TURBO-EXPANDERS FOR COLD PRODUCTION AND ENERGY RECOVERY

Everywhere in the GAS SUPPLY CHAIN
Innovation for CONTINUOUS EXPANSION
Cryostar - turbo expander expertise for the gas supply chain in natural gas processing and petrochemical applications

For more than 30 years Cryostar has been recognized as a world leader for their superior product quality in radial inflow turbine technology, pumps, LNG boil off gas compressors and air separation.

Since Cryostar began in 1966 and followed with the production of their first turbine in 1974, their focus and expertise has been to provide their customers with turbo-expander/compressor and liquid recovery systems for cold production ensuring economical and reliable operations.

Cryostar’s head-quarters and production facility is located in Hesingue, France, just across the border from Basel, Switzerland, and employs over 400 staff in management, engineering and production. In addition, Cryostar has opened Business Centers strategically located throughout the world in the USA (Houston, California and Pennsylvania), United Kingdom, Singapore, China and Brazil to provide our customers with first class service.

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

Cryostar’s innovative drive and continued commitment to invest in and develop their world class engineering skills has moved them to the forefront of technological development in all their product lines. Every turbine is designed using state-of-the-art technology to ensure each customer the very best in product design. With a policy to the commitment to excellence, Cryostar has earned a position as a world leader in their markets.

The results of Cryostar’s policies are clear: Companies have put their trust in Cryostar by selecting Cryostar to supply turbo-expanders for many of the major projects in the Middle East, the North Sea and Africa. Their success is explained by their commitment to the needs of their clients and partners in:

- Basic engineering phase and FEED design.
- Customized design incorporating API and other high quality standards and strict customer requirements.
- Continuous innovation and development in the use of magnetic bearings, liquid turbo-expanders and LNG reliquification systems.
- Uncompromising lifetime customer support.
The key advantages of Cryostar

Cryostar: the pioneer company in active magnetic bearings expander with an unequal experience

- Cryostar was the first company to develop an expander equipped with active magnetic bearings (AMB) in 1988.
- Cryostar was the first company to supply 8 AMB expanders for natural gas processing (offshore conditions in the North Sea environment)
- Cryostar has the largest base of expanders equipped with AMB in operation in the world

- Proven expertise of applications: dew point control, ethane recovery, NGL recovery, LNG production and project with high amount of liquid at expander outlet.
- Capability to reply to the applications of petrochemical industry such as ethylene plants, CO processing...
- A complete range from 100 kW up to 12 000 kW with inlet pressure up to 150 bar and inlet temperature down to -196°C as standard
- A company certified ISO 9001/2000. Cryostar was one the first companies to be ISO certified in its field of activity.
- Use of the latest technologies to design their turbo-expander to obtain for each project the best performance (each wheel is unique): Final Element Analysis, Computational Fluid Dynamic, 3D modelisation, Laser Holographic test...
- Combination of their qualified service department with a design focus towards minimal downtime and high availability results in maximum savings for your plant operations.

Mechanical centre section pressurized with nitrogen for long term storage
Cryostar provides the best configuration to match to the application

Cryostar designs all their turbo-expander packages to the strictest of industry and client requirements. Compliance to API 617 is standard and in addition, each machine can be fully customized to meet even the most stringent of client requirements. To assure customers on-time delivery to the agreed specification level, an engineering team is selected at the beginning of each project. The team includes of aero-designers, specialists in rotating machinery, instrumentation and control systems, seal gas and lube oil systems all coordinated by a project manager in conjunction with the quality department, fully involved at each step of the project.

Example of configuration of Cryostar Turbo-Expander

Turbo-expander/compressor equipped with active magnetic bearings.

Main parts consisting in:
- rotating machinery
- electrical connections for magnetic bearings
- seal gas system
- local gauge board
- local control panel
- junction boxes panel
- base plate

Turbo-expander / compressor equipped with oil lubricated bearings.

Machine assembly with:
- rotating machinery
- seal gas system
- local gauge board
- local control panel
- junction boxes panel
- base plate

Oil system assembly:
- reservoir
- coolers
- pumps
- accumulators
- demister...

