

more than
CRYOGENICS

HYDROCARBON TURBO-EXPANDERS

FOR NATURAL GAS, PETROCHEMICAL & POWER GENERATION APPLICATIONS

★ **PROCESS MACHINERY**
CRYOSTAR



more than
CRYOGENICS

THE CRYOSTAR GROUP

As a pioneer in the design and manufacture of cryogenic equipment, CRYOSTAR started out in 1967 producing cryogenic pumps for liquefied industrial gases. The company has become a major actor in the field of industrial and medical gases, clean power generation, LNG and hydrocarbon applications. CRYOSTAR brings to you over 50 years of experience and know-how.

With its headquarters located in France and Business Centers in Brazil, China, India, Singapore, the United Kingdom, and the United States of America, along with numerous partners, CRYOSTAR is always close to customers, available and ready to act. CRYOSTAR employs close to 650 people all over the world. They are CRYOSTAR's strongest asset. Together they share the same values to support the company towards ever greater innovation, technology and knowledge.

CRYOSTAR has equipped thousands of plants. Cryogenic pumps, expansion turbines, cryogenic compressors, small scale liquefaction plants, LNG vaporizers, cylinder filling stations, and natural gas fueling stations... these are at the heart of CRYOSTAR's products range.

To optimize your plant availability and consequent uptime, CRYOSTAR also offers full servicesolutions: on-site installation and commissioning based on strict safety standards (24/7 technical support, service contracts, on site training support), maintenance and repair (technology updates, factory and on-site maintenance agreements), as well as equipment lifelong recurrent and uptodate training sessions. Through our locations based on all continents, we make sure there is always a CRYOSTAR helper near you.

★ Innovate

★ Take up challenges

★ Have a passion for excellence

★ Be generous in what we do

★ Respect and empower our people

★ Act with integrity

VISION VALUES



We are a leading innovative company, sustainably providing proactive customer service, supported by a strong culture encompassing skilled and engaged personnel.

Samuel ZOUAGHI
President

Headquarters in France



WORLDWIDE PRESENCE

Since the production of equipment began in 1967, CRYOSTAR has always emphasized the need to support the end-user for the life of equipment. Our machines are built to last; it is our priority to maintain high Quality throughout the lifetime of our products.

For each new project, a Service engineer will be assigned to help you plan commissioning activities. CRYOSTAR is also capable of offering customized service contracts to help you run our equipment at maximum efficiency.

In case of unplanned maintenance, CRYOSTAR's service team is geographically distributed, offering quick reaction times wherever you may be, and the 24h service line guarantees that you will get a response.

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



INNOVATION

At CRYOSTAR, innovation is at the heart of everything we do, not just for teams dedicated to Research & Development, but also for teams who work every day to design the equipment we sell.

A community of Experts, Specialists and Referents also capitalizes on their own experience and the feedback received from customers to continue to innovate.



more than
CRYOGENICS



PRODUCTION AND TESTING

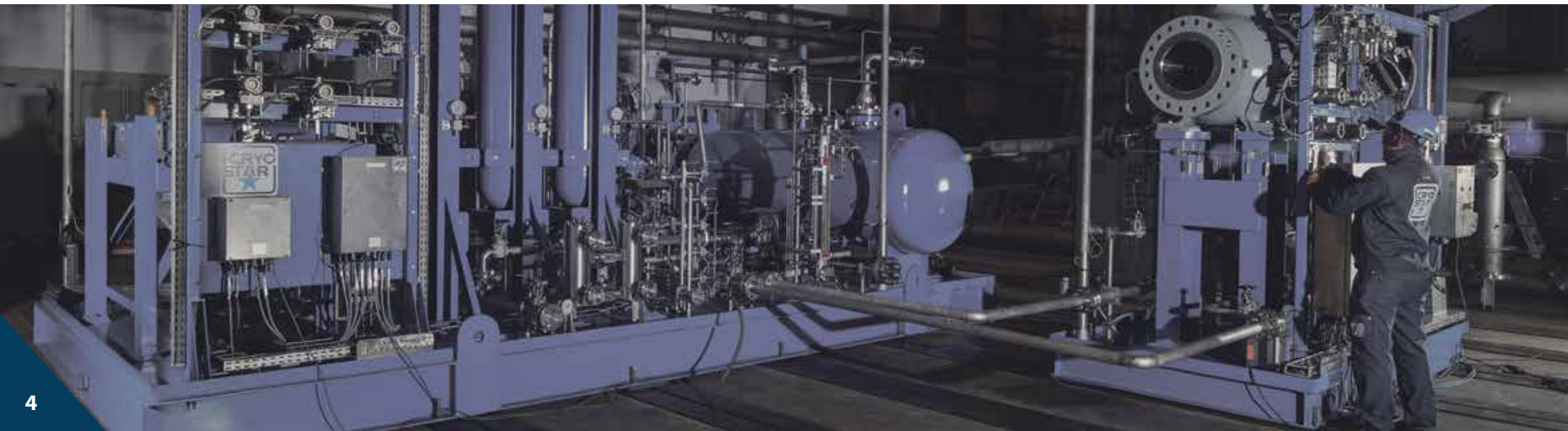
All our hydrocarbon expanders are manufactured and tested in our French HeadQuarters.

Critical parts are sourced from West-European suppliers and are subject to stringent quality control. CRYOSTAR warehouse has thousands of reference in stock and is equipped with an Automated Storage & Retrieval System.

Our production team employs 150 qualified workers located in 3 production halls among which the largest one is equipped with a 50 ton heavy crane lift.

All our machines are tested in accordance with API 617 and ASME PTC10 standards in one of our 2 test benches. Our 3.8 MW air compressors can deliver up to 38 000 Nm³/h of air when connected together.

For specific project requirements, CRYOSTAR has also the capability to package skid assembly overseas, in our North American or Chinese workshops.



HEALTH, SAFETY, ENVIRONMENT

CRYOSTAR's HSE policy is based on a double certification: **OHSAS 18001 and ISO 14001** (V2015).

This structuring approach made it possible to anchor continuous improvement in the company's culture.

CRYOSTAR guarantees its machines' compliance with customer specifications and the regulations in the country where they are installed to enable customers to operate equipment with complete confidence. **Safety of both property and people is our priority.**

CRYOSTAR is **committed to the social and societal area for its employees' well-being**. Therefore, diversity, balance and well-being at work, are notions which CRYOSTAR views as being of vital importance through targeted actions at the heart of its human resources policy.



