium gas cryogenic lines
- Option: Cryogenic helium lines

Not included: liquid gas

- Storage vessel
- Helium/gas heat-exchanger in storage vessel

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6. INSTALLATION OF THE SPC-1

Refer to the lay-out drawing for the size of the SPC and its connection positions.

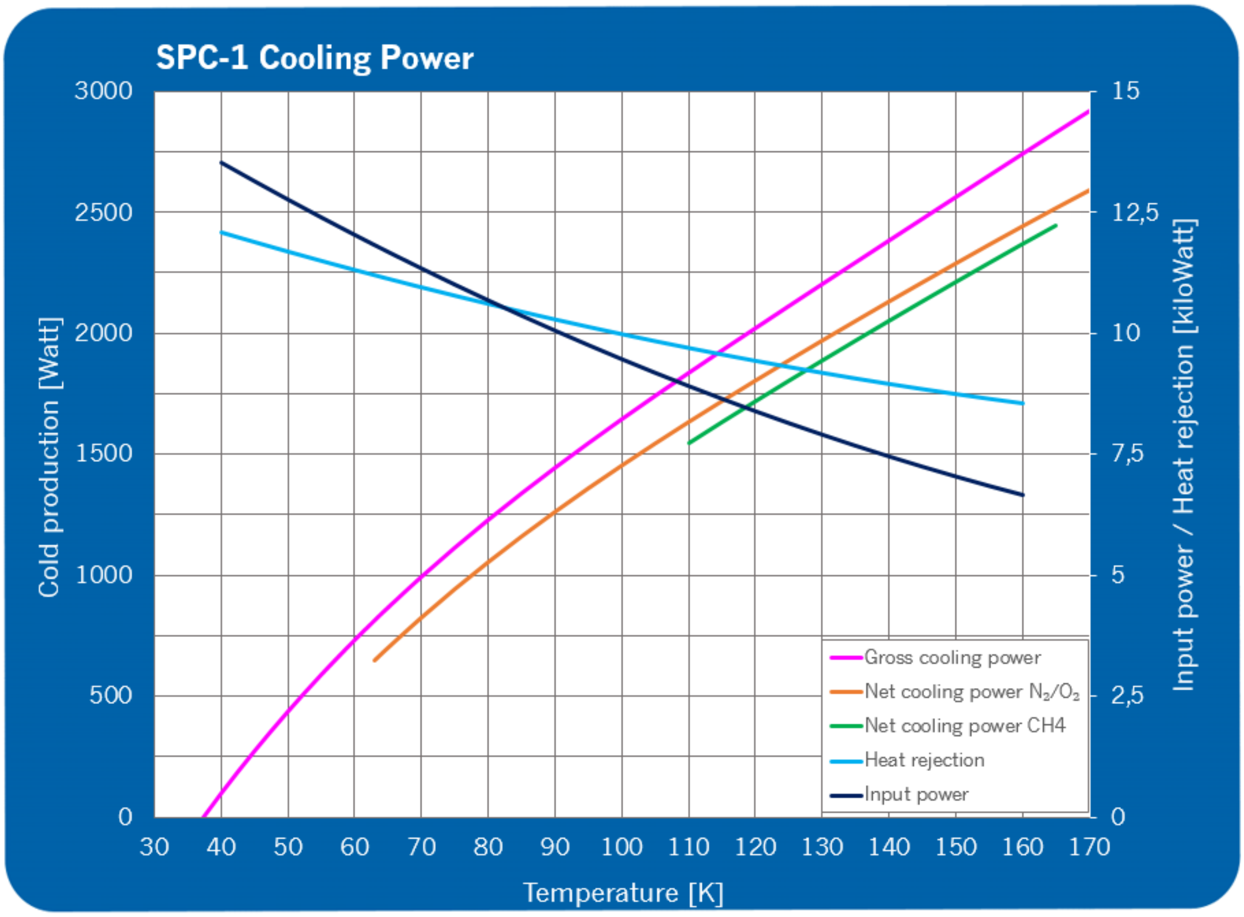
Installation of a cryogenerator is relatively simple. It involves placing the cryogenerator at its position and connecting it to the several interfaces:

- Gas inflow line
- Liquid outlet line
- Cooling water lines
- Power and signal cables to the control box.

