



Equipment and Solutions

NATURAL GAS AND SMALL SCALE LIQUEFACTION APPLICATIONS

StarLiteLNG™
liquefaction systems



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 eight business centers and 16 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's engineers continuously innovate with patented solutions for various applications throughout the LNG supply chain such as small scale liquefaction, LNG transportation, LNG/LCNG 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.

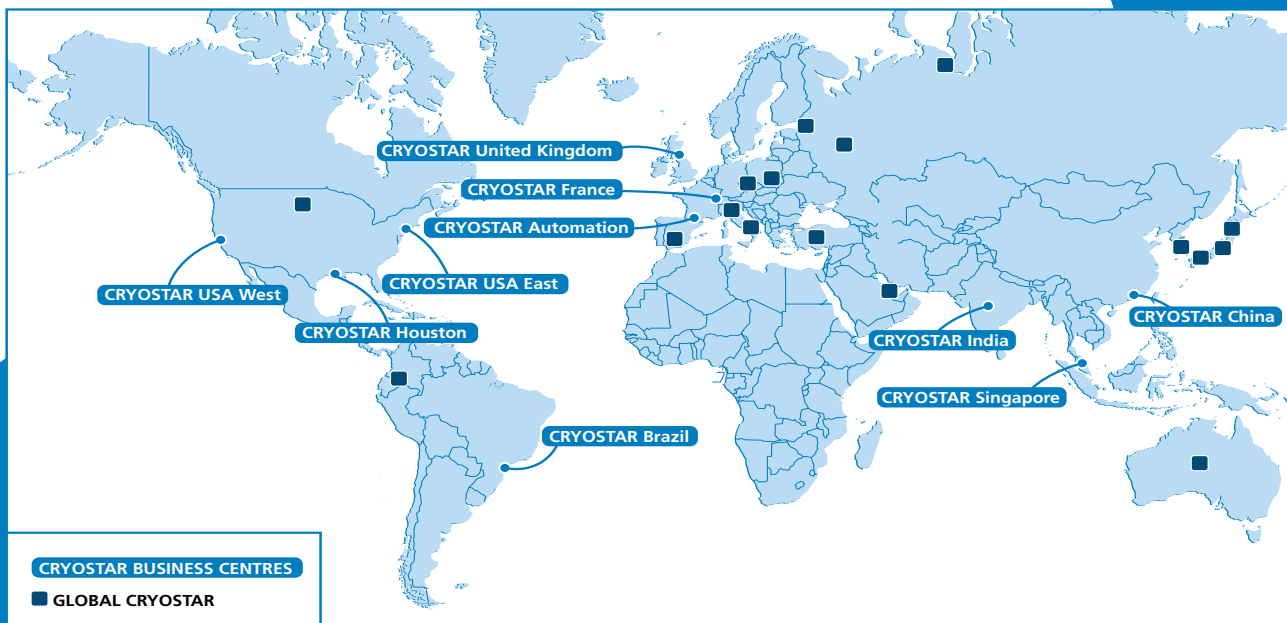


FACTORY AND ON-SITE ACCEPTANCE TESTS

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 onsite performance testing for liquefaction plants and refueling stations.

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, CRYOSTAR 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.

