THE CRYOSTAR magazine
N°3 Spring 2004

★ Clean electricity

Do expansion turbines hold the key?

★ Breakthrough!

The latest in liquid O_2 parts cleaning technology

★ The future here today

New propulsion concepts for LNG carriers

EDITO

Welcome to CRYOSTAR Magazine. This, the third edition, looks to provide a taste of some of the new developments Cryostar has introduced to the Energy sector.

Cryostar, predominantly a solutions provider to the industrial gases market, has over the last 40 years invested in research and development to meet the needs of many niche markets, such as LNG and hydrocarbon turbo expanders.

By applying this experience and proven technology, Croystar has developed new applications – in particular the Energy Recovery expansion turbine, recently commissioned in a natural gas pressure let down station in Switzerland.

The liquid turbines described in the feature on page 10 also provide added value options. Customers can choose to reduce main compressor energy costs or produce more with the same amount of energy input.

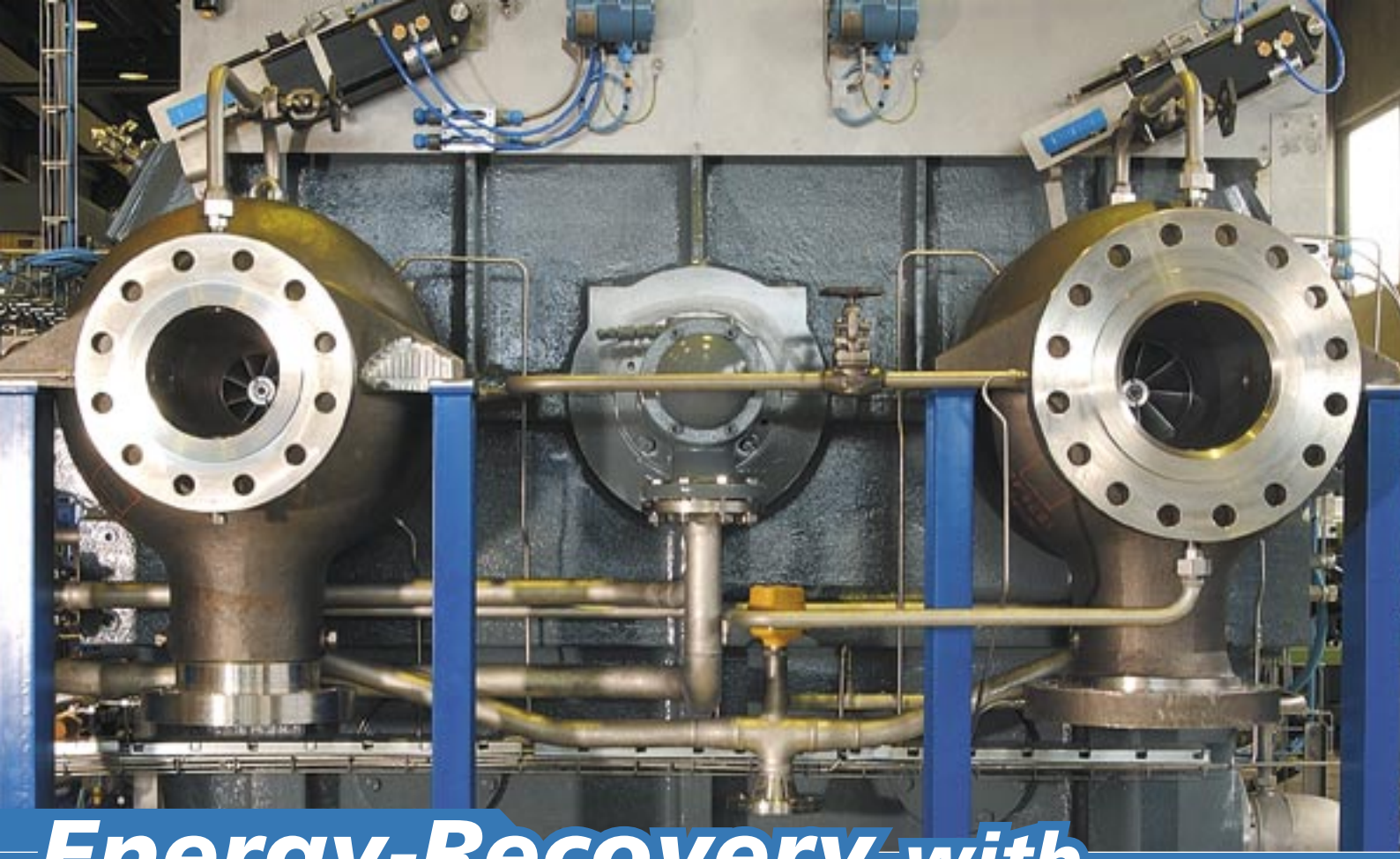
Clean energy production has a great future in all industrialised countries and Cryostar, a supplier of leading edge technology, constantly looks to pioneer applications for that technology.