QUALITY

The Quality department features a large and highly qualified multi-disciplinary team, which is involved in implementing Quality strategy in areas of the utmost importance:

- ★ Metrology / Quality System
- ★ Supplier Quality
- ★ Operational Quality
- ★ Engineering Quality
- ★ Product Safety



TRAINING

CRYOSTAR Training Center offers training sessions adapted to all the equipment and solutions.

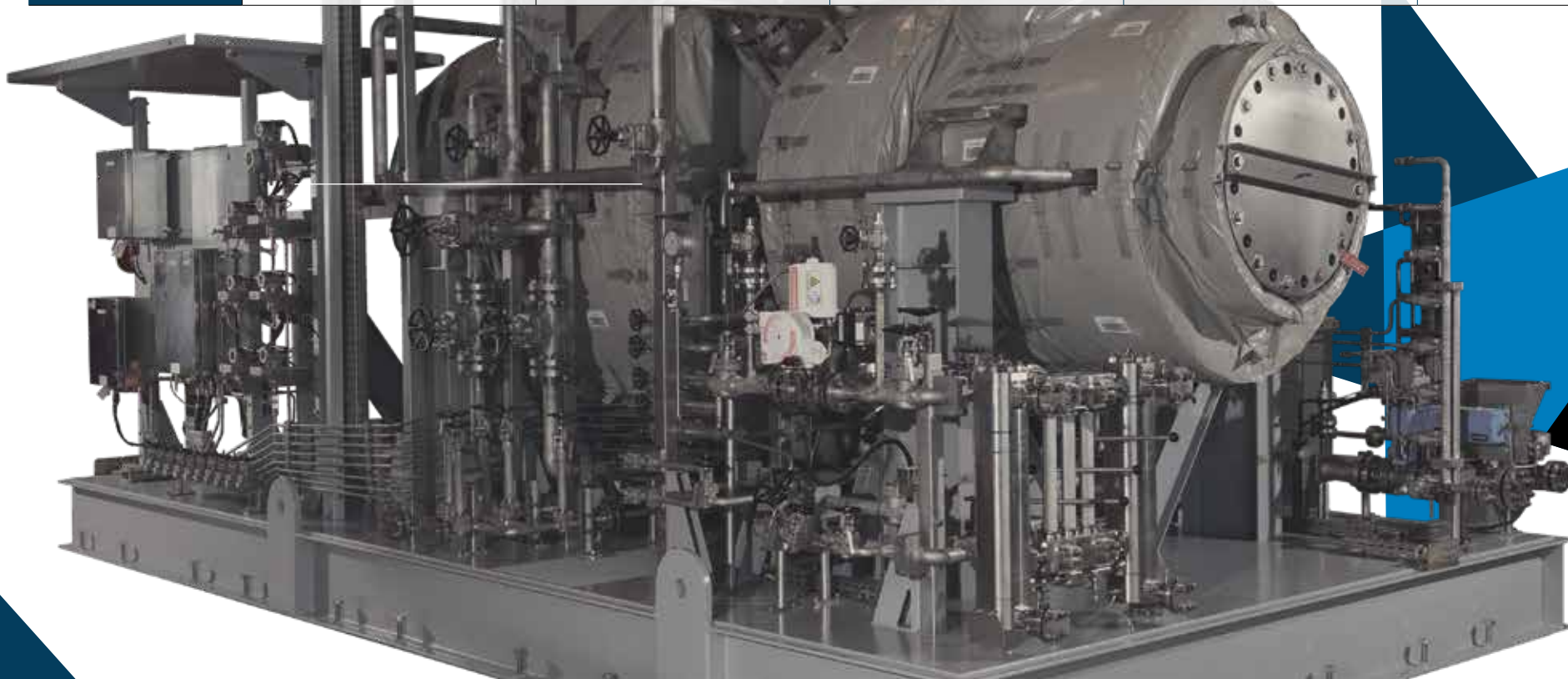


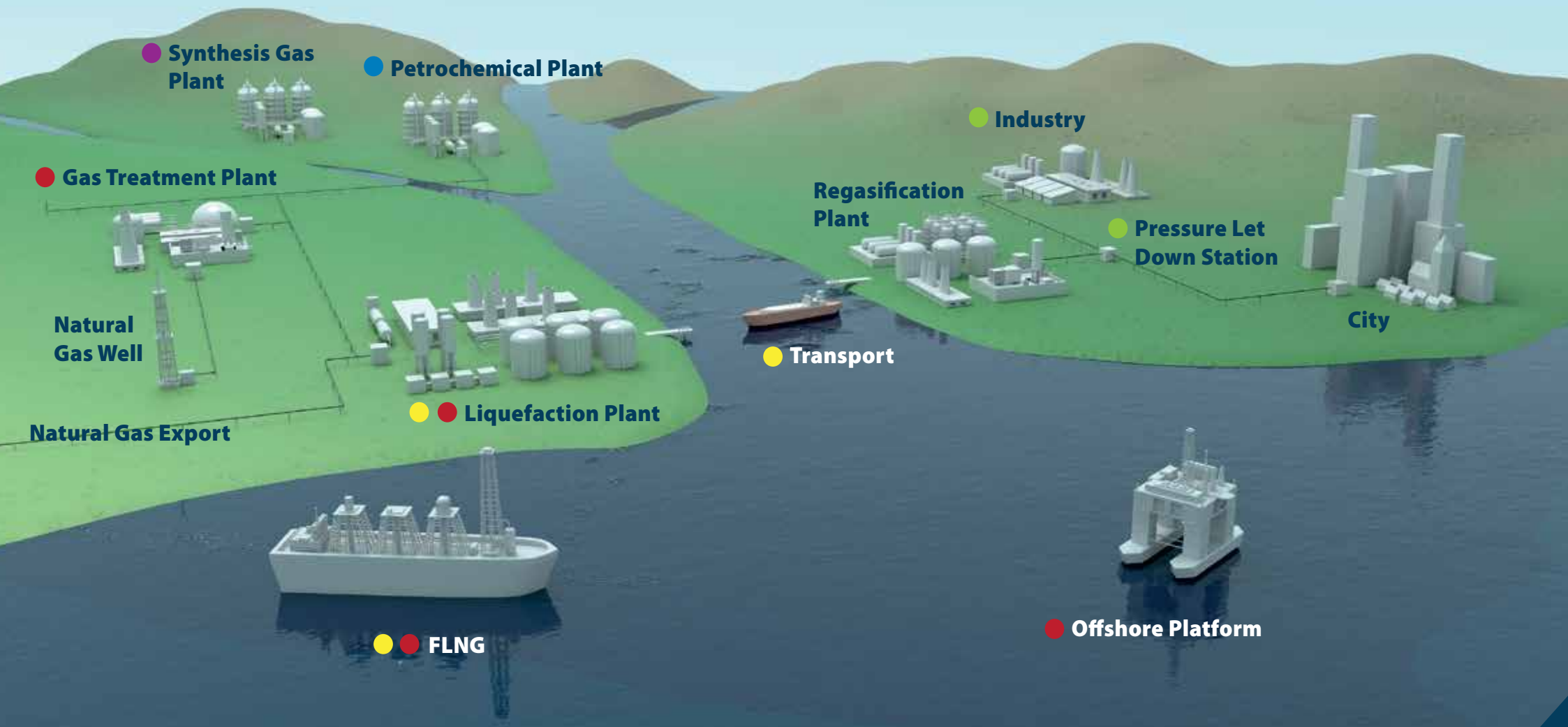
Theoretical courses can be combined with practical sessions, depending on the availability of the equipment on the customer's site or in CRYOSTAR's factory.