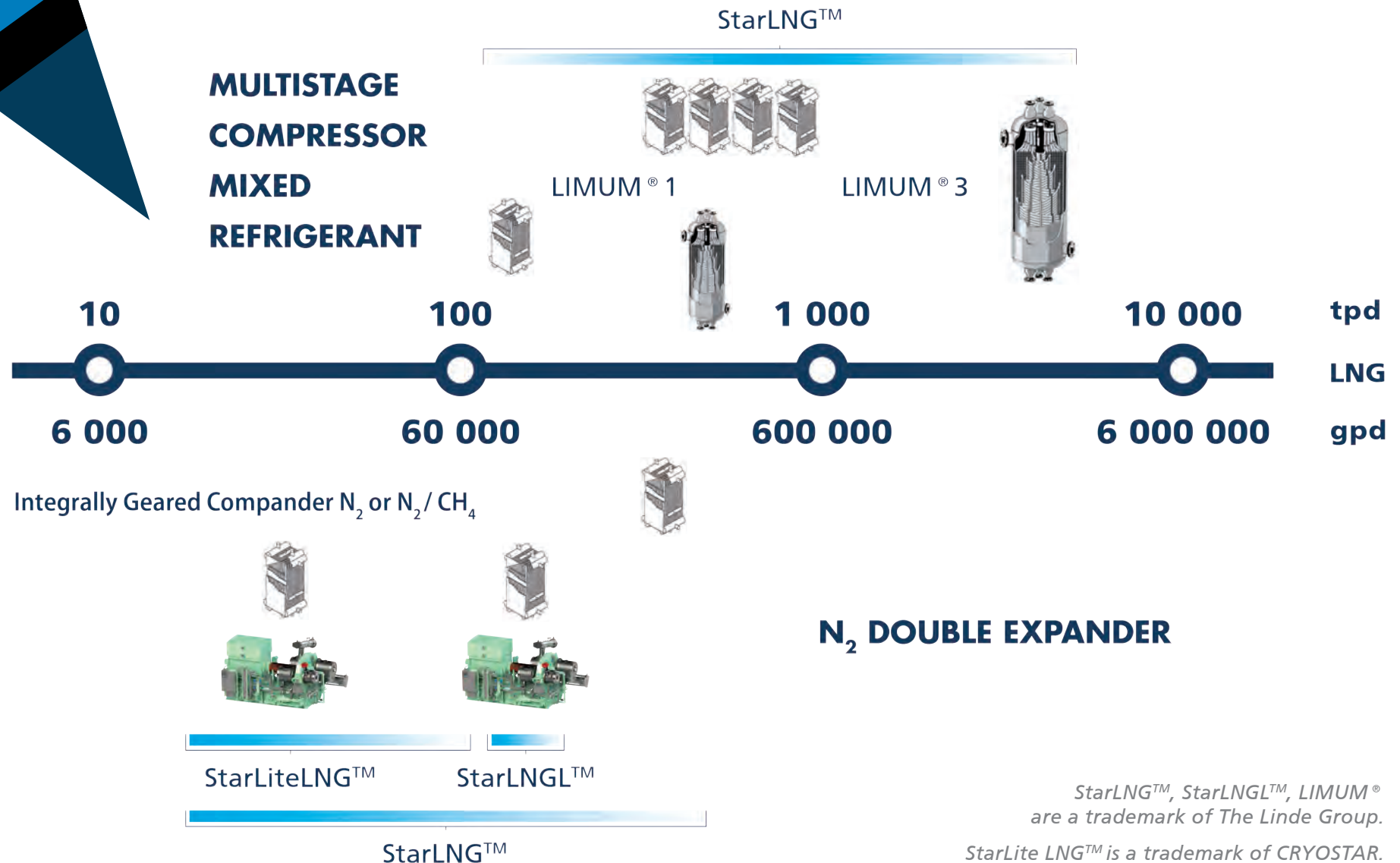






CRYOSTAR StarLiteLNG™ from the LINDE StarLNG™ family

At CRYOSTAR, we have the requisite operational and industrial experience to have a global understanding of your challenges in monetizing natural gas. Based on your specific environment and objectives, we create flexible solutions based on our wide portfolio of natural gas liquefaction technology, "StarLite LNG™."



StarLNG™, StarLNGL™, LIMUM®
are a trademark of The Linde Group.

StarLite LNG™ is a trademark of CRYOSTAR.

Hands-on experience with small to mid-scale plants with StarLNG™



SMALL-SCALE



120 tpd
(~70,000 gpd)

Bergen, NORWAY



MID-SCALE



900 tpd
(~530,000 gpd)

Stavanger, NORWAY

SMALL-SCALE



21 tpd
(~12,000 gpd)

Altamont, USA



SMALL-SCALE



175 tpd
(~100,000 gpd)

Kwinana, AUSTRALIA





CRYOSTAR's first liquefaction units: Boil-off gas systems on LNG carriers

Capacity ~**7 tonnes per hour** (turn down ratio ~30%),

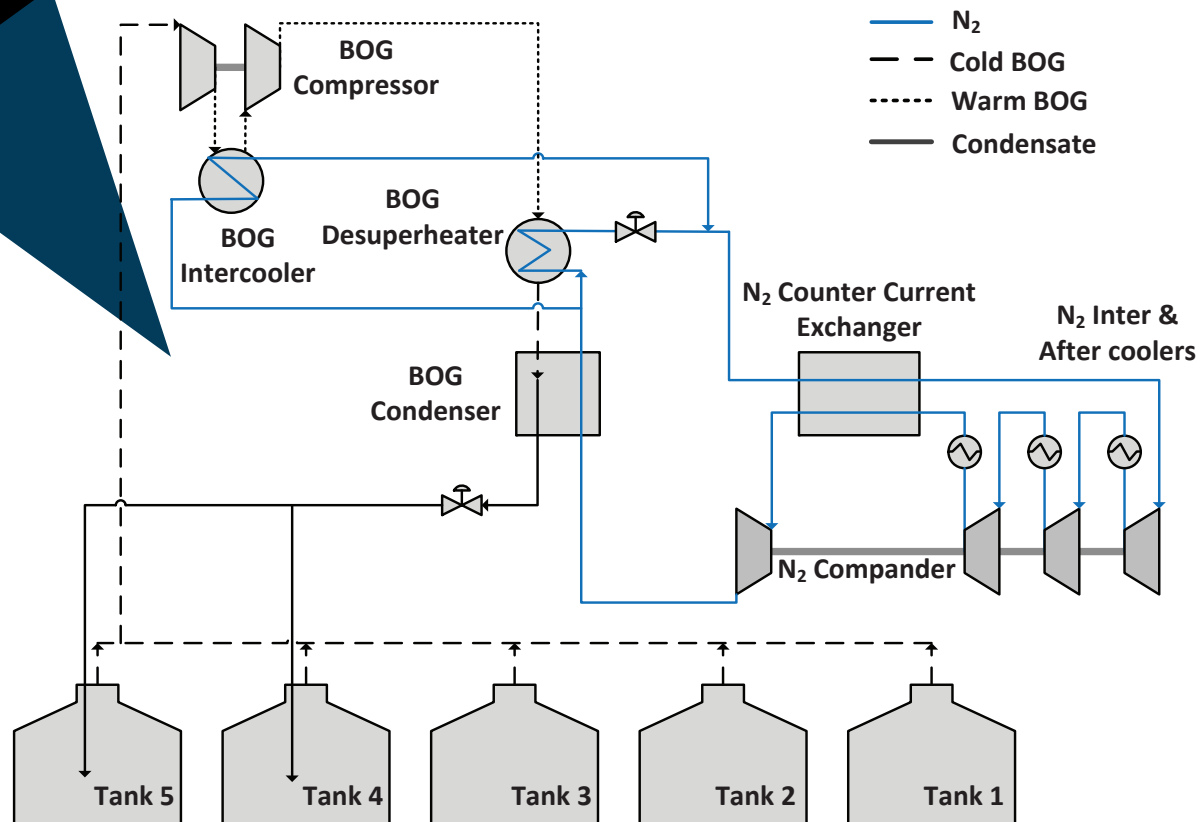
Following an extensive development program CRYOSTAR's Ecorel process was **selected for installation on the world's largest LNG carriers Q-Max to the Qatar Gas Transport Company.**

