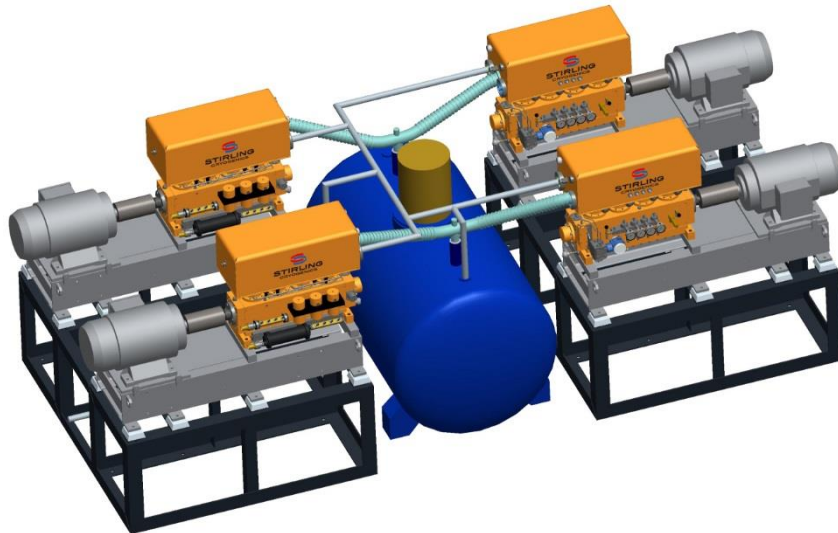


TECHNICAL SPECIFICATION

StirLNG-16

Stirling Gas Liquefying system for re-liquefaction of LNG
(4-10 T/day)



Reference 80 8406_02
Issue Date Sept 4, 2015

1. INTRODUCTION

Since more than sixty years Stirling Cryogenics has designed and manufactured gas liquefaction system, serving customers all over the world under all possible climatic conditions. This experience is used for our methane Cryogenerators (liquefiers) called StirLNG. These have three specific fields of application:

- Production of LNG from a purified gas source such as pipe line or biogas to make it suitable for transport and/or to use it as fuel.
- Re-liquefaction of (cold) evaporated methane to compensate for losses due to heat load into a cryogenic (storage) system.
- Re-liquefaction of boil-off gas on vessels, an adapted version specifically for maritime use.

We trust that this information demonstrates that our plant will be a valuable asset in meeting your methane re-liquefaction demand.

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

2. WORKING OF THE STIRLING

For technical description, working principles and details on a (single) StirLNG-4 (re-) Cryogenerator please refer to the enclosed technical specification 80 8414 02 / 80 8404 02.

3. SYSTEM DESCRIPTION

The StirLNG-16 re-liquefaction system is a stand-alone, plug and play LNG solution, consisting of 4 StirLNG-4 Cryogenerators, an intermediate tank and LNG pumping system. This unit can either be used for LNG production (for instance from (cleaned) bio- or pipeline gas) or for re-liquefaction of boil off gas (conditioning of LNG).

The customer will have to install the StirLNG-16 system in a housing to protect it from ambient environment. This could be a simple shed or a container.