Turbo-expander/generator equipped with oil lubricated bearings

Single skid package including machine assembly and oil lubrication system

Possibility to provide expander loaded with oil brake for application where it is not worth to recover the power available on the shaft.
**General principle of cryostar hydrocarbon turbo-expander equipped with oil lubricated bearings**

1. **Expander casing**
   - Designed and built under ASME specifications
   - Hydrostatic test at 1.5 times the MAWP
   - Material selected as per the application

2. **Expander wheel**
   - Open/closed 3D wheel
   - High efficiency up to 92%
   - Milled from solid
   - Heat treatment for maximum strength and durability
   - Material: aluminium alloy, SS or Titanium

3. **Inlet guides vanes**
   - Aerodynamically efficient design
   - Erosion-resistant materials
   - Wide operation range

4. **Shaft/rotor**
   - Special attachment for best moment transmission

5. **Labyrinth seals**
   - Very safe and reliable system

6. **Bearings**
   - Combined radial tilting pad and axial tapered land bearing
   - Maximum stability and reliability

7. **Compressor casing**
   - Designed and built under ASME specifications
   - Hydrostatic test at 1.5 times the MAWP
   - Material selected as per the application

8. **Compressor wheel**
   - Open 3D wheel
   - High efficiency
   - Milled from solid
   - Heat treatment for maximum strength and durability
   - Material: aluminium alloy, SS or Titanium
Inlet guide vanes adjusting mechanism - variable flow nozzles

For efficient flow control the expander is equipped with a variable inlet guide vanes assembly. Cryostar expander variable inlet guide vanes are designed to provide zero by-pass losses (no loss of efficiency), precision movement control and high efficiency over a wide operating range.

Similar to the wheel design, extensive use is made of superior computer programs for the optimization of the nozzle shapes. It allows the optimal design of the vanes and limits the size of the actuator.

Preconditioned materials, matched clearances and special surface treatments assure smooth operation at all conditions.

Advanced expander wheels
Turbo-expander wheels are matched to specific customer applications in order to provide the best performance and maximum efficiency. They are machined from forged solid material blank. Cryostar expansion turbine wheels are milled out of Aluminum alloy, Titanium or stainless steel to minimize performance losses due to blade shroud gap with open wheels.

All Cryostar expander and compressor wheels are designed for the best efficiency. Modal analysis is carried out for each wheel with the latest FEA methods, avoiding wheel blades resonances.
Connections between wheel and shaft: innovation for reliability and efficiency

Cryostar has developed a special connection between shaft and wheels: the Hirth connection. It offers a superior moment transfer. This connection is a method that yields excellent results for balancing. It is especially adapted for high power and high tip speed applications.

Shaft seal system
Cryostar can provide different types of shaft seal arrangement depending on the application and client requirement. They are suitable for atmospheric or pressurized reservoirs.

Labyrinth seal

It is used when leakage of process gas can be recovered inside the system or when it can be sent to a vent/flare system. The number of labyrinths depends on the process conditions. The buffer gas is injected between the labyrinths. This arrangement is not too sensitive to the quality of buffer gas (particles content).

Depending on the application, this arrangement can be combined with a drainer that allows the installation of an atmospheric oil reservoir instead of pressurized one.

Dry gas seal

The dry gas seal minimizes drastically leakage rates and hence improves the efficiency. The non contacting mode of operation also means a lower amount of friction and wear compare with conventional mechanical seals.
**BEARINGS: conventional type (oil lubricated bearings) or active magnetic bearings?**

**Active Magnetic Bearings:** not only the solution to decrease the dimensions and weight of the machine (no lube oil system) but also a package with three key advantages:

- no risk of process contamination by oil.
- elimination of vibration: the active bearings cancel synchronous vibrations by letting the shaft free to rotate around its inertia axis.
- no maintenance concept.

Cryostar has been the first company to develop and to implement AMB on expander/compressor used in natural gas processing.

The system includes also auxiliary ball bearings with damping mechanism to prevent destructive whirl during coast down of the machine. Auxiliary ball bearings typically consist of ceramic balls with steel races. A dedicated control panel containing amplifiers, control electronics and other equipment necessary for the operation and safety of all magnetic bearings is part of the package. It provides alarm and shutdown protective logic for the magnetic bearings, auxiliary bearings and control cabinet by itself. Monitoring information in terms of speed, radial load, thrust load are available.
AROUND THE EXPANDER: an oil lubrication system (applicable for compressor loaded expander or generator loaded or oil brake loaded expander)

The oil lubrication system is dedicated to ensure a proper and continuous lubrication of all bearings and gears of the machine.
Cryostar is able to provide simple and low cost oil lubrication system but also some optimized systems designed as per API 614 standard, latest edition. These systems meet the most stringent technical requirements in term of selection of equipments, materials and test to be performed.