The capacity of these vessels, 266'000 m³, exceeds by far all that of all other LNG vessels ever built

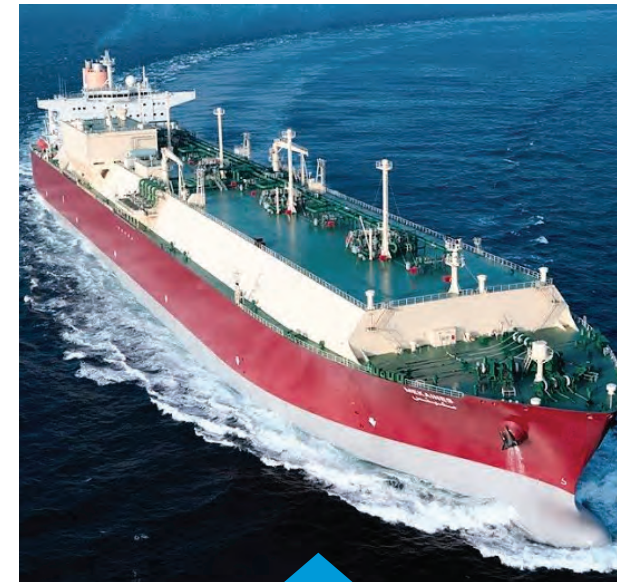
More than **150,000 hours of combined operation (100 to 120 journeys)**

2 x 14 units on Q-Max LNG carriers. In operation since 2008, 187 tpd

2 x 4 units to MOL for PNG LNG project, operational from 2015



Process flow diagram for boil off gas re-liquefaction onboard tankers



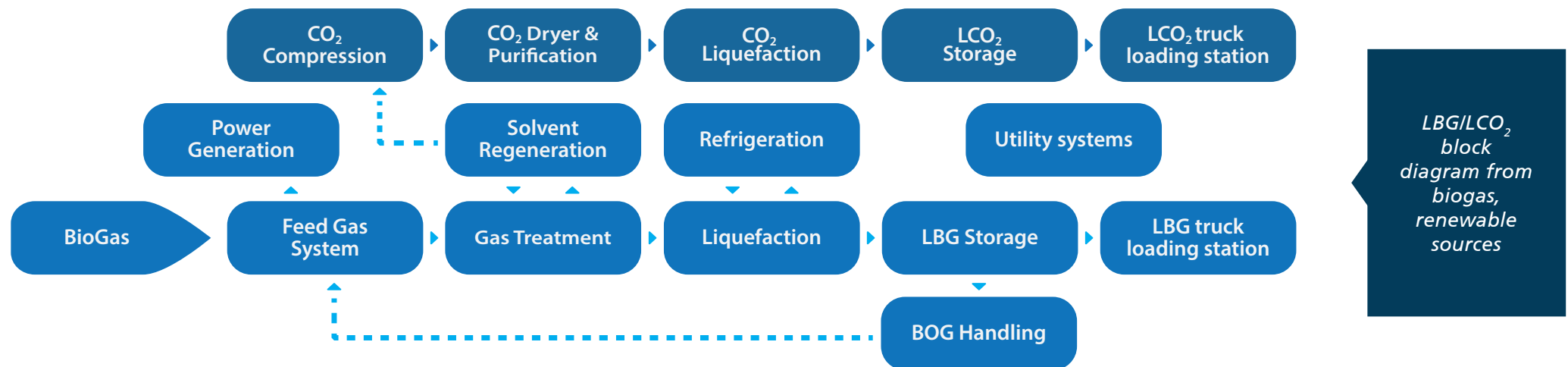
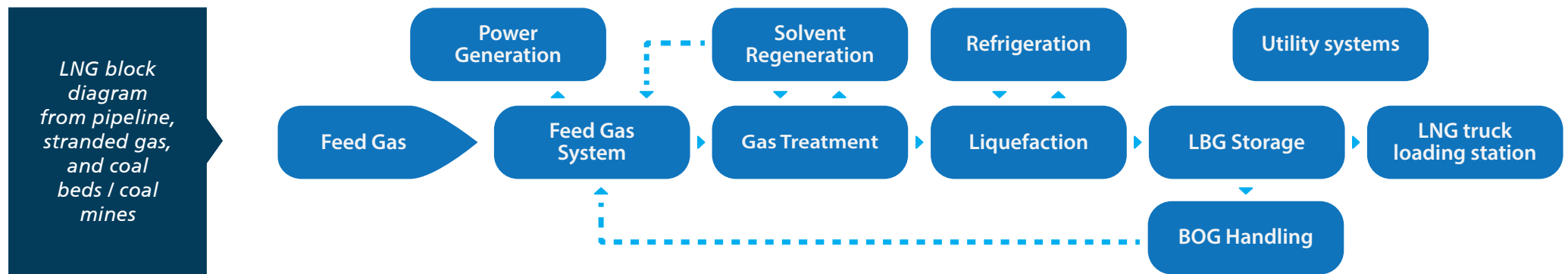
A Q-Max LNG carrier with 266'000 m³ of LNG cargo capacity, arrives in the UK to unload its cargo.