In line with that commitment, Cryostar has developed solutions in response to several processes presently being considered in the energy market place.

And the synergies realised between the demand for high performance equipment and Cryostar technology clearly demonstrate we are at the forefront of innovative and eco-friendly energy handling and recovery.

I hope you enjoy this edition.

Daniel MEYER
Managing Director



Energy-Recovery with Cryostar - Turbines

Producing clean energy is the way of the future. Through the use of expansion turbines in natural gas pressure let down stations, Cryostar combines the growing demand for natural gas fuel with production of clean, 'green', electricity.

Clean Energy-Production and Energy-Recovery (ER) have been high on the agenda of the energy sector for many years. Cryostar realised the advantages of ER early on, and since 1985 has been developing expansion turbines for such applications. The first ER-unit with a Cryostar turbine was installed at Ravenna, Italy, in 1987, with an output of 1,400 kW.

Since then, ER-units have been operating successfully in Italy, Germany and the Netherlands. The latest, and most modern unit utilising Cryostar technology, was commissioned in Arlesheim, Switzerland, for the gas utility company Gasverbund Mittelland AG (GVM). The installed power is 3,050 kW, with electricity production standing at about 18,000 MWh per year. Output is produced by one Cryostar expansion turbine and two block-type thermal power stations (BHKW) from Jenbacher, and will run at full power for about 5,000 hours per year. The general planning of the Arlesheim site was done by Swiss engineering firm, Eicher + Pauli AG.

Technical Data of the Plant

Pressure drop of the natural gas:	40 to 55 bar
Max. through-put of the natural gas:	35,000 Nm3/h
Annual electric power production:	18,000 MWh
Thermal efficiency:	85%
Turbine efficiency:	81%
Electrical power of the turbine:	1,800 kW
Electrical power of the two BHKWs:	2 x 625 kW
Total electrical power:	3,050 kW
Supply voltage into the network:	13 kV

Such ER-units utilise the potential energy of natural gas being delivered under high-pressure. The gas is only expanded when it reaches the pressure let down station, and it is here ER-units come into their own.

To reduce the gas pipeline pressure of 55-bar to meet the low pressure of 5.5-bar of the local gas distribution networks, a pressure drop is needed. In other words, the gas is allowed to expand and during this process drives the Cryostar turbine within the ER-unit.

The resulting electricity recovered in this way is then supplied to local electricity suppliers. The efficiency of these units is about 85 per cent, vastly superior value when compared to BHKWs, to gas- and steam-turbines or even fuel cells.

The new ER-unit in Arlesheim is quite revolutionary. It uses a two-stage expansion turbine, equipped with a synchronous generator, to ensure each stage produces the same power.

It allows 35,000 Nm3/h of natural gas to expand from 55-bar to 5.5-bar at full capacity, generating 1,800 kW. The expanded gas volume can also be reduced in summer time from 35,000 to 15,000 Nm3/h, and the inlet pressure of 55-bar can decrease to 30-bar on very cold days.

The turbine system consists of the dual stage expansion turbine, a turbo-gearbox, low speed coupling and the synchronous generator. The whole unit, including the seal gas and lube oil system is mounted on a rigid base frame.

The reaction turbine is of a radial type and the construction is based on a proven design for easy maintenance. But the use of a synchronous generator is new in the energy recovery business.

Previously, asynchronous generators were favoured purely for simplicity of use. But, in comparison, the combination of a synchronous generator and expansion turbine produces no reactive current, drastically elevating the ER-unit's profitability.

And for simplicity of use, control of the turbine and the auxiliary systems is performed by a programmable logic controller (PLC). The PLC controls a constant outlet pressure (pressure control) or a constant gas flow (flow control) through the turbine.

In other words, under pressure control, the outlet pressure is adjusted to a set point by opening or closing of the adjustable inlet nozzles. In turn, the gas flow through the turbine will change so that the actual downstream gas pressure will adjust to the set point. In case of flow control, the adjustable inlet nozzles will supply a constant flow, and will be opened or closed only by higher or lower flow demand.

To use the energy for the new ER-unit in the most efficient way, all heating losses (waste heat of all auxiliary systems) is recycled to preheat the natural gas. Therefore the ER-unit is equipped not only with a high temperature heating system, but also with a low temperature heating system. This recycles all heat losses from the turbine coolers and BHKW's exhaust gases. Each turbine stage is equipped with a preheater fed by the low temperature heating system and with a second preheater fed by the high temperature heating system. This heats the natural gas up to 30°C (LT system) respectively up to 78°C (HT system).

