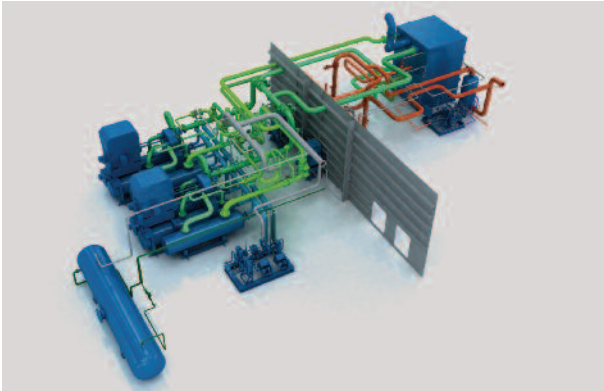


# LNG Systems for Marine Application

LNG Reliquefaction & LNG Regasification

Gas Systems



LNG reliquefaction plant arrangement for a Q-flex membrane tanker

# Reliquefaction system

## for LNG Carriers

Hamworthy is a leading supplier of gas carrier cargo handling technology, as well as manufacturer of key cargo handling equipment. Extensive experience with cargo systems for LPG, ethylene and LNG handling is the basis of supplying new solutions in an ever expanding technically driven environment.

Liquefaction of boil-off gases on LNG carriers results in increased cargo deliveries and allows owners and operators to choose the most optimal propulsion system. Hamworthy Gas Systems AS holds a worldwide license for detailed applications and sales of the patented Moss RS™ LNG reliquefaction system. The system can be used in connection with all cargo containment systems.

LNG carriers have, up to 2006, mainly been driven by steam turbines. The boil-off gas from the LNG cargo has so far been used as fuel. This is a costly solution that requires special skills during construction and operation. Alternative propulsion systems offer far better fuel economy than steam turbines.

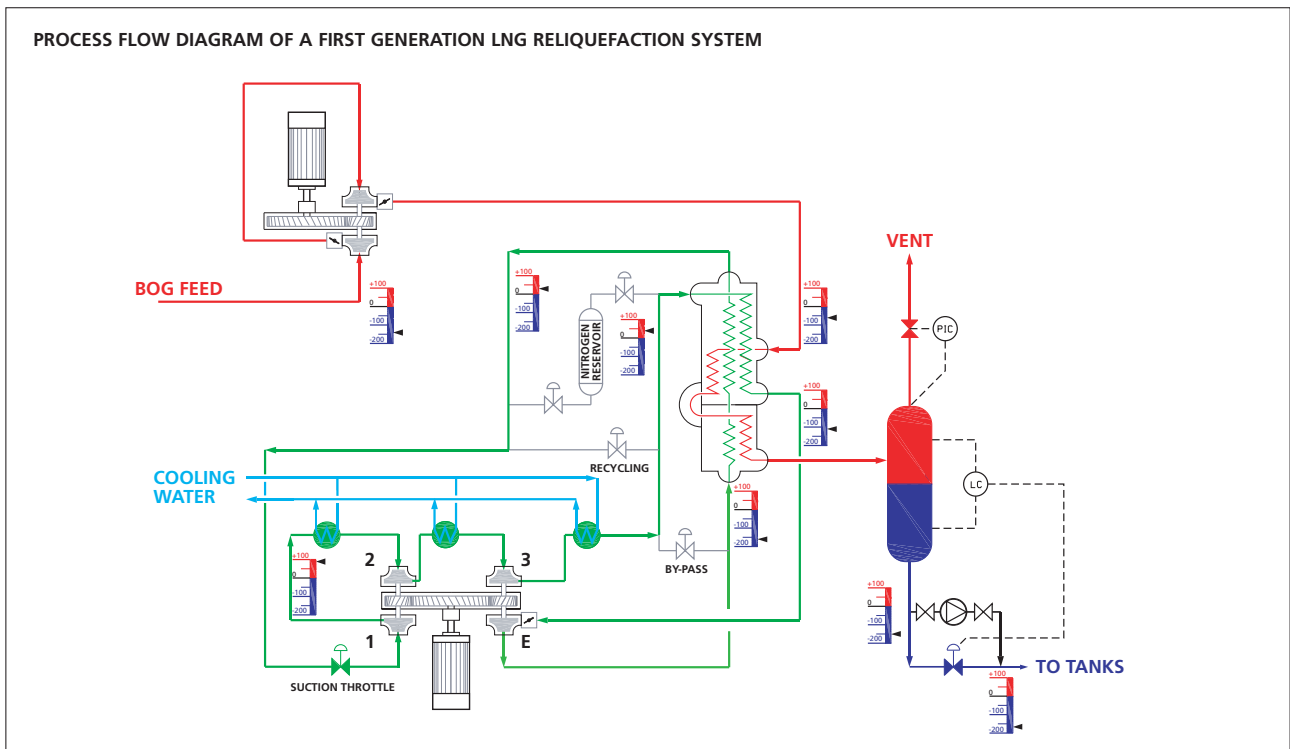
Instead of previous practice using boil-off gas as fuel, the reliquefaction system establishes a solution to liquefy the boil-off gas and return the LNG back to the cargo tanks. This results in;