IMAGE QatarGas

StarLiteLNG™ - small scale liquefaction system

Based on its experience with the boil off gas re-liquefaction systems onboard LNG carriers, CRYOSTAR developed and now offers, through its StarLiteLNG™ family product, small scale LNG or LBG plants for onshore natural gas or biogas liquefaction applications with capacity from 20 to 200 tonnes per day (17 to 124 k GPD).

CRYOSTAR focuses on a skid-mounted liquefaction unit. For additional packages such as gas treatment, polishing and balance of plant, we offer a solution in collaboration with customers and our network of partners.





StarLiteLNG™ toolbox

The idea of StarLiteLNG™ is to standardize and optimize a small scale LNG system from 20 to 200 tonnes per day (17 to 124 k GPD) based on a wide set of process variations. The toolbox is designed to cover about 90% of real-life boundary conditions, with the following major benefits:



SAFE

No flammable or toxic refrigerant storage for simpler regulatory compliance and less time to LNG production.

FINANCEABLE

CRYOSTAR has produced cryogenic machinery for 40 years and has a strong parent company with investment grade credit rating.

FLEXIBLE

Turn down to 30% of design volume as required, for instance to avoid high demand charges from utilities.

RELIABLE

Highest in-house content thanks to complete engineering, manufacturing and commissioning of the liquefaction module, including core components. Wide range of services including global maintenance facilities near our customers.

SIMPLE

A straightforward process control based on a single turbomachine (compander) in the refrigeration system. Automatic load control in a range of ambient conditions, gas compositions, pressures and temperatures.

ECONOMICAL

High efficiency expansion and compression processes minimizes power consumption. Lowest equipment count minimizes installation and maintenance expenses.

INNOVATIVE

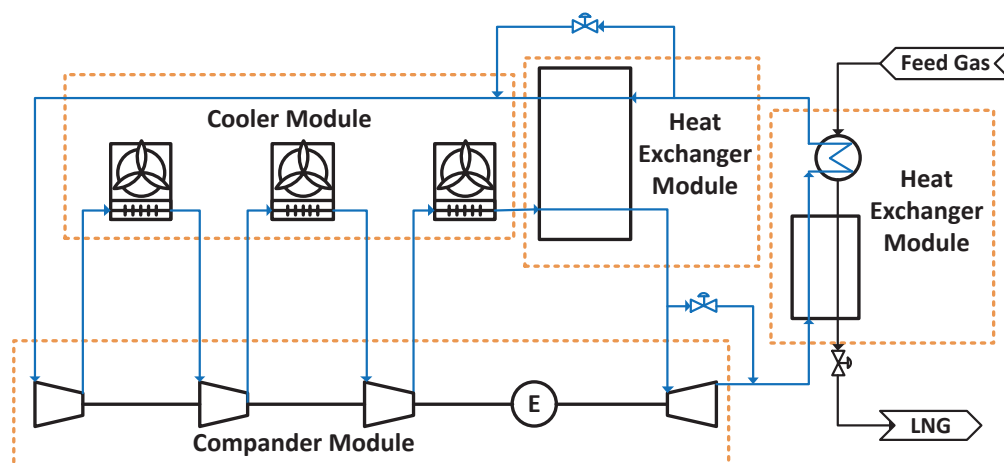
CRYOSTAR continuously improves its product offering through strong R&D investment and by leveraging the knowledge of its parent company. StarLiteLNG™ products portfolio is the latest extension of the Linde StarLNG™ family of liquefiers.

StarLiteLNG™ liquefier models and Nitrogen process toolbox

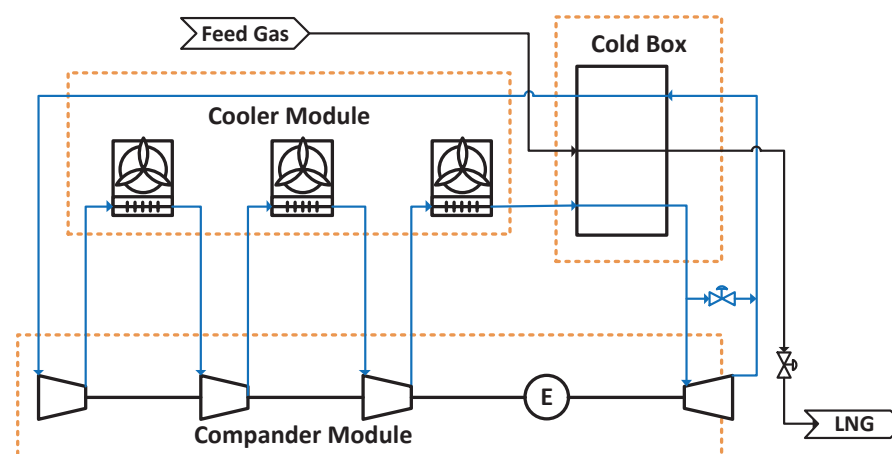
Simple, robust and easy-to-operate process with a nitrogen reverse Brayton closed loop, based on CRYOSTAR and Linde's proven technology and equipment.