- ★ Get the best out of your equipments
- ★ Maintain the equipment safely & efficiently
- ★ Improve your awareness to increase the MTBF

HYDROCARBON TURBO-EXPANDER APPLICATIONS

	● Natural Gas Treatment Plant	● LNG Plant	● Petrochemical Plant	● Clean Power Generation	● Hydrogen & Synthesis Gas Plant
GAS TURBO-EXPANDER	Dew Point Control	Condensate Removal	Olefin (Ethylene) recovery	Pressure Let Down (PLD) Station	CO purification
	Ethane Recovery	Nitrogen Refrigeration	Propane De-Hydrogenation (PDH)	Geothermal power plants	Hydrogen Recovery
	LPG / NGL Recovery		Energy Recovery (Pressure Let Down)	Waste Heat recovery	Syn Gas purification (Ammonia Plant)
	Nitrogen Rejection Unit				Energy Recovery (Pressure Let Down)
	Helium Extraction				
LIQUID TURBO-EXPANDER		LNG subcooling			Methanol Expander
		Refrigerant expander	Refrigerant expander		Refrigerant Expander







more than
CRYOGENICS

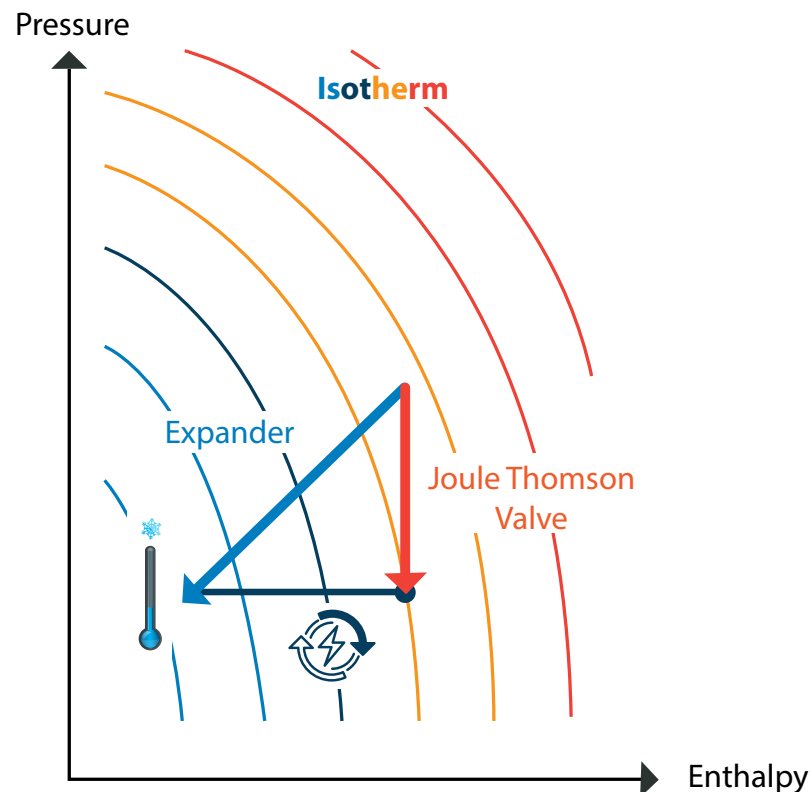
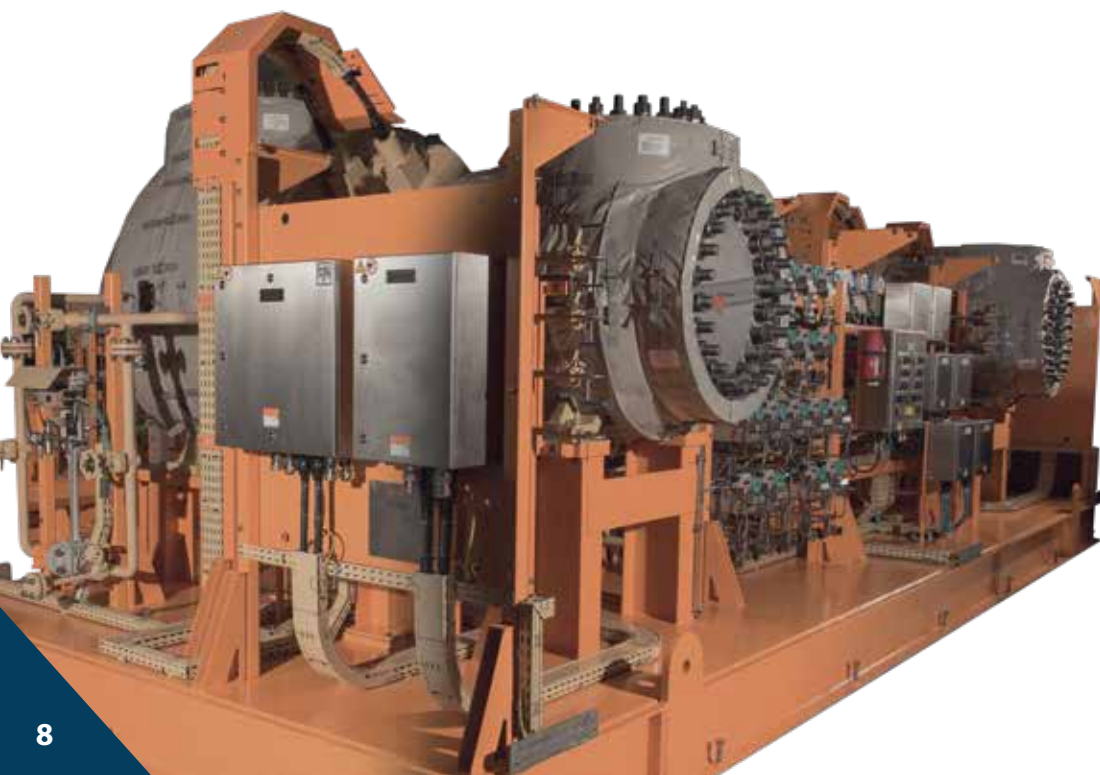
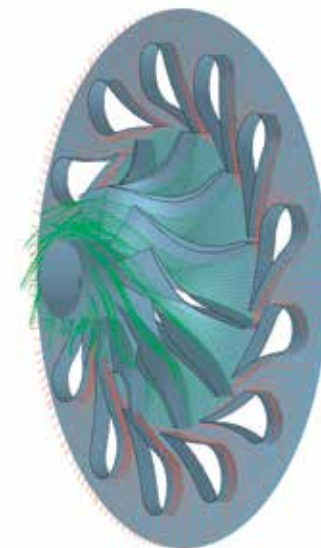
TURBO-EXPANDERS