### Economical merits

- ▶ Increased cargo quantity delivered. The total quantity of LNG loaded can now be delivered to the customer.
- ▶ Reduced heel required on ballast voyage.
- ▶ Large saving in total fuel consumption.
- ▶ Improved propulsion redundancy.
- ▶ Competitive investment level.

### Technical merits

- ▶ The system uses only proven components with extensive references.
- ▶ The IGC code requires system with 100% redundancy, which is offered in two alternatives.
- ▶ The LNG nitrogen content is reduced during the voyage.
- ▶ The system is prefabricated in skid modules for installation and hook-up on board.
- ▶ Limited rearrangement of cargo machinery spaces required.
- ▶ The system has automatic capacity control from 100% to 0%.
- ▶ The system can be stopped when the cargo pumps are in operation. This will reduce the need for extra generator capacity.
- ▶ No extra personnel are required for operation and maintenance.



## The Moss RS™ concept

The Moss RS™ concept is based on a closed nitrogen expansion cycle extracting heat from the boil-off gas. The first generation concept has (by end 2006) been contracted for some 20 membrane type LNG carriers for serving the Qatargas II and Rasgas III LNG-trains. Several novel features such as partial liquefaction and separation of non-condensable items has resulted in a compact system.

The 3D image (page 2) and flow diagram above shows the equipment located in the cargo machinery deck house. BOG is removed from the cargo tanks by means of a two stage centrifugal compressor, which is similar to conventional LD compressors. The BOG is cooled and condensed to LNG in a