Under client request, Cryostar can build the oil system according to the latest edition of NACE MR0175 standard, in order avoid any risk due to sulfide stress and stress corrosion cracking.
Control system of turbo-expanders

Cryostar turbo-expanders can be built with simple or very sophisticated control systems, standard or fully customized. The control system can be installed locally on the skid or can be remote for installation in the control room for instance. In case the client requires the possibility to achieve a local control (local start/stop...) a combination is also possible.

The control system may include a PLC (programmable logic controller) which is often redundant with dedicated visual display unit so as to provide all the necessary information for a safe operation. Cryostar can propose some PLC’s fabricated from different suppliers (France, Germany, Japan, USA).

Depending on the type of expanders, the control system can include a vibration and temperature monitoring system, an anti surge control system, a dedicated overspeed protection...

In case of expander loaded with synchronous generator, Cryostar can provide a full package including the generator control panel with protection devices, synchronizing function, voltage regulation...
**TECHNOLOGICAL EVOLUTION:**
*The latest technology to design your turbo-expander*

During recent years, technological advances have provided modern high tech tools and they have drastically changed the way Cryostar designs its equipment. Cryostar has invested in the latest technology to support the expertise and shorten its response time. Cryostar employees use state-of-the-art tools through the entire process.

- **Computer Aided Design/Computer Aided Manufacturing [CAD/CAM] systems** are used across the entire design and production process.

- **Finite Element Analysis [FEA] system** is used to analyze static and dynamic impeller stresses for robust wheel designs.

- **Three-Dimensional Computer Fluid Dynamic [CFD] codes** enables the analysis of the flow through each stage. Combined with in-house blade design tool this results in the design of high-efficiency impellers, inlet guide vanes and diffusers.

- **Product Data Management [PDM] system** enables to perform concurrent design activities by different engineering disciplines which in turn significantly reduces the time of delivering a high quality turbo-expander for your application.

- **Fully computerized monitoring and data acquisition system** performs accurate and precise testing.

Cryostar has invested in tools and facilities in order to reduce manufacturing costs, improve quality, and shorten delivery schedules.
Inspection and testing

For each machine built by Cryostar, an inspection and test plan (ITP) is prepared. Depending on the project, the API 617 standard and ASME PTC10 code requirements are followed.

The ITP includes detailed information relating to the tests performed on the machine: hydrostatic test, non destructive examination test, hardness test, welding test, positive material identification, painting, wheels and rotor balancing, over speed testing, mechanical running test with vibration measurements, performance test, noise test and other tests as per client requirements.

For example, all Cryostar rotating elements are dynamically balanced by precision microprocessor controlled balancing equipment to ensure smooth operation over the entire operating speed range. Cryostar uses state-of-the-art computer based data acquisition and vibration analysis equipment for testing our turbo-expanders and all tests are conducted in accordance with ASME test codes. Cryostar test facilities provide high-test accuracy, repeatability, and reliability.

A completely in-doors test facility is available since October 1999. Performance and mechanical run testing are carried out with air using an open loop configuration.

Investing in excellence

To meet growing customer demands Cryostar committed to a rolling programme of investment in workshop, test and office facilities. In 2006, the company completed a new workshop, and in 2007 opened an adjacent test stand. This third compressor/turbine facility offers:

- A total area, including compressors and frequency drive room, of 910 m² (650 for the test facility itself and 260 m² for the air compressors and inverter rooms.
- A power supply of 6 MW / 6.6 kV / 50-60 Hz with the possibility to increase to 8 MW with additional external generators
- Two air compressors of total 2 MW which can achieve 20000 Nm³/h - 10 barg in order to test the high powered turbines
- A frequency drive of 6 MW
- A water tower of 6 MW with a circuit designed for 550 m³/h and
- An air compressor to supply dry and clean air for the whole facility

With the additional test facility, Cryostar will be able to test not only the ‘companders’ but also the high powered TG and MTC turbines (3-12 MW).
Other integrated solutions including rotating machineries dedicated to the LNG supply chain

Integrated boil-off reliquefaction solution for LNG carriers
Cryostar offers a fully integrated package to handle continuous LNG boil-off during transportation. The solution, unique to Cryostar, is its combined cryogenic machinery for the cargo handling system on LNG carriers. This includes:

- Boil off gas compressors: low and high duty single-stage compressors, low duty EcoBot dual-stage compressors
- Gas heaters and vaporizers: Boil-off / warm up heaters, main or LNG vaporizer, forcing vaporizer and mist separator
- Cryogenic equipments related to re-liquefaction systems: 2-stage boil-off gas compressors, interstage coolers, N2 companders.