Modern turbo-expanders can achieve almost isentropic expansion resulting in **much lower temperature** drops than possible with a valve. The **Extracted Energy** is used to drive another rotating machine such as compressor, generator or pump.

CRYOSTAR have manufactured thousands of turbo-expanders since the early 70s. Our machine range includes turbo-expander/compressor, turbo-expander/generator and turbo-expander/Oil-Brake.

All our hydrocarbon turbo-expanders are built in accordance with **API 617** of which CRYOSTAR is an active member.

Our expanders are radial inflow turbo-machines with a degree of reaction of 50% allowing near adiabatic expansion: half the expansion is performed in the Inlet Guide Vanes (**Stator**) which accelerate the fluid, the other half occurs in the wheel (**Rotor**) which converts fluid speed into kinetic energy.



VARIABLE INLET GUIDE VANES (IGVs)

Our variable IGVs maintain optimal efficiency on a large operating range while allowing smooth regulation of your process. Typically, IGVs allow an operating range between 30% and 120% of the nominal mass flow.

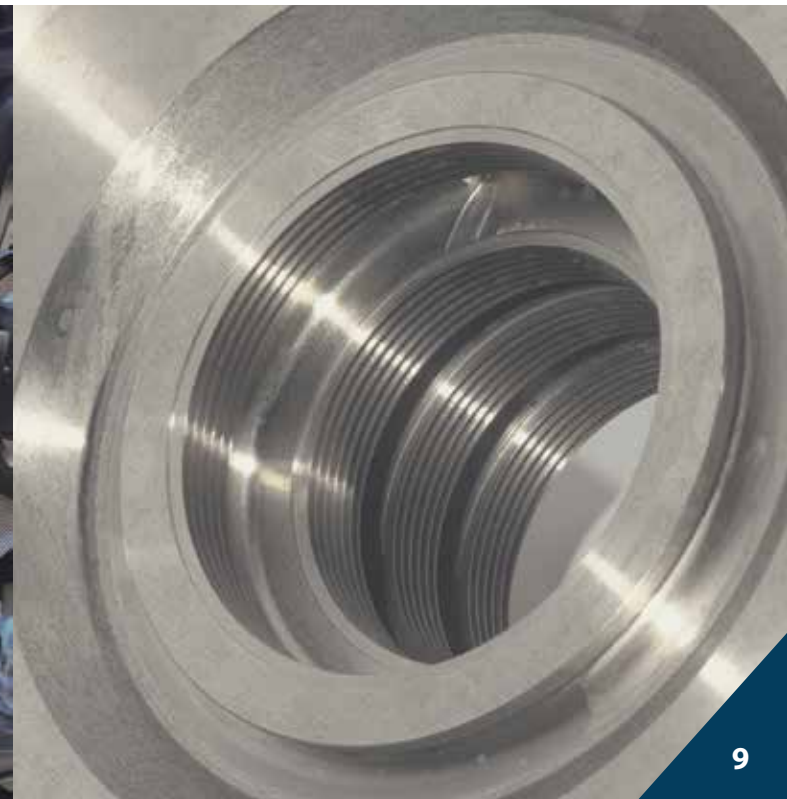
WHEELS

CRYOSTAR specifically designs each wheel to maximize efficiency. Depending on your needs, open or closed wheels can be proposed in various materials, Aluminium, Titanium or Stainless Steel ranging from 70 mm (2 ¾ inches) to 900 mm (35 ½ inches) with peak isentropic efficiency up to 92%.

SHAFT SEALS

Depending on process gas, operating pressure and machine model, the various shaft seals can be proposed by CRYOSTAR.

- ★ **Labyrinth Seals:** Designed by CRYOSTAR, these seals have no moving parts and offer unmatched reliability (no wear parts). They are used on a wide range of applications.
- ★ **Floating Carbon Rings:** Floating Carbon rings consume slightly less seal gas than labyrinth seals but require regular maintenance due to the carbon ring wear.
- ★ **Dry Gas Seals:** Dry Gas Seals allow the lowest seal gas consumptions but require very high gas cleanliness. They can be proposed in several configurations: single, dual or tandem.
- ★ **Oil Seals:** The Oil Seals may be used on applications where Dry Gas Seals are too sensitive for the operating conditions.





more than
CRYOGENICS

TURBO-EXPANDER/COMPRESSORS

The turbo-expander/compressor is a single shaft machine where the compressor is directly driven by the expander. The rotor can be supported either by Oil Lubricated Bearings (OLB), CRYOSTAR's TC model, or Active Magnetic Bearings (AMB), CRYOSTAR's MTC model.

