

Equipment and Solutions LNG / NG STARVAP[™] REGASIFICATION APPLICATIONS



THE CRYOSTAR GROUP



CRYOSTAR is a cryogenic equipment manufacturer with more than 600 employees including 150 engineers. With its Headquarters located in France, the company operates five production sites and is present worldwide through seven business centers and sixteen business partners.

Founded in 1966 the company has over 40 years experience with LNG and has become the world leader for boil-off gas compressors and on-board liquefaction units for LNG Carriers. The company has delivered thousands of cryogenic pumps for liquid hydrocarbon applications (including methane, ethylene, ethane, etc.)

CRYOSTAR engineers continuously innovate with patented solutions for various applications throughout the LNG supply chain such as small scale liquefaction, LNG transportation, LCNG/LNG vehicle refueling stations and LNG bunkering.



SAFETY AND STANDARDS

Safety is an integral part of CRYOSTAR's management and manufacturing commitments. For each new development or project, the company performs a risk analysis using approved techniques such as HAZOP (Hazard and Operability) and FMEA (Failure Mode and Effects Analysis). CRYOSTAR's equipment and solutions comply with most stringent machine and safety regulations such as the Pressure Equipment Directive 97/23/CE (Module H and H1) and ATEX.



FACTORY AND ON-SITE ACCEPTANCE TESTS

CRYOSTAR's Headquarters host the world's largest and most sophisticated liquid nitrogen test facility for cryogenic pumps as well as three test facilities dedicated to turbines. CRYOSTAR engineers subject each pump and turbine to a performance test prior to shipment, offering customers guaranteed performance. CRYOSTAR provides commissioning, start-up and support for onboard performance testing for LNG Carrier Regasification unit.

QUALITY AND ENVIRONMENT

CRYOSTAR is ISO 9001-2008 certified. To structure its environmental approach, CRYOSTAR has used the ISO 14001 standard to set up all the organizational and operational processes necessary for an aspiring Environmentally Responsible company. In parallel, CRYO-STAR has applied this approach to Health and Safety through the OHSAS 18001 standard. ISO 9001-2008/ ISO 14001-2004 / OHSAS 18001-2007 quality assurance system.





LNG / NG STARVAP[™] REGASIFICATION APPLICATIONS





OVERALL VIEW OF REGASIFICATION BUSINESS

Floating LNG regasification is used to meet fast track project natural gas demand peaks or for smaller markets where costly infrastructure is a limitation.

A FSRU (Floating Storage and Regasification Unit) is a flexible, cost effective method of supplying natural gas for fast track project peak requirements or as an intermediate solution until the shore-based plant is completed.

FSRU's are typically purpose-built based on the design of a regular LNG Carrier, allowing it to still be used as a trading vessel, or by conversion of an existing vessel.

Since the first FSRU in 2002, the market has developed from a niche into a more broadly used business model, with more and more players involved. CRYOSTAR has recognised this as a growth market, and in addition to the traditional Cargo Handling and Fuel Gas supply machinery and systems, has developed technology and processes to support this regasification market.



STARVAP™ – PROCESS DEVELOPMENT

CRYOSTAR continuously develops new technologies for LNG applications. Regasification has been highlighted as one of the key future markets.

In order to demonstrate the technology as well as development and studies of the process control, a scale 1/40th capacity pilot plant was constructed in our facility to perform this work.

Main Characteristics: ★ Flow: 8t/h **PILOT PLANT *** Pressure range: 30 to 70 bar ★ Vaporized Fluid: LN, **Fresh Water** ★ Heating Medium: **★** Heating type: **Intermediate Propane Loop** ★ Heating Power: **1 MW** Experience gained from this Pilot Plant: ★ Demonstration of Regasification with propane loop ★ Controlled through a Remote I/O system similar to IAS Integration onboard a ship * Pressures, temperatures, levels, flows were monitored during the test **★** Trends were recorded for better process analysis & control improvment ★ Ramp Up/Down, Start/Stop functions were validated Performance target achieved

STARVAP[™] – TECHNOLOGY VALIDATION



In cooperation with DNV (DET NORSKE VERI-TAS), CRYOSTAR has validated the Propane & Glycol Water Intermediate Loop technology through an A.I.P. (Approval In Principle).

This program has resulted in a review of key aspects of the design and equipment, in order to ensure compliance with Class rules.

In addition CRYOSTAR has produced a risk analysis in accordance with World Class Safety Requirement.





Technology	Assessment of ECOVAP regas system
	CRYOSTAR MAS
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OVERALL SOLUTION FOR LNG VESSEL

« One Stop Shop » for a complete integrated solution, from the management of the BOG to the NG Send-Out Header.

Flexibility of this concept is based on 250 MMSCFD per train, with additional trains according to requested capacity. The range of operation of each unit is from 20% to 100%.