3.1 Features

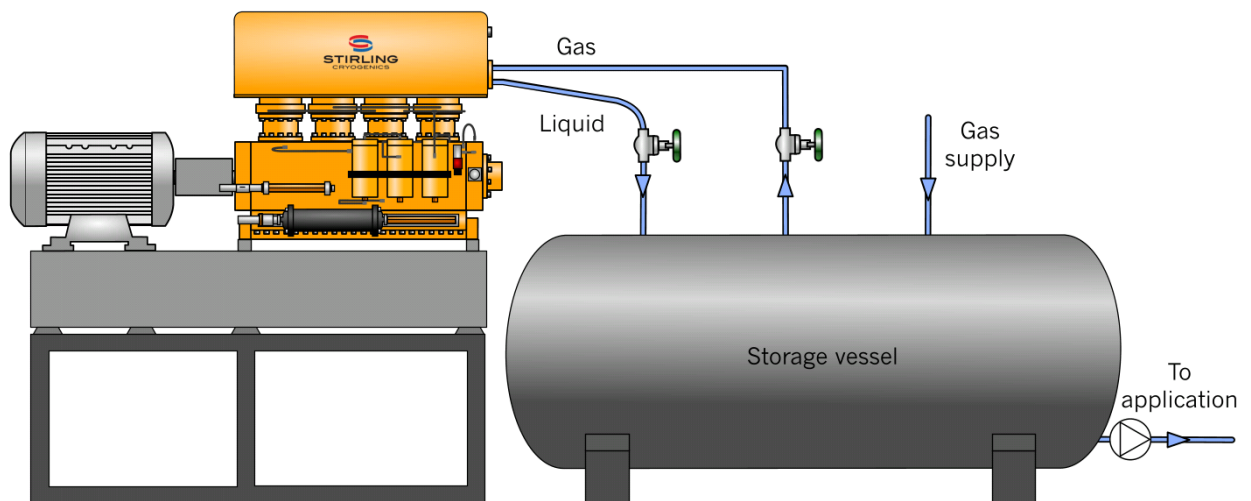
The StirLNG-16 (re-) liquefaction system has the following features and advantages:

- **Plug and play design:**
All equipment will be installed, aligned and pre-wired on (a) skid(s), ensuring minimal installation time.
- **Compact design:**
Aprox. 6,5 x 2,3 x 2,7 mtr (see pag. 11 for details).
The unit will be designed to fit a standard (shipping) containers
- **Flexibility and redundancy:**
The system uses 4 high efficient Stirling Cycle based Cryogenerators to produce the required cooling capacity. At reduced load one or more of the Cryogenerators can be shut down to reduce the capacity (in about 25% gross capacity increments). This reduces the overall power consumption with the same ratio. The system can continue to operate (at reduced capacity) while one or more (of the four installed) Cryogenerators are off line for repair or maintenance
- **Quick response time / Start up:**
The unit will be at LNG liquefying temperature within minutes from start up. The Cryogenerators in stand-by mode will be fully operational within minutes as well.
- **High reliability:**
The unit is designed with proven technology. It uses the high reliable Stirling Cycle based Cryogenerators from Stirling Cryogenics, of which over 3,000 units have been supplied since the 1950's. They have proven their suitability and reliability over the years and some units from the 1960's and 70's are still in operation
- **Flexible operations:**
The plant can, without any modifications, handle different temperatures and pressures.
- **Preventive maintenance is only required after 6,000 operating hours.** This procedure can be done at site, by customer's own engineers (after training) without bringing the whole plant off line (liquefaction, at reduced rate, can continue during maintenance).

3.2 Re-liquefaction of Boil off gas

Working principle of the system:

(Cold) Methane (boil off) gas (between 0-15 barg) from the customer's application is fed to the StirLNG-16 system, through a single connection. This gas flows into the coldhead of the (4) Cryogenerators where it is liquefied. The LNG produced by the StirLNG-16 flows out downwards by gravity into the storage vessel (part of the system). From the storage vessel, the LNG will be pumped back towards the customer (through another single connection).



4.2 Capacity of the StirLNG-16

The mentioned capacities are indications only. The actual capacity of the StirLNG-16 system depends on the inlet temperature of the gas, the pressure and the gas composition (especially Nitrogen content):

- Lower inlet temperature of the boil off gas to the system increases capacity, as less energy will have to be removed by the Cryogenerators.
- A high(-er) inlet pressure of the BOG will have a high(-er) liquefaction temperature (as the system operates at saturation point). At higher temperatures the Cryogenerators will have a more capacity.
- The composition of the BOG will determine its liquefaction point, especially Nitrogen will lower this, compared with pure Methane, reducing the capacity of the Cryogenerators.

Re-liquefaction can be a continuous process, until the system control decides that a low enough pressure is reached or when the customer switches it off. Due to the fact that the system uses 4 independent Cryogenerators it is also possible to shut down individual units, decreasing the capacity with increments of about 25%. Any (or all) Cryogenerators can be back at operating (re-liquefaction) temperature within minutes. The power consumption will decrease linear with the amount of cryogenerators in operation.