LIQUEFIERS MODEL	CAPACITY		HEAT EXCHANGER		SPECIFIC POWER CONSUMPTION at 100% capacity	LIQUEFIER FOOT PRINT w/o Air coolers	
	TPD, metric (1)	K GPD (2)	Number	Configuration		m	ft
XS	28	17	2	2 skids	1,1	30 x 15	100 x 50
S	50	31	1	cold box	1,0	20 x 15	65 x 50
M	88	54	1	cold box	0,8	20 x 15	65 x 50
L	125	76	1	cold box	0,7	20 x 15	65 x 50
XL	200	124	1	cold box	0,6	20 x 15	65 x 50

(1) Varies with project specifics (2) Thousands of US gallons per day



Process diagram for XS liquefier

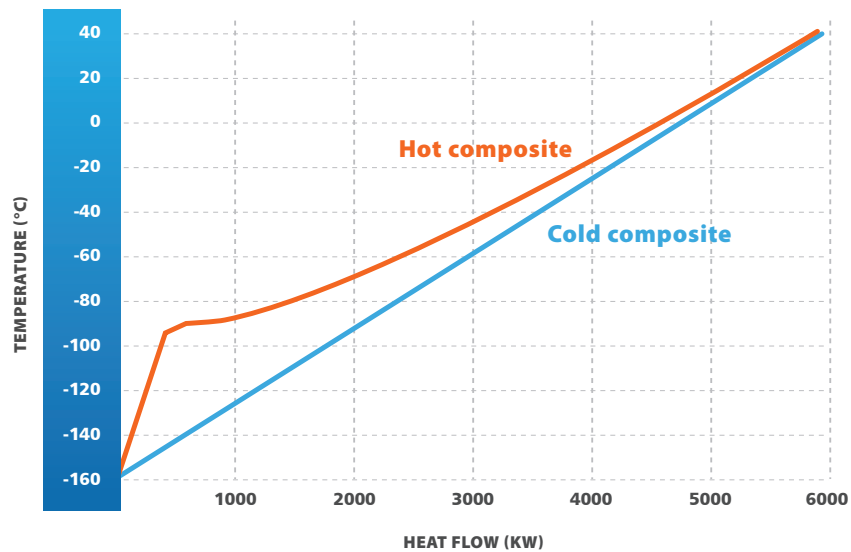
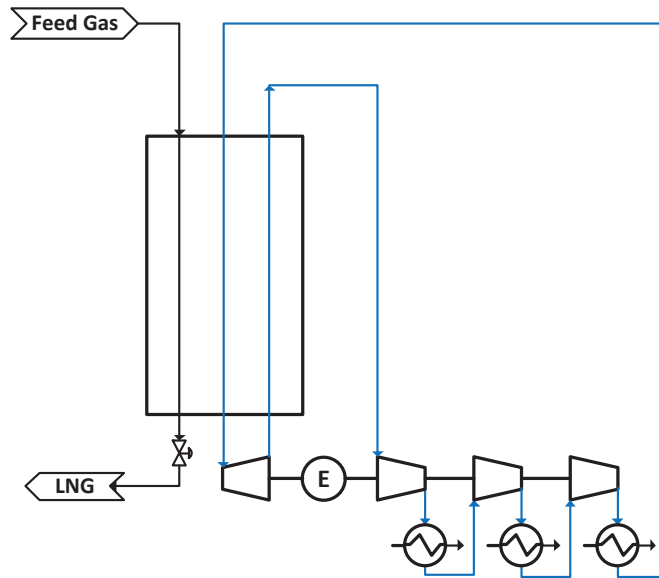


Process diagram for S, M, L, XL liquefier

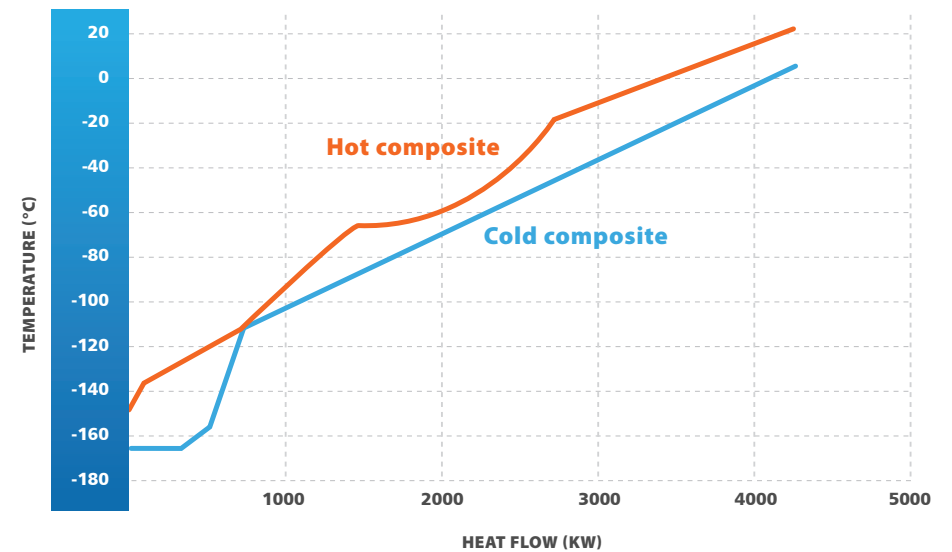
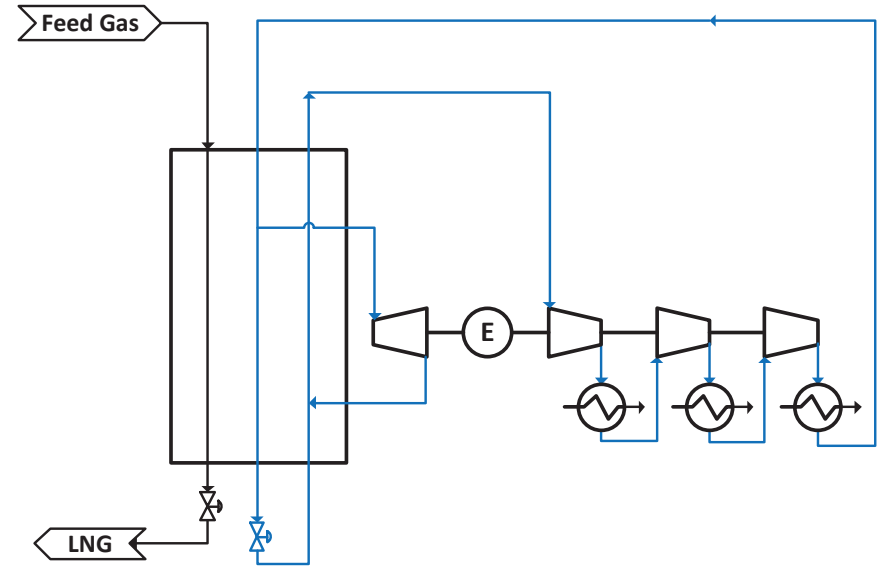