STARVAP[™] LNG / C3 – PROPANE INTERMEDIATE LOOP

Propane as a heating medium, why?



- * Not toxic or forbidden by Montreal Protocol like Fluoro compounds.
- ★ Highly Flammable (F+) fluids excluded
- ★ Propane available on a large scale
- ★ Propane does not have any freezing issue
- ★ Tolerant of wide sea water temperature range





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STARVAP[™] LNG / GW – GLYCOL INTERMEDIATE LOOP

Glycol as a heating medium, why?

- ★ Non flammable product
- ★ Lower safety impact
- ★ Widely available Glycol
- ★ Flexible operation
- ★ Easy to install

PCHE = Printed Circuit Heat Exchanger PHE = Plate Heat Exchanger S&T = Shell & Tube Heat Exchanger





MODULAR DESIGN

Packages and Modules for Regasification & Liquefaction are delivered to our Clients. These packages are based on in-house know-how which makes CRYOSTAR a world leading company.

In order to comply with the demanding constraints of the modern day market, we have dedicated our resources to develop a top notch modularization strategy, simplifying installation activities and decreasing construction cost and time for Client.



LNG / NG STARVAP[™] REGASIFICATION APPLICATIONS

BENEFITS OF MODULAR DESIGN

CRYOSTAR has selected worldwide partners able to manufacture modules close to Shipyard.

Benefits of Modularization:

★ Pre-engineered process solutions and a modularized design approach to accomplish shortest delivery time with minimum on-site construction.

★ Applying toolbox approach to ease module customization while maintaining the benefits of standardization.

The idea of StarVap[™] is to standardize and optimize a regasification LNG / NG Off-Shore Unit based on a wide set of process variations.

This "Process Toolbox" is designed to cover about 90% of real-life boundary conditions, with the following major benefits:

★ Safety as for world class LNG (QRA, HAZOP codes & standards)

- ★ Fast-track time schedule (reduction by up to 2 months)
- ★ Reduction of CAPEX
- ★ Highly efficient process, easy to operate (lowest OPEX)
- * Modularized units for process and main pipe racks

LOWER CAPEX \star LOWER OPEX \star EASY INSTALLATION



Prefabricated Recondenser Module

ONE SINGLE REGAS MODULE

CRYOSTAR is able to develop a tailor-made solution for retrofit of LNG Carrier with One Single Module integrating the capacity of several train and recondenser. Our Clients turn to CRYOSTAR for modular construction solutions when building offshore facilities.

These projects are often in challenging locations and require innovative execution approaches. In breaking new ground in modular construction, CRYOSTAR has developed sophisticated methods of identifying modules, developing module specification packages, auditing fabricators' design, conducting inspections, planning and coordinating transportation of the modules at the project shipyard.



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DE-RATING & STEAM MAKE-UP HEATING

Cryostar can produce specific curves like de-rating tools and steam heating system requirement in case of sea water condition evolution.



Sea Water temperature (°C)



Heater Capacity (%) 100 80 60 CLOSED OPEN LOOP COMBINED LOOP LOOP (Steam Heaters Off) (Sea Water heaters off) 40 20 10 25 20 15 5 0 Sea Water Inlet temperature (°C) Steam Heaters SW Heaters

STEAM HEATING SYSTEM REQUIREMENT



BOG RECONDENSER

The BOG Recondenser is able to treat all or part of the vapour from the BOG compressors, with the recovered liquid added to the feed for the HP booster pumps.

The Recondenser consists of a vertical vessel containing a number of packed screen elements. The BOG and part



of the send-out liquid are introduced to the vessel, and through a direct contact reaction, perform the recondensing function.

Control is simple and stable operation can be managed automatically.

The Recondenser can be isolated from the system during maintenance, while the surplus BOG treated by the vessel's GCU without affecting the vessel's send-out capability."



Caring for your equipment for 40 years

Since the production of equipment began in 1967, CRYOSTAR has always emphasised the need to support the end-user for the life of the equipment.

In the world of marine applications, the reliability and efficient operation of the equipment is mission critical. This is why CRYO-STAR allocates each vessel to a single point of contact for most efficient servicing, parts supply and technical back-up.

Many end-users benefit from our maintenance agreements when it comes to dry-dock servicing. Dedicated spare part kits ensure that no critical parts are missing during this time-pressured period off-hire. Routine and major servicing can be handled by our large team of technical experts anywhere in the world.

Unplanned maintenance interventions are always a challenge, with the vessel presenting a moving target. It requires skill, patience and immense co-operation to achieve seamless service under these circumstances. CRYOSTAR's service team is geographically distributed, affording quick reaction times wherever you may be, and the 24h service line means that you are guaranteed a response.

Most equipment only needs servicing at 5 and 10 year intervals, so it is key that the organisation is well planned and our team is always ready to work with you to define a course of action.





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