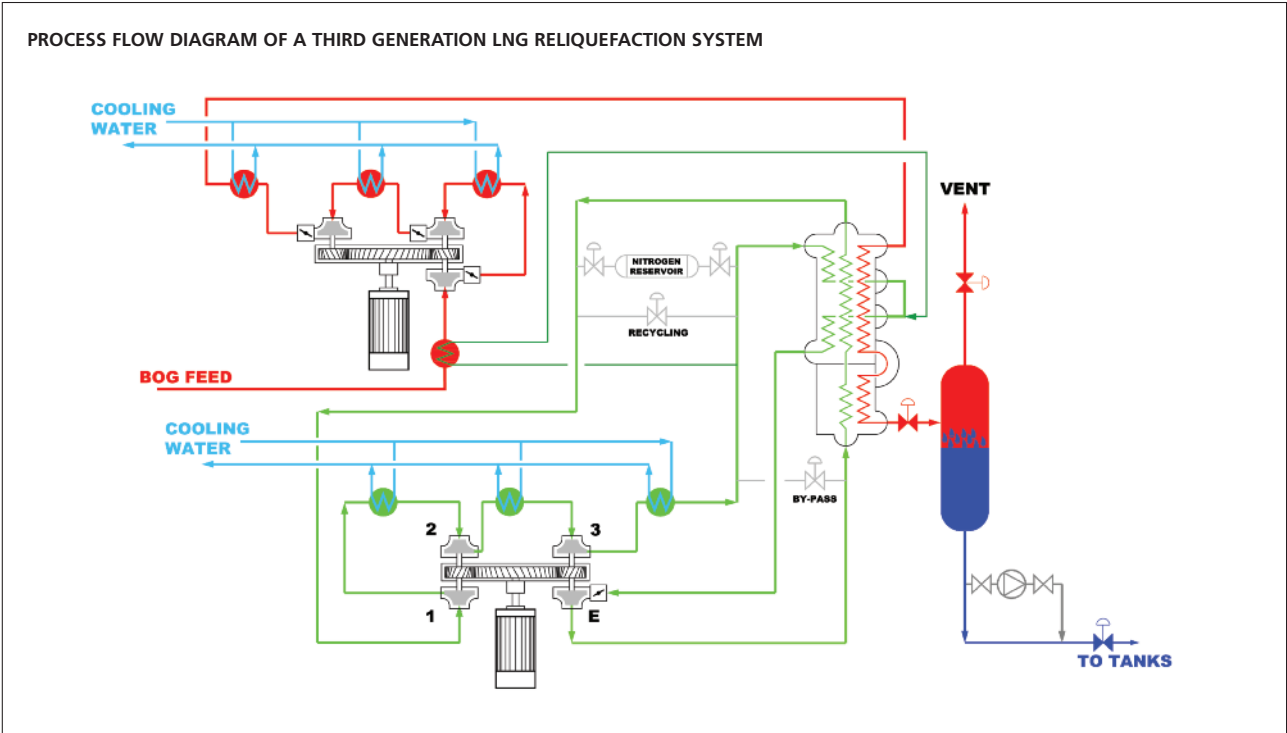
cryogenic heat exchanger (cold box). Non-condensable items, mainly nitrogen, are removed in a separator vessel. From the separator, the LNG is returned to the cargo tanks by the differential pressure in the system.

The cryogenic temperature inside the cold box is produced by means of a nitrogen compression-expansion cycle. The BOG compressor capacity is adjusted automatically in accordance with the BOR. Increasing and decreasing the nitrogen filling - and thus the compressor mass flow - is the basic control mechanism for the cooling capacity of the nitrogen cycle. Sensors and transmitters provide the required input signals to a programmable logic controller which will be part of the main vessel control system and enables 0-100% capacity control.

The first generation concept is offered to medium size LNG carriers; however Hamworthy has made innovative decisions and reduced the power consumption in a range of 15% in the so called third generation concept (Mark III) (for further details see page 4).