COMPRESSOR DESIGN

It consists in a single stage centrifugal type compressor. It is designed in accordance with API 617.

COMPRESSOR DIFFUSOR

To optimize compressor range and performance, CRYOSTAR can propose a variety of fixed or variable diffusers:

- ★ Vaned to maximize compressor head.
- ★ Vaneless to maximize operating range.
- ★ Low Solidity Vaned Diffusor as a compromise between head & range.

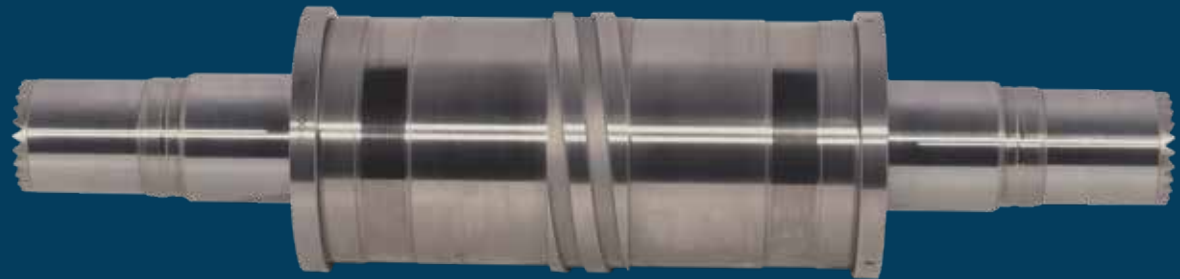
SHAFT

Since the machine is single shaft (without coupling), it always operates below its first lateral critical speed. It is therefore robust and reliable.

The shaft is machined from a single forging.

Wheels are attached to the shaft with HIRTH coupling thus avoiding the use of keys.

It allows an optimal torque transfer and proves excellent in term of balancing. It is especially useful for high power and/or high tip speed applications.



OIL LUBRICATED BEARINGS TURBO-EXPANDER/COMPRESSOR (MODEL TC)

CRYOSTAR manufactures Oil Lubricated Bearings Turbo-expander/compressors since 1974 and has delivered thousands of them ever since.

ROTOR

Machined from Solid forging, low thermal expansion



BEARINGS

Combined axial (tapered land) / radial bearings (tilting pads): High capacity on a large operating range



LUBE OIL SYSTEM

It can be designed in accordance with **API 614** General or Special Purpose. Since most OLB Turbo-expander/compressors use labyrinth seals, lube oil reservoir is usually connected to compressor inlet in order to recover seal gas. It is therefore pressurized.

In case of use of Dry Gas Seals, an atmospheric lube oil tank will be used instead.



	Wheel range Ø (mm)	Radial Bearing Ø (mm)
TC	120	25 or 32
	200	50
	300	60 or 70
	400	90
	500	110
	600	130
	700	150

ACTIVE MAGNETIC BEARINGS TURBO-EXPANDER/COMPRESSOR (MODEL MTC)

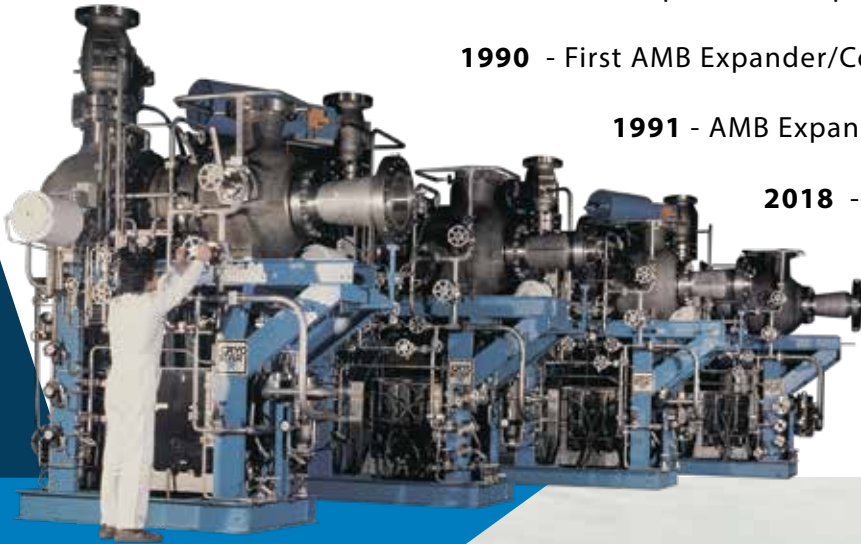
CRYOSTAR was the first company to develop the hydrocarbon expander/compressor with Active Magnetic Bearings in the 90s. Thanks to their unmatched reliability, these machines are a well proven design and have become a standard.

1988 - World first AMB Expander/Compressor | Air Separation Unit (Motherwell, UK, British Oxygen Company)

1990 - First AMB Expander/Compressors (4 units) | Natural Gas Processing (Sleipner A Platform, Norway, Statoil)

1991 - AMB Expander/Compressor | Olefin Plant (Notre-Dame de Gravenchon, France, ExxonMobil)

2018 - Around 200 machines sold worldwide



more than
CRYOGENICS



	Wheel range Ø (mm)	Radial Bearing Ø (mm)
MTC	200	90
	300	110
	400	150
	500	200
	600	240
	700	310



AMB CARTRIDGE

Equipped with Radial and Axial bearings and instrumentation (displacement, speed, temperature)

Material compatibility with upstream natural gas:

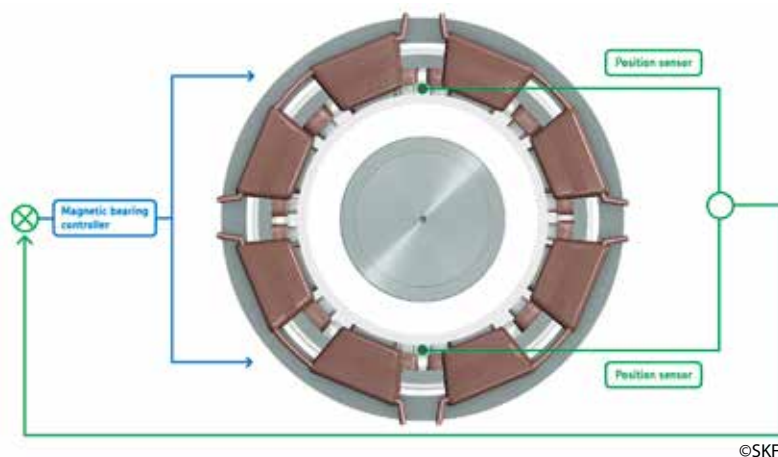
- ★ Mercury compatible
- ★ NACE region 0 or 1 as option



©SKF

CONTROL LOOP

The AMB control system is based on a 14 kHz control loop which measures shaft position and adjusts bearing current accordingly. This control loop allows for active damping of vibrations.