StarLiteLNG™ liquefier models and Nitrogen process toolbox

Single stage N_2 process with compander

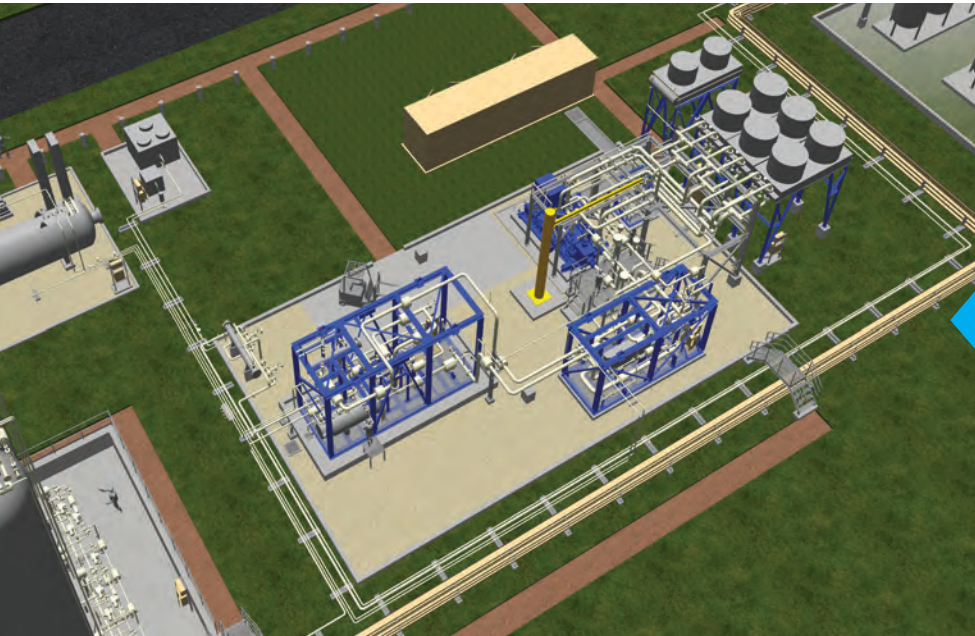


Dual stage N_2 process with compander + JT valve



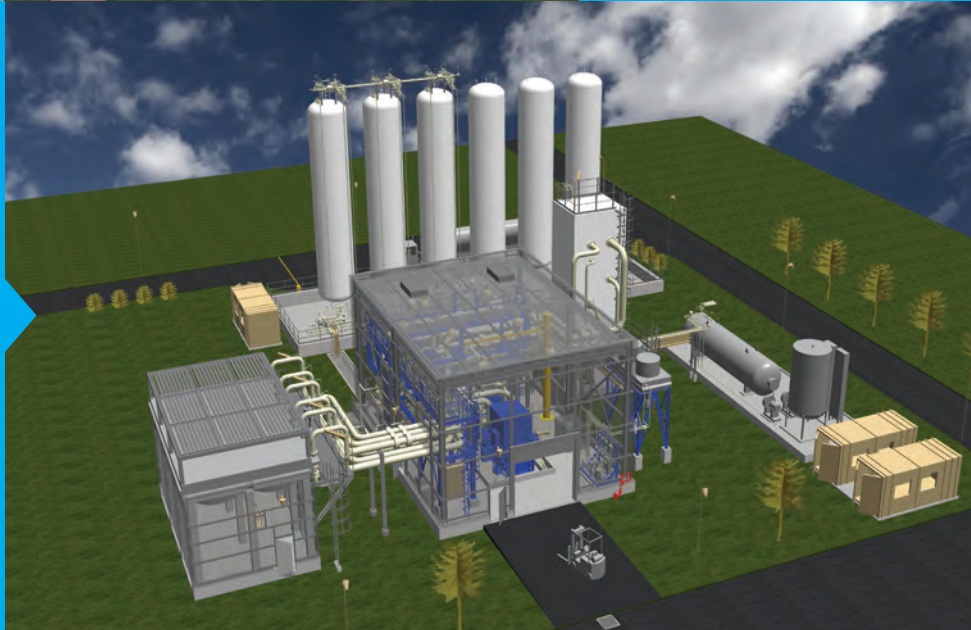
StarLiteLNG™ plant overview

- Pre-engineered process solutions and a modularized design approach to accomplish shortest delivery time with minimum on-site construction.
- Applying toolbox approach to ease plant customization while maintaining the benefits of standardization.