To increase capacity, several StirLNG-16 systems can be put in parallel.

4.3 Methane feed gas specification

The (Methane) feed gas specifications to the StirLNG system will have to meet the following minimum specification:

Main gas stream	CH ₄
Contaminants	
• C _x H _y (C ₂ to C ₄)	< 10%
• C _x H _y (C ₅ ⁺)	< 1 ppm
• CO ₂	< 50 ppm @ atm. pressure ^{Note 1}
• H ₂ O	< -70°C dew point
• H ₂ S	< 3,3 ppm
• Oil content	< 0,01 mg/m ³
• Particles	< 0,1 micron
• N ₂	< 10%,

Note 1:

The 50 ppm CO₂ stated above is not a specific requirement for the StirLNG-16, but (possibly) for the entire LNG logistic chain:

50 ppm is the maximum solubility of CO₂ in LNG at atmospheric pressure. At higher pressures, the solubility increases and thus more CO₂ can be allowed in the feed-gas to the StirLNG.

However, it must be considered that when, down-stream in the logistic chain, the LNG pressure is decreased, solid CO₂ will deposit. This will collect in vessels and potentially block or damage valves and pumps. Therefore, the lowest pressure in the logistic chain determines the maximum CO₂ content of the feed-gas.

5. SCOPE OF SUPPLY

Stirling Cryogenics offers the following scope of supply for the StirLNG-16 system:

- Four (4) StirLNG-4 Cryogenerators suitable for Methane liquefaction.
- Explosion proof certification as specified in the quotation
- 1000 liter (intermediate) storage tank, including the required instrumentation and sufficient connections.
- In and outlet connection for gas and liquid incl. valve(s)
- LNG pump skid
- Connection for water
- All above mentioned items skid mounted
- All internal wiring, cables and lines (+ conduits, if needed).
- Control panel (either CE or UL) to be placed in safe area
- 20 mtr wiring between the system and control panel (no ducts or conduits in case they might be needed).
- Documentation (in English):
 - Pre-installation manual
 - Operating and maintenance instructions
 - CE or UL declaration of conformity or incorporation (depending on which is applicable)
 - 3.1 Material certificates for LNG pressure parts

Options:

The following options can be ordered for the StirLNG-16 system:

Suitable for outdoor placement:

The system can be made suitable for outdoor placement at the following conditions: -5 to + 45°C (23 to 113F). Other temperatures upon request.

When the temperature drops below +5°C provisions need to be made to prevent the system to become too cold. Possible solutions need to be discussed with customer

A system placed outside requires sufficient protection and shielding from the elements (canopy, rain, snow and debris protection) provided by the customer.

Water chiller:

This option will supply stand-alone water chillers to provide the cooling water to the system, suitable for the conditions specified. The water chiller will be non-explosion proof and needs to be placed in the safe area. 20mtr. connection lines are included. The water chiller will be either CE or UL/ASME.

Cylinder of Helium gas:

The Cryogenerator needs to be filled with helium gas during installation, min. purity of 99,99%. Only after maintenance the unit needs to be refilled.

This option will supply a European certified 200 bar, 50L gas cylinder of Helium including a suitable pressure regulator.

Consumable parts and tools:

Consumable parts for xxx hours (see quotation) of operation (several packages are available) + required tools.

Site services:

Commissioning, start-up assistance and installation can be provided by a Stirling Cryogenics certified Engineer, at customer's site for the duration, and according to conditions, as specified in the quotation.

Training maintenance Engineer:

1 Week of training in The Netherlands for operations and maintenance. Lodging, breakfast and lunch is included. Travel expenses are at customer's account.

Not included in the delivery are:

- Housing/enclosure/canopy for the system
- Lines for liquid and gas to and from the system
- Main power box and fuses
- Ducts and conduits (if required) between the system and the control panel (in the safe area)

Notes:

- Service interval is 6.000 operating hours.
- The StirLNG-16 system will be tested at the factory for its performance using liquid Nitrogen. You can witness the final 2 days of Factory Acceptance Test at your own cost. Additional factory acceptance test/requirements need to be discussed and might be subject to additional charges.