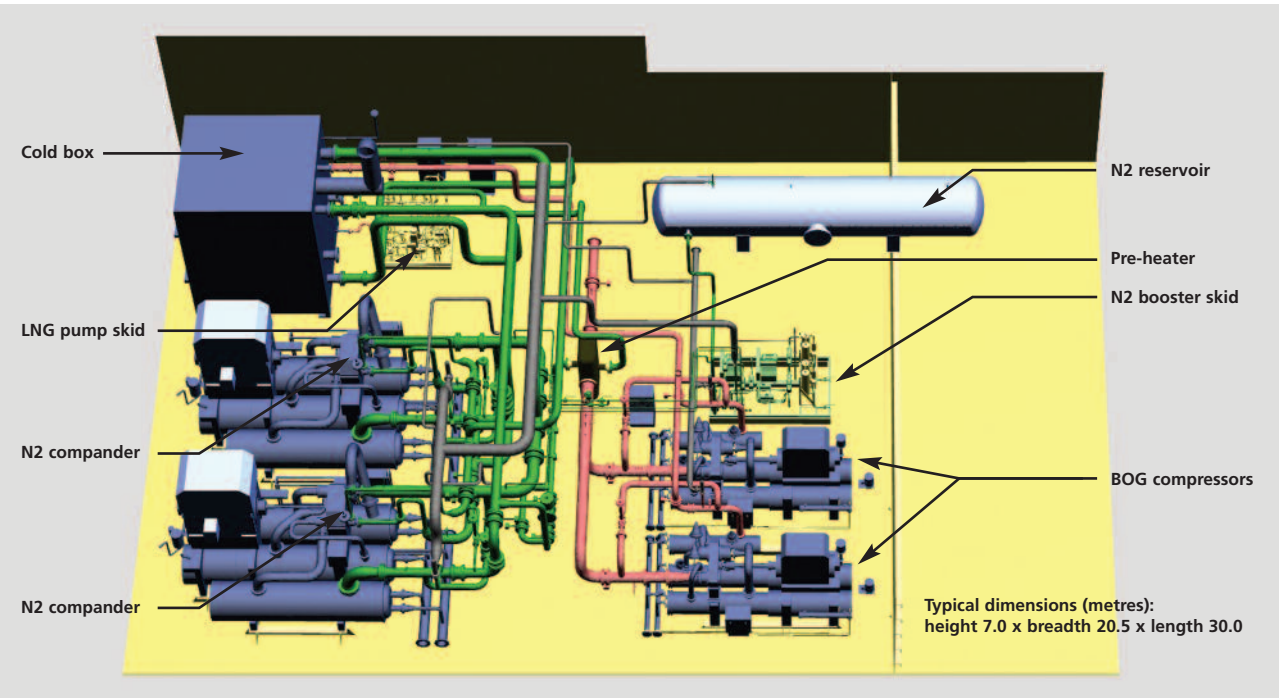
Typical N2-compressor with coolers (one expander)



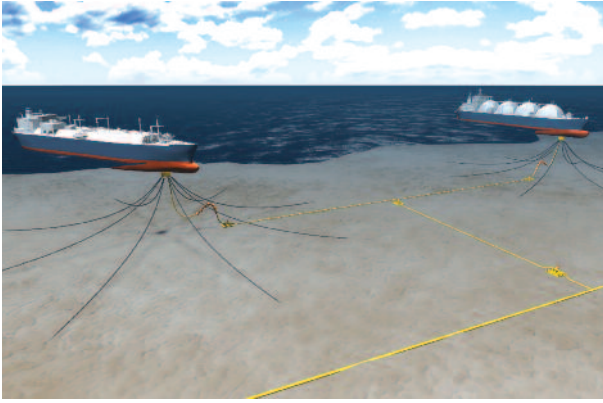
### Hamworthy third generation (Mark III) LNG reliquefaction system

The main difference compared with the first generation is that the LD compressor unit has an additional compressor stage and inter-stage cooling. Heat is added to the BOG before it enters the main cooling circuit so that the heat of compression can be removed at high temperatures in the cooling arrangement. The additional compressor stage allows the process to condense the BOG at high pressure and

temperature. This effect and that the heat of compression is removed early in the process is the main reason whereby the power consumption is reduced by some 15%. High efficiency is essential for large LNG carriers. The Mark III system is patented by Hamworthy Gas Systems and several contracts have already been signed.



Typical arrangement of LNG RS Mark III (2 x 100% capacity and one cold box)



Offshore LNG unloading terminal (by courtesy of Hoegh LNG)

# Regasification system

## for LNG SRVs, FSRVs and FSRUs

Hamworthy is a leading supplier of onboard regasification systems for installation on Shuttle Regasification Vessels (SRV), Floating Storage Regasification Vessels (FSRV) and Floating Storage Regasification Units (FSRU).

The LNG regasification units are skid-mounted, very compact and can easily be arranged on deck. Systems have capacities of 50 to 1100 tons per hour and send-out pressures from 46 to 130 bar are available.

As an example, a system with three units can provide a regasification capacity of 720 million standard cubic feet per day and empty a 145 000 cubic meter tanker in approximately 4 days. Each unit has in this case the capacity to regasify about 210 tons per hour or about 240 million cubic feet per day.