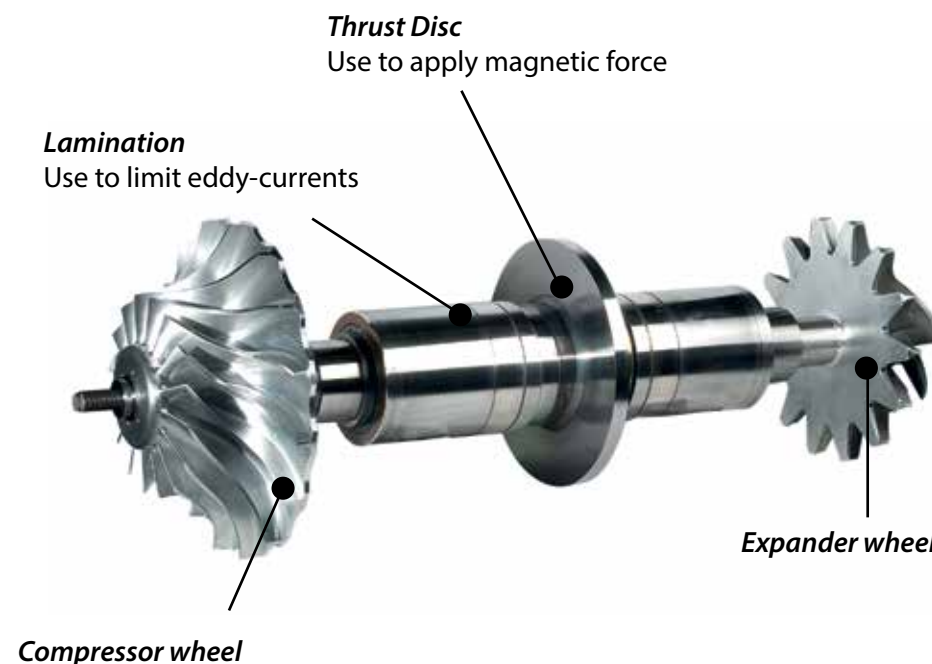
©SKF

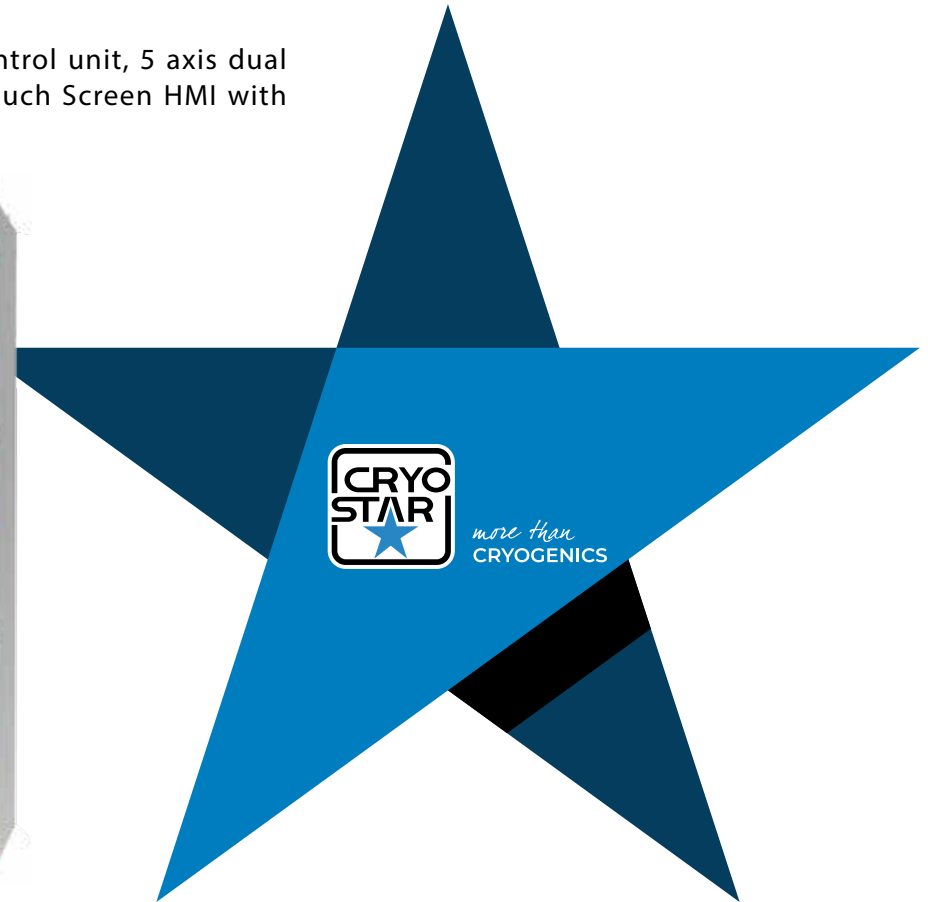
AUXILIARY LANDING BEARINGS

They are used as ultimate back-up and consist in ceramic ball bearings. In the unlikely event of loss of levitation, they will allow the rotor to stop while protecting the system from damage.

ROTOR

The shaft is fitted with ferromagnetic lamination (stacked ring layers) to ensure optimal magnetic induction whilst limiting eddy current losses. It is also fitted with a large thrust disc to apply axial magnetic force in order to manage high thrust loads.