Outdoor
concept and
3D overview,
for **model XS**

Winterization
concept and
3D overview,
for **model L**



CONTENT OF TOOLBOX

Set of generic documents prepared and validated for the base case including :

- ★ **BASIS OF DESIGN**
- ★ **PFD**
- ★ **PROCESS DESCRIPTION**
- ★ **PID AT PRELIMINARY STEP**
- ★ **SAFETY CONCEPT REQUIREMENT**
- ★ **WINTERIZATION CONCEPT**
- ★ **PLOT PLAN**
- ★ **3D MODEL**
- ★ **MODULARIZATION DESIGN**
- ★ **MTO STEEL STRUCTURE**
- ★ **MTO PIPING**
- ★ **EQUIPMENT LIST**
- ★ **VALVE / INSTRUMENTATION LIST**
- ★ **OPTIMIZED PLANT LAYOUT CONCEPT + COLDBOX**
- ★ **CONCEPTUAL HAZID**
- ★ **MASTER PROJECT SCHEDULE**



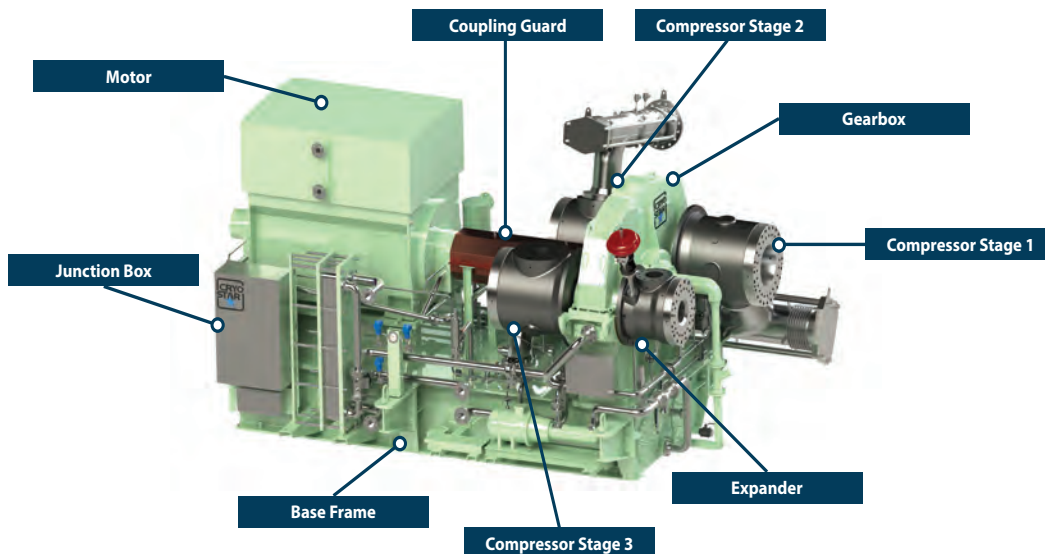
StarLiteLNG™ compander machine

A compander is a combined expander and compressor in a single, integrally-gearred machine installed in the refrigerant cycle. CRYOSTAR built the first compander in 1996.



Compander with water cooling system for marine applications

- ★ 3 compression and 1 expansion stages mounted on a common motor driven speed increasing gearbox. Expander power is recovered and reduces drive motor consumption.
- ★ Lube oil and seal gas system (25 to 45 Nm³/h of N₂ consumption)
- ★ Motor with medium voltage requirement
- ★ PREVENTATIVE MAINTENANCE
2 days per year and 14 days every 35,000 operating hours (4-5 years)



Compander during final test in CRYOSTAR test bench hall

Truck loading station and equipment



LOADING AND OFFLOADING SOLUTIONS

Skidded unit

- ★ CRYOSTAR centrifugal pump with external or submerged motor
- ★ ATEX skid with piping, valves, instrumentation and safety devices
- ★ ATEX control panel
- ★ Manual or full automatic execution

Interface panel

- ★ Control box with start/stop buttons, lights, pressure and level indicators
- ★ Automatic management of trailer offload process which ensures higher safety
- ★ Accessibility to the trailer flexible hose outside of the equipment area
- ★ Possibility to have a wired connection with trailer for higher safety