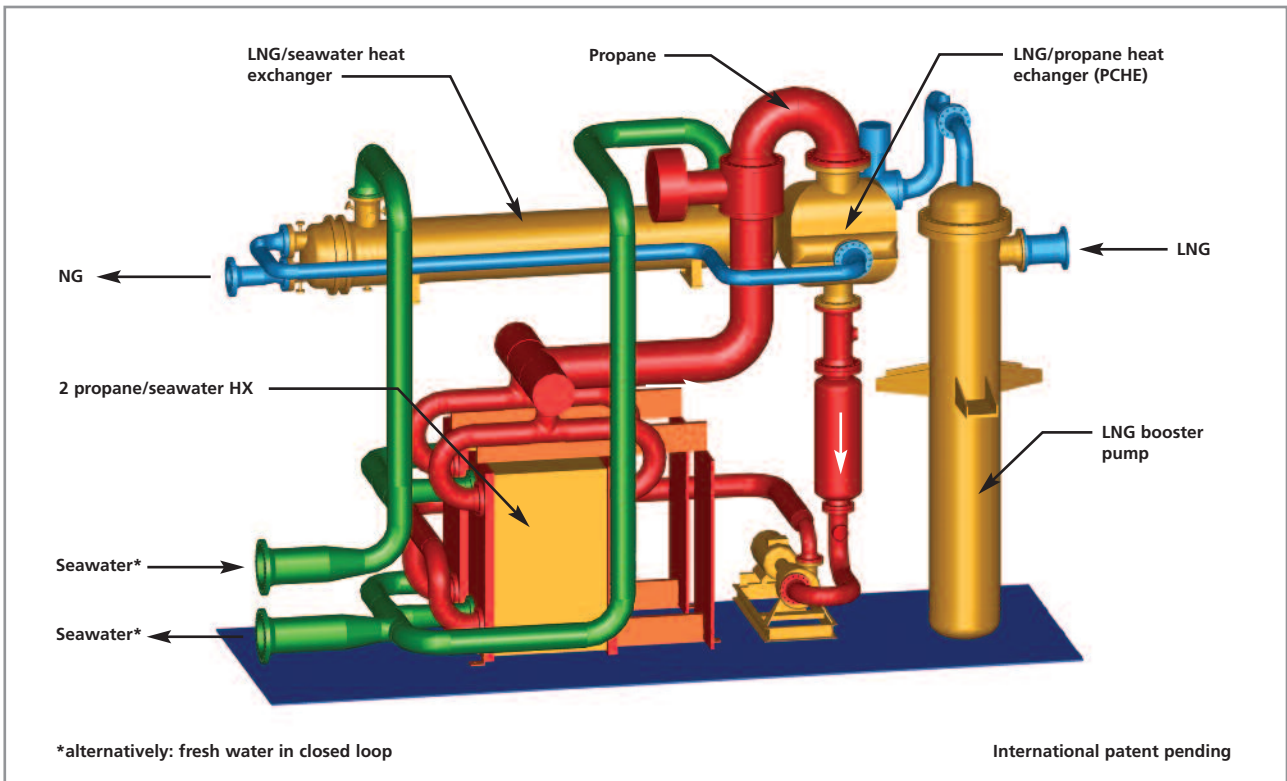
By selecting the appropriate number of units, the send-out capacity can be adopted to the specific needs of a project. The LNG regasification unit by Hamworthy is designed for marine installations and for cryogenic working conditions. Only proven equipment with extensive references has been specified, but since it is a novel design, a small-scale test plant as a joint industry project with Hoegh LNG has been set

up in Norway for the testing of two alternative regasification systems. One using Glycol/Water heated by steam from a ships boiler system, another using a cascade system with Propane and water heating which will give a more compact system.

It is anticipated that future offshore terminals will be attractively close to market areas that have significant variations in the seawater temperature. This has been taken into consideration in the design of the regasification plant.