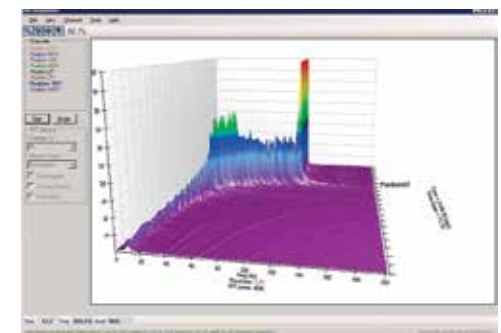
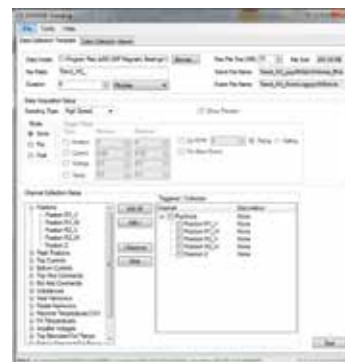
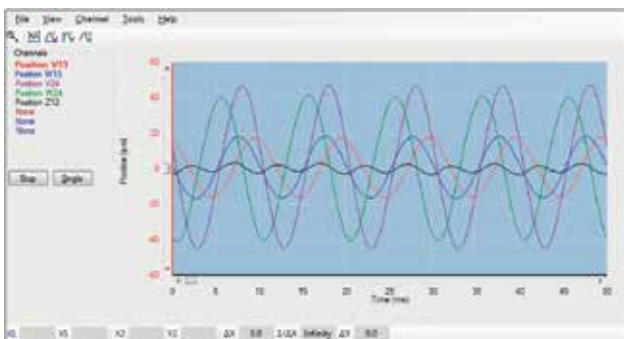




Allows online vizualisation of shaft position, frequencies, etc.

Allows data transfer to storage server at high frequencies (up to 14 kHz)

Allows advanced analysis of stored data
(waterfall, polar plots, etc.)



COMPARISON CHART: OLB vs AMB

	Oil Lubricated Bearings (OLB)	Active Magnetic Bearings (AMB)
Technology	★ Conventional Technology, well proven & well known	★ State-Of-The-Art Technology, well proven & well accepted
Maintenance	★ Regular but simple maintenance required	★ Maintenance-free
Vibrations	★ Passive Technology: synchronous vibrations (i.e. rotor unbalance vibrations) can only be damped, not avoided. ★ Machine casing always vibrates	★ Active Technology: shaft position is actively controlled thus avoiding synchronous vibrations ★ Machine casing does not vibrate
Monitoring	★ Bearing instrumentation must be connected to a third-party monitoring system	★ Bearing instrumentation is connected to the AMB Panel with its integrated monitoring system
Load	★ Bearing load is unknown and measured indirectly through bearing temperature and oil film pressure	★ Bearing load is proportional to bearing currents which are constantly monitored
Lube Oil	★ Possible migration of oil inside the process ★ Synthetic oil often required for natural gas application to avoid viscosity loss. In this case, the cost of oil fill must be considered in capital and operational expenditures ★ Winterization required when installed in cold environment ★ Oil disposal is always a problem ★ Firefighting system shall be considered	★ N/A
Footprint & weight	★ Large footprint required for lube oil system, 50% heavier than AMB execution	★ Compact, single skid machine
Investment Cost	★ Depends highly on lube oil system requirements: API 614 General Purpose or Special Purpose, customer specifications, materials (Carbon Steel or Stainless Steel), operating pressure, ... ★ Indirect costs such as power / instrumentation cables or first oil fill must also be considered	★ Large machines will usually be more competitive when compared to OLB machines ★ Indirect costs are limited to AMB cables and instrumentation cables (similar to OLB machines)
Operating Cost	★ Higher overall consumption: oil pump motors ~10 kW, oil cooler motors ~3 kW, oil heater ~5 kW, etc.)	★ The normal consumption of the AMB Control Panel is only 2 kW (rated 6 kW)



more than
CRYOGENICS

TURBO-EXPANDER/GENERATOR (MODEL TG)

In cases where the process does not require compression power, or when maximum process flexibility is necessary, or for electrical power generation, our turbo-expander/generators can answer your needs. Our TG are fully customizable and are engineered to fit your purpose. Our engineering team will help you select the most suitable solution for your process.

EXPANDER(S)

Depending on required expansion ratio, single, dual or four stage expander(s) can be proposed. In case of multi-stage machines, all the expander stages will be fitted on a single integral gearbox. Each expander stage will be equipped with its own casing, wheel and Inlet Guide Vanes assembly.

GEAR

- ★ Epicyclic (Planetary) gearbox
- ★ Parallel gearbox, as per **API 613**
- ★ Integral gearbox as per **API 617**, Part 3
- ★ Direct driven (no gearbox) for low speed applications

GENERATOR

- ★ Induction type generator (asynchronous)
- ★ Alternator type generator (synchronous)

Can be supplied with Generator Protection Panel and Automatic Voltage Regulator for synchronous machines.

LUBE OIL SYSTEM

- ★ Integrated within machine skid or on a separate skid
- ★ API 614 Special or General Purpose
- ★ Emergency coast down ensured by shaft driven pump or rundown tank

COUPLING

Low speed coupling as per **API 671** (API 671 execution if required)