Metering skid

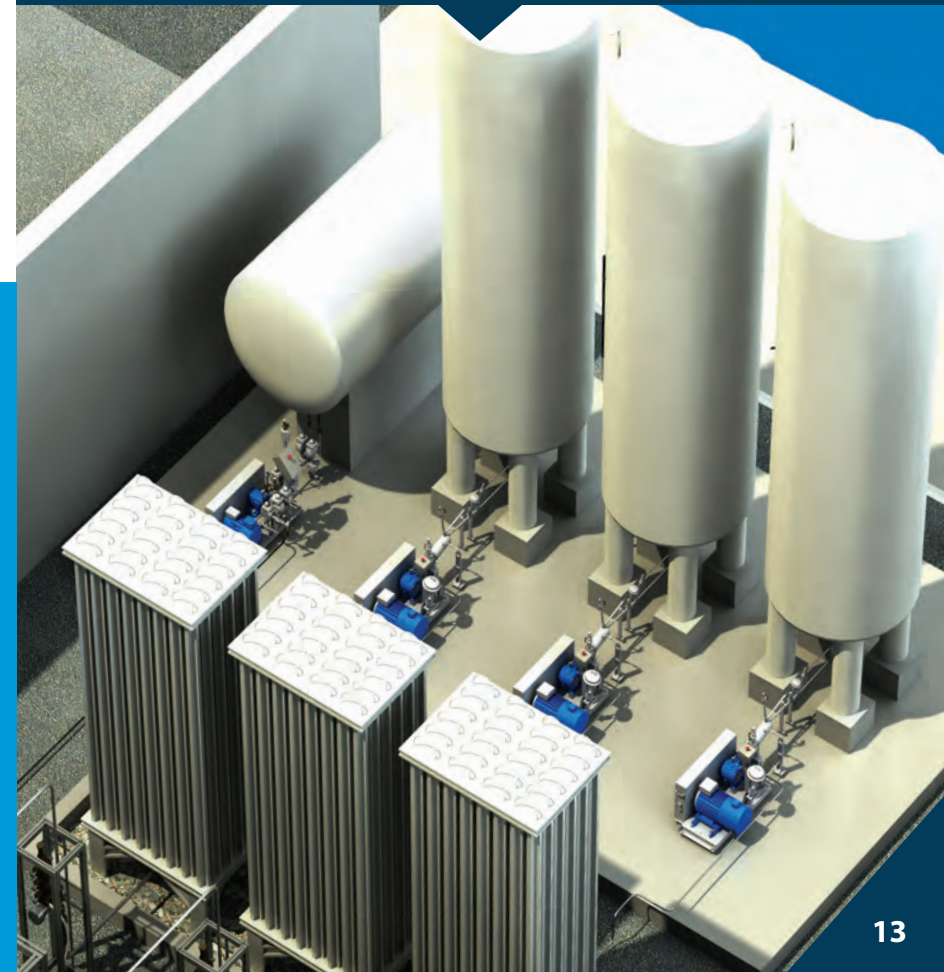
- ★ Coriolis technology based on flow management
- ★ Weights and Measures approval option available
- ★ Measurement of loading and gas return flows

PEAK SHAVING SYSTEMS

The peak shaving system allows natural gas to be stored and supplied on demand in case of increasing gas consumption, or gas supply outages from the natural gas grid.

These systems usually require very high flows, as well as medium to high pressure. Once the LNG is pressurized, it is sent to the vaporizers before

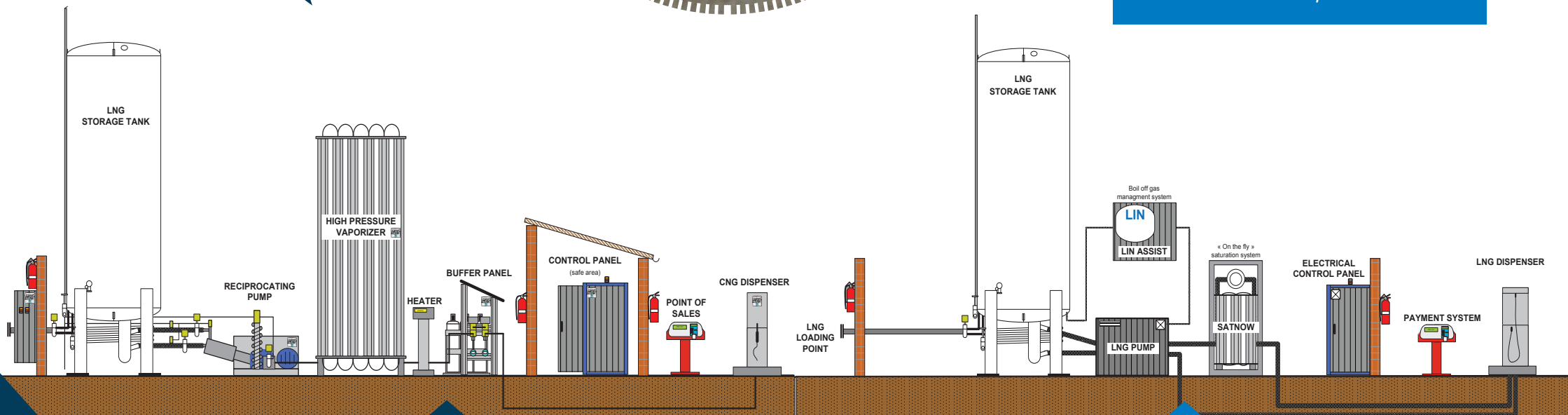
being injected into the grid. As part of our LNG systems portfolio, CRYOSTAR offers trailer unloading pumps, booster pumps, reciprocating high pressure pumps, as well as complete PLC controls solutions and cryogenic process consultancy to meet customers' requirements in terms of plant performance and reliability.





LNG / LCNG refueling stations

CRYOSTAR
equipment in
Rolande LNG
station, Tilburg
(The Netherlands)



Turbo expander/compressor for cold production in LNG processes

Turbo expander with compressor mounted on a common shaft with a large range of cold production, pressure and flows are available from the TC120, ~ 50 kw to the TC600 up to 8 MW.

Usual gases handled : air, nitrogen, or waste gas from air with high oxygen or with CO, CO₂ (Sour) Natural Gas, H₂ & CH₄ mixtures, LNG, NGL, LPG.

CRYOSTAR designs all turbo expander packages to the strict industry and client requirements for various process refrigeration cycles.

Today, CRYOSTAR's installed base, including industrial gas machines, exceeds more than 1,200 turboexpanders located in more than 60 countries worldwide.





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INDIA

SINGAPORE

UK

USA

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