The diversity of the equipment allows Cryostar to cover a full operating envelope, maintaining a safe and reliable operation whatever the propulsion system may be.

BOG compressors, centrifugal blowers, ethylene blowers: Cryostar’s experience acquired with the LNG carriers allows us to propose additional solution for the LNG terminals (BOG compressors, centrifugal blowers) but also for petrochemical plant such as ethylene compressor.

Expertise in partnership with clients is the starting point for strong collaboration regarding the development of new products: the dedicated R&D department is continuously working on new concepts so that to fulfill tomorrow technical requirements.
Forming partnerships with customers enables Cryostar to offer efficient and bespoke services. The company’s Training Centre is an extension of that partnership, adding value where the customer needs it...

From its humble beginnings to support customers with knowledge about Cryostar equipment, the Centre is now looking to offer bespoke training packages across a wide range of topics.

To date, the Centre has attracted the support of many major companies, including Daewoo, Samsung and Hyundai Korean Shipyards, Statoil of Norway, Toyo Engineering of Japan, CLSICO of China, Petrofac UK, Air Liquide and White Martins Gases of Brazil to name but a few.

Didier Walch, Customer Service Director, said: “The Training Centre has become a strong relationship and technical link between the company and more than 250 customers who attended our courses last year”.

Lucien Gruppi, Training Co-ordinator added: “In the future, the number of courses and sessions will increase. Hands-on-sessions will also be improved, with the help of assembly and maintenance workshops, and our test bed facilities.”

Cryostar’s global network of Business Centres will also be involved, ensuring training sessions can be held locally, a huge advantage when it comes to keeping travel costs down.

“It is Cryostar aim to expand this training offer, to give customers access to a true centre training of excellence. As a result, Cryostar has selected the best engineers and people to identify topics and design courses.

All courses will be available in a database managed with “Livelink from Opentext”.

Structured learning
The training Centre is driven by three main processes:
• Analysis of the training needs (customers and internal).
• Production of the training material and updates.
• Training courses preparation and performances.

Each course is split into modules. This modularity gives flexibility to deal with all subjects and also particular concepts of the equipment, like:
• Theoretical basics and physical phenomenon involved
• Construction and technology
• Auxiliaries and instrumentation
• Special installation cautions, operation and maintenance
Cryostar service department

Given the critical nature of its products for energy recovery and subsequent cost savings, Cryostar is well aware of the importance of their service. Consequently, Cryostar’s role goes beyond the delivery of the turbines to finding solutions and bringing added value to their customers.

Our pre-sales and after sales service is second to none, which means customers receive expert advice through the whole design and purchase cycle as well as possibilities of long term maintenance contracts once the turbine is up and running to guarantee investment.

The Cryostar headquarters in Hesingue, France hosts one of the world’s biggest and most sophisticated pump and turbine testing facilities. Here they pre-test all turbines leaving their site, ensuring that only products that have passed their stringent test requirements are shipped to the customer.

Service department data, engineering department data, development department data... How to ensure their integrity?

Investment: The techno-future

As Cryostar continues to grow, the business is investing in state of the art information technology to ensure the integrity of all its data. To this end, it has transitioned to Blade Center and Storage Area Network IT systems.

This allows Cryostar, in a single rack, to consolidate up to 64 processors, called quad core technology, with up to a total of 256 cores and manage up to 24 Terabytes data using fibre channel technology disks.

Boot on SAN technology, virtual server (VM) and equipment redundancy, now allow the online change of servers, disks, and all hardware, without any down time of servers. Plus, if a failure was to occur, an alert is sent directly to the manufacturer HP.

With this new architecture, Cryostar is now ready to tackle future challenges and growth opportunities.