- ★ Flexible disk pack coupling
- ★ Torque limiter option



TG	Frame wheel range Ø mm
	120
	200
	300

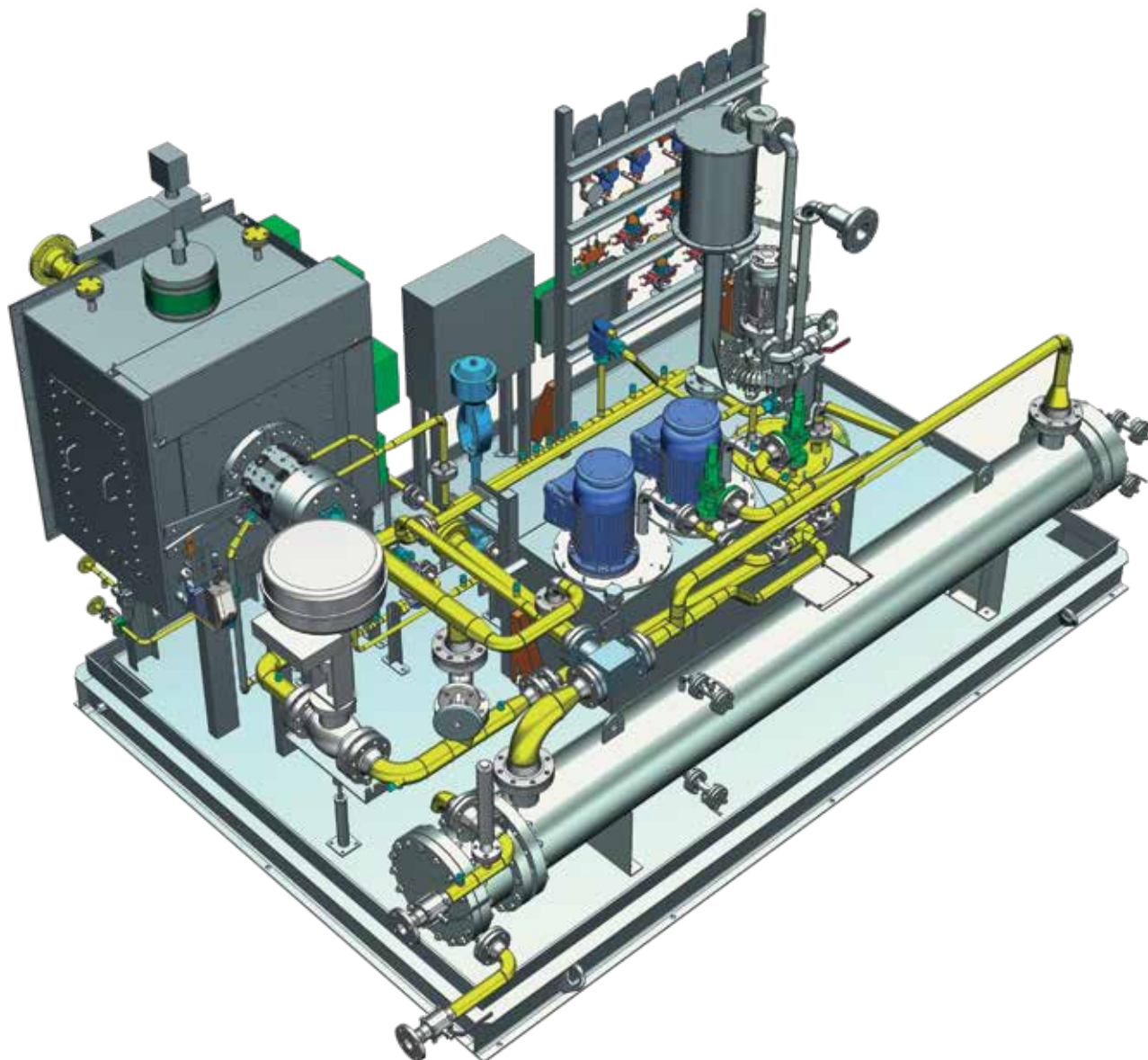
	900

TURBO-EXPANDER/OIL BRAKE (MODEL TP)

For low power applications (typically below 200 kW) where it is not interesting to recover electrical or compression power, the turbo-expander can be coupled to an oil brake.

These machines achieve near adiabatic expansion without injecting power to the grid thus allowing maximum availability.

These units can be completely integrated inside a 'coldbox' to ensure no cold-power is lost.



TP	Frame range (wheel Ø mm)
	120
	200
	300





more than
CRYOGENICS

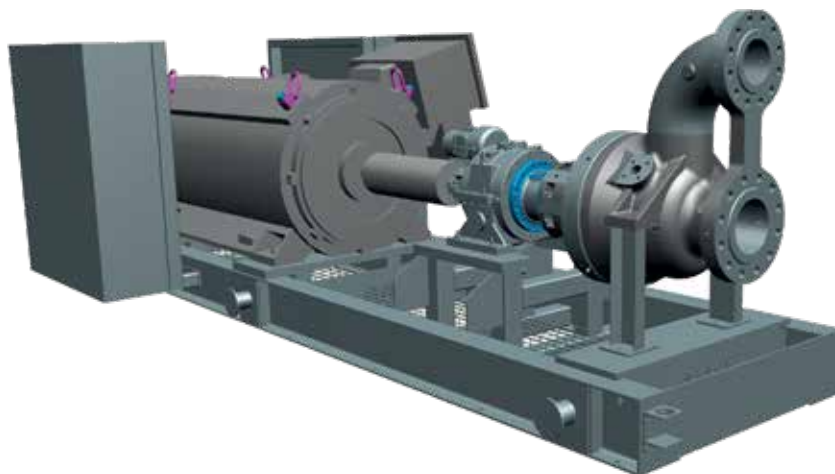
LIQUID TURBO-EXPANDER/GENERATOR (MODEL LTG)

Liquid turbo-expanders have been a major breakthrough when first introduced by CRYOSTAR in the 70s for Air Separation Units. Nowadays, all major Air Separation Units are equipped with CRYOSTAR LTG, with hundreds of references in operation.

Our Liquid expanders are radial inflow expanders very much alike our gas expanders. They are usually coupled to a generator just like our TG model allowing easy installation and maintenance.

In any refrigeration loop, replacing your Joule-Thomson Valve by a CRYOSTAR Liquid Expander will help you save up to six times in compression power which is generated by the expander itself. Moreover, since our liquid expanders are single stage machines, they can handle up to 20% flashed gas at expander outlet.

Our Liquid expanders are fixed speed machines equipped with variable Inlet Guide Vanes allowing near adiabatic expansion on a large flow range.



	Frame range (wheel Ø mm)
LTP	70
LTG	90
	120
	200
	300
	400

CONTROL SYSTEM

Our instrumentation & control engineering department is developing and optimizing control systems for our turbo-machines.

CRYOSTAR has developed its own algorithms to control all systems around the expander such as Expander Inlet Trip Valve, Lube Oil System, Seal Gas System, etc.

Each new machine is provided with its dedicated control logic that can be programmed inside your control system or in a CRYOSTAR's supplied Unit Control Panel.

Our Unit Control Panels are customized to fit your needs: PLC configuration, dedicated controller/monitoring system configuration, HMI views, serial link, etc.

CRYOSTAR also has in-house capability for Anti-Surge Control, Performance Control and Load Sharing between multiple machines.

In addition, CRYOSTAR can implement these process control loops within a Dynamic Simulation to validate the Turbo-Expander response. Our recognized expertise in that field can help you size key equipment (Anti-Surge Valve, Joule-Thomson Valve, etc.), simulate HAZOP scenarios or be used for operator training purposes.





more than
CRYOGENICS

BRAZIL

CHINA

FRANCE

INDIA

SINGAPORE

UK

USA

For contact and address of the CRYOSTAR
locations worldwide, please go to
www.cryostar.com/locations

★ www.cryostar.com ★

© CRYOSTAR - all rights reserved