6. INSTALLATION AND MAINTENANCE

Refer to the drawing for an indication on the size of the StirLNG-16 system.

Installation of a system is relatively simple as it is designed for plug and play operation. It involves placing the system at its position and connecting the several interfaces:

- Methane gas inlet line
- LNG outlet line
- Cooling water lines
- Signal cables to the control box.
- Power cables

The System can be placed in a hazardous area for which its components are suited.

The control box must be placed in the non-hazardous area. From here wiring for signals are directed to the system's termination box.

Feed of power to the system is part of the customers preparation according local regulations.

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

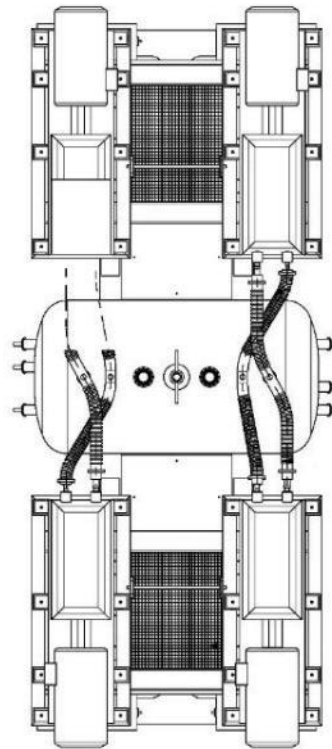
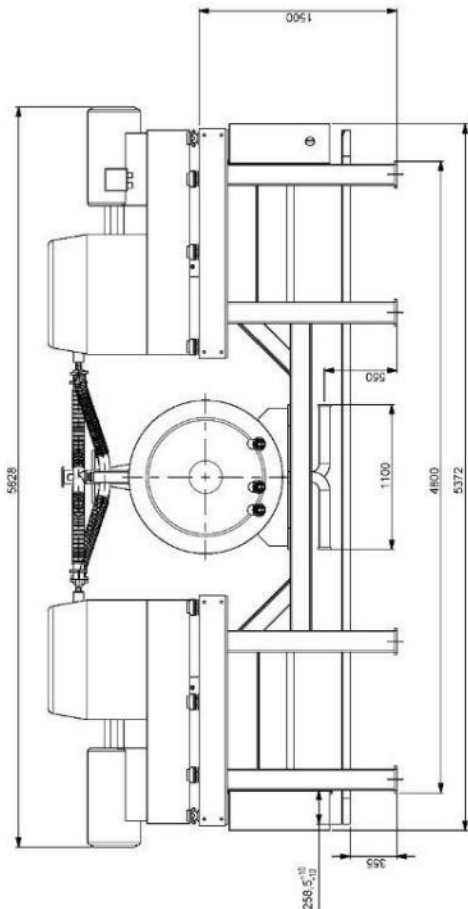
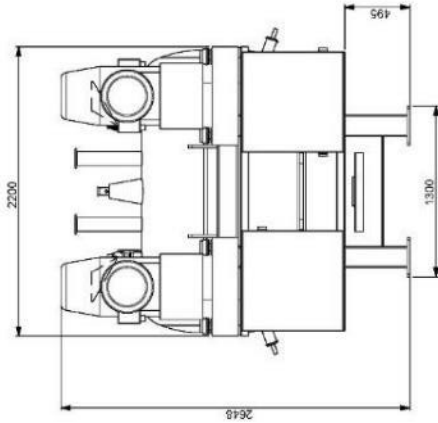
Stirling Cryogenics also offers training courses at our facilities in Son, The Netherlands, to improve the knowledge of plant operators and technicians.

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.

We recommend to include in your order a set of consumable parts and tools to cover the initial requirements.