### Main advantages

- ▶ **A reliable way to regasify LNG with low risks of freezing the system.**
- ▶ **Use of proven equipment with extensive references.**
- ▶ **Operational flexibility with regards to sending out pressure and capacity.**
- ▶ **Compact units.**
- ▶ **Short project implementation schedule, environmentally friendly, cost efficient and a safe solution.**



## Cascade regasification system

In this system, LNG is heated by propane in a closed loop and the propane is heated by seawater. In situations where the seawater is too cold to supply all the required heating energy, additional heat can be introduced.

The cascade concept is recommended instead of directly heat exchanging with seawater. LNG heat exchanged directly with seawater increases the risk of freezing the seawater in the heat exchanger. Propane as a secondary medium is suggested because of its thermodynamic properties with a low freezing point.

A HAZID analysis has been carried out with DNV to identify risks related to the design and operation of the regasification system. For example, it was concluded that the cascade system is a safer system than the pure seawater based. LNG enters a cryogenic pump capable of producing the required send-out pressure (e.g. up to 130 bar has been studied). LNG at the required discharge pressure is heated in two stages.

In the first stage LNG is heated from -160°C to -10°C in a compact printed circuit heat exchanger with propane as a heating medium.

In the second stage, LNG can be heated further using seawater as a heating medium in a shell and tube heat exchanger.

In the LNG/Propane heat exchanger, heat is exchanged against propane circulating in a closed loop. The propane enters the heat exchanger at approx. 0°C at 4.7 bar as gas. In the heat exchanging process propane is condensed, and leaves the exchanger in a liquid state at approximately -5°C. The propane in the closed loop is then pumped by the circulating pump and heated against seawater in titanium semi welded plate heat exchangers. In these heat exchangers, the propane is evaporated and heated to 0°C before returning as gas to the printed circuit heat exchanger.