Installation footprint is approx. 1,5 x 2 meter, refer to lay-out drawing.

Feed of power to the control box is part of the customer preparation according local regulations.

Installation by a Stirling engineer is offered separately and is recommended for users not familiar with this equipment.



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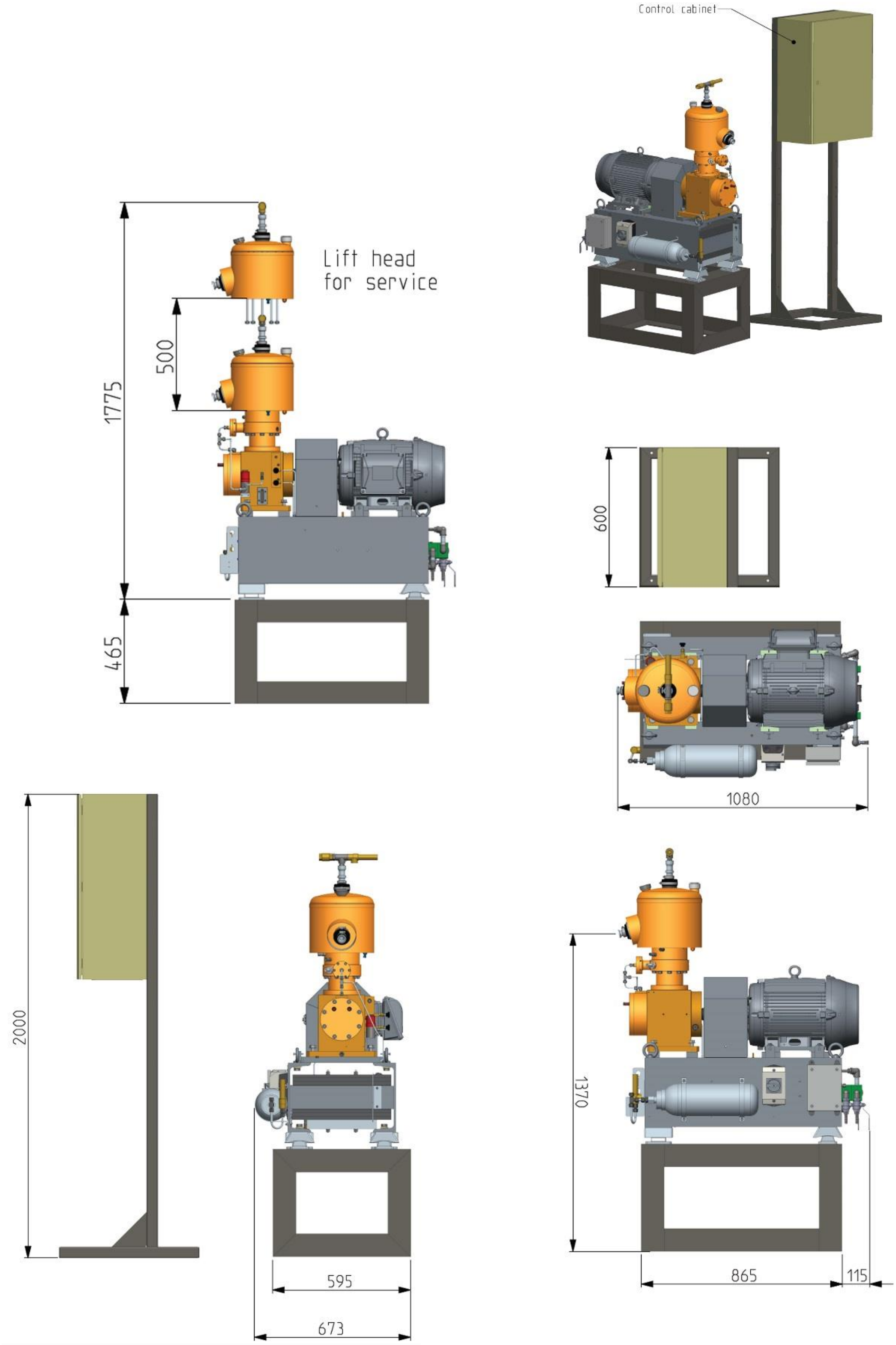

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