APPENDIX 1: Lay-out / impression:

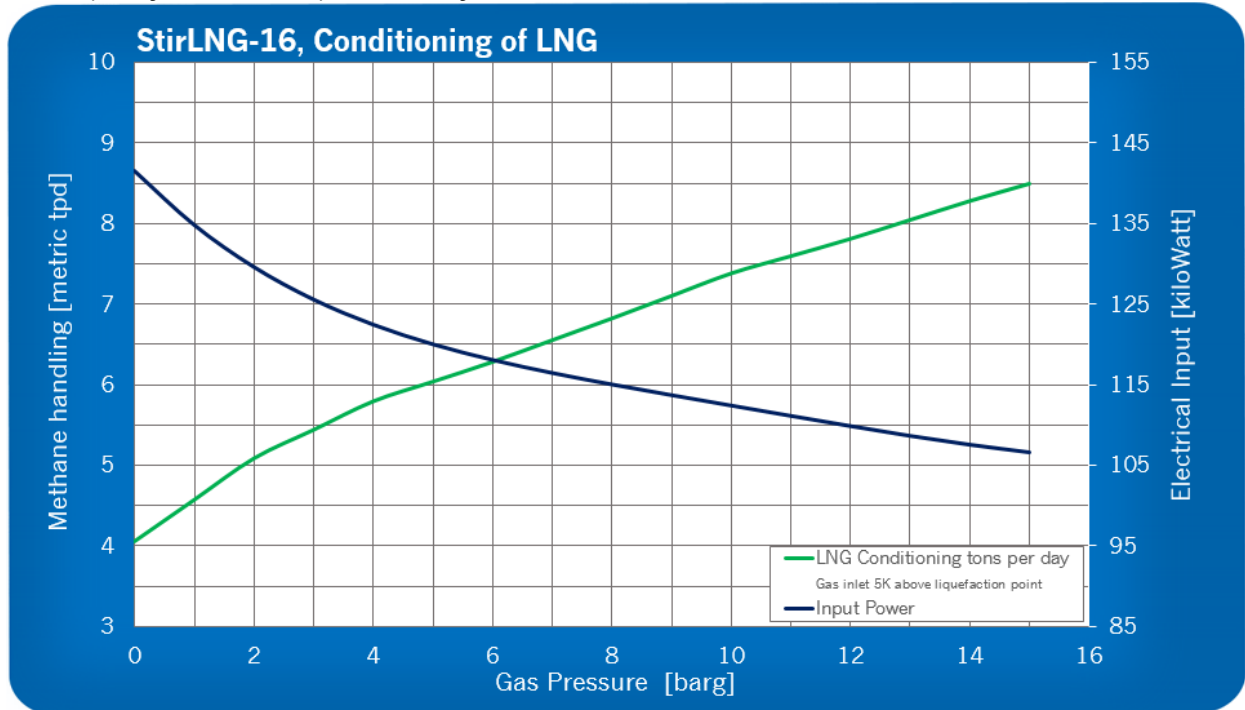
Preliminary drawings: Dimensions (in mm) and lay-out are for indication only



Pump unit
800x 800

APPENDIX 2: Capacity

The capacity of the Re-liquefaction system is as follows:



Gas Pressure	Electrical Input	Capacity bases on Inlet gas temperature 5K above liquefaction point
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Inlet gas pressure (Barg)	Power consumption (kW)	Quantity BOG Nm ³ /hr	Production of LNG l/hr	Production of LNG T/day	Production of LNG Gal/day
0	142,4	235	400	4,05	2530
2	128,0	297	535	5,13	3389
4	123,2	335	627	5,79	3968
6	118,8	364	701	6,28	4440
8	115,6	395	780	6,82	4942
10	112,0	445	859	7,68	5438
12	108,8	452	937	7,81	5936
14	104,4	480	1016	8,28	6436
15	102,6	492	1054	8,50	6676

Notes:

- This is for indication only.
- The mentioned capacities include all pump and thermal losses.
- The above mentioned data is based on pure Methane. The actual capacity might be lower, based on the composition of the gas. Especially Nitrogen will lower the re-liquefaction point (hence cold head temperature) and therefor will reduce the available cooling power. Upon request we can provide the available capacity at known Nitrogen content.