Artist impression of an LNG FSRU with a Hamworthy regasification plant

## Steam regasification system

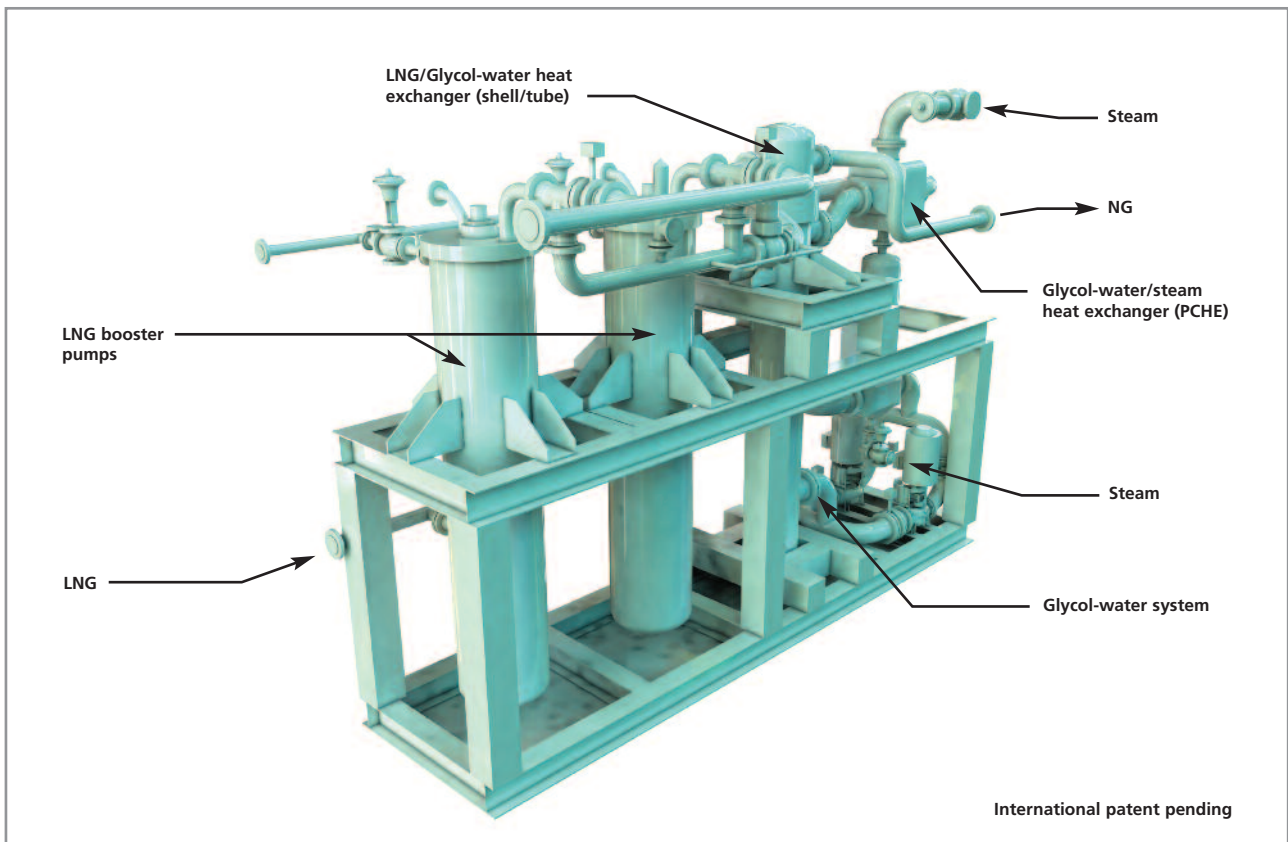


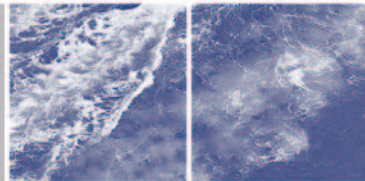
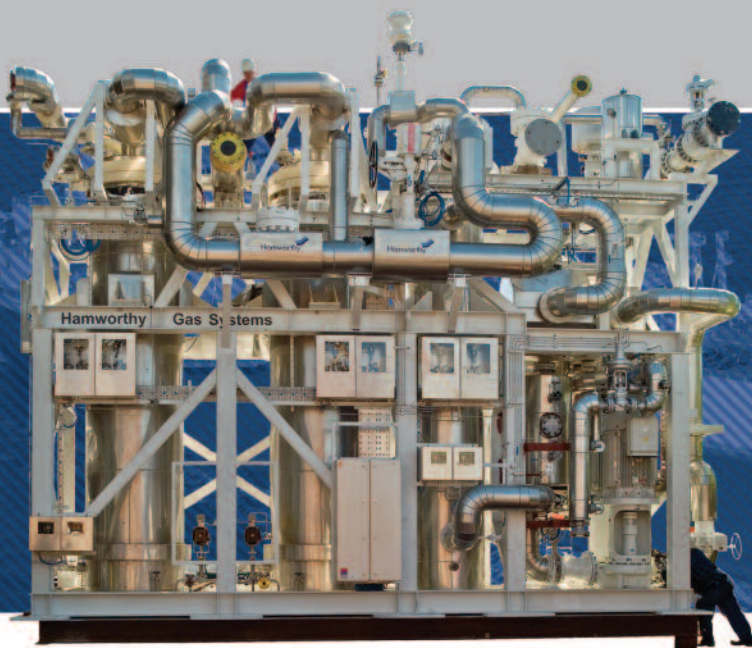
Hamworthy regasification plant for Hoegh LNG/Neptune SRV

Hamworthy has also developed a steam heated system for areas where seawater is not allowed to be used to heat the LNG.

Such systems are contracted to Hoegh LNG SRVs for serving the Neptune offshore terminal at Massachusetts.

Each unit has 2 x 50% booster pumps installed in canisters, designed for a send out pressure of 130 bar. The LNG is then pumped through a shell & tube type heat exchanger heated by a glycol water mixture which is looped through a compact heat exchanger with steam from the SRVs steam system. The natural gas is then passed to the export manifold.





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