Where a plant operates in low-flow conditions, the high temperature heating system is fed from the BHKWs, At high-flow it is fed from the BHKWs in combination with the existing heating boilers, which also supply the heating system of an adjacent office building.

The electricity from the synchronous generators (BHKW 400V, Turbine 6.3kV) is fed into the electricity grid and delivered to local consumers. For this the expansion turbine as well as the BHKW's are equipped with a transformer.

The whole plant is controlled by a master PLC, which sends all necessary information for dispatching. It operates in separate system groups, and each group is equipped with a PLC (slave) to control their own auxiliary system. This arrangement allows independent operation of each group, and gives better plant redundancy.

The big advantage of ER-units is that they supply absolutely clean energy, and therefore fulfil all regulations regarding environmental protection.

ER-units are not only more efficient and profitable but meet the environmental criteria – no emissions of sulphur dioxide, nitrogen oxide or carbon dioxide.

And even though the investment in such plant is relatively high, demand is increasing year-on-year. This mirrors the increasing pressure on the energy generation sector to produce clean, environmentally-friendly, electricity.

Use of natural gas is a step in this direction and, with reasonable reserves available worldwide, looks to have a bright future.

Certainly no one can afford to ignore the short-term value of coal and oil to produce energy, but the production of clean electrical power is growing in importance.

Already, where possible, many household consumers and trade and industry companies are moving to heating by natural gas instead of coal or oil. The reasons are simple: not only is it 'greener' than coal/oil but it's cheaper.

The market is also shifting towards designing ER-plants on a smaller scale for villages and small towns.

And, timely investment in research and development means Cryostar already has the technologies – solutions like expansion turbines with magnetic bearings and/or high frequency generators – to service this new sector.

Breakthrough for liquid O_2 cleaning

Safety is Cryostar ... there is no other way to do business, be it internally through best operating practices or externally, applying the same safety principles to the benefit of customers. Nothing is more important than guaranteeing that all parts and machines used in liquid oxygen operations are totally degreased.

Cryostar is using an innovative solution for cleaning liquid oxygen process machinery. The technology, a result of two years research and development, utilises an automatic closed-chamber process based on chlorinated hydrocarbons as the cleaning agent.

The development of the new system means the gases industry is assured that all Cryostar machinery and spare parts for processing liquid oxygen are totally degreased – negating the risk of catastrophic failure when the unit/parts come into contact with liquid oxygen.

The methodology behind Cryostar's new technology consists of a cleaning and a drying process in a hermetically-sealed, closed work chamber, managed by an automatic control system to maximise efficiency.

All parameters such as pressure, temperature and time are governed by predetermined settings within the control system's programmes. Operator interface is strictly limited.

The system also permits rotation and swivel movements during both the cleaning and the drying phases. Cleaning efficiency is further enhanced through the use of ultrasonics and an ingenious, patented, airflow displacement process.

The system continuously re-treats the cleaning agent via an integrated vacuum distillation, water separation and residual distillation unit that limits consumption while guaranteeing efficiency.

Each week the solvent pH, alkalinity acceptance and acidity acceptance checks are carried out to ensure product quality and avoid any risk of deviation to the cleaning acceptance criteria. The whole process guarantees total degreasing of parts.

To date excellent results have been achieved for various materials with different degrees of soiling. The design has also proved to be very user-friendly and is in line with industry safety and environmental protection standards.

NOTE

under Cryostar's strict health and safety and best operating practice rules, all parts cleaned – regardless of end-use – are subject to ridged quality control wipe tests or black light tests. Similarly, all spare parts designed to come in to contact with liquid oxygen are automatically degreased and then vacuum-sealed in plastic bags that are marked with the O_2 cleaning mention..

Belgian filling stations renewal performed by Cryostar Automation

In the first quarter of 2003, Cryostar Automation was approached by independent Belgian gas supplier, IJS Fabriek Strombeek, to fully modernise its turn-of-the-century installation.

The customer was in search of solutions to provide greater efficiency and traceability, and software technology to enable precise production management control.

After the initial assessment phase, Automation identified the need to replace electrical cabinets, based on small PCs, Elintec input/output cards and TSX17 PLC, with Cryostar standard cabinets based on SIEMENS and Profibus technology.

Cryostar engineers opted, for the most part, to recycle the mechanics and kept the fully equipped, steel frame, valves and electrical cabinets. However, filling modules were added to enable the multitask capability.

The greater part of the challenge was to replace everything without any loss of production.
Cryostar Automation engineers achieved this through the use of 'configuration software' to adapt the new management programme to the existing configuration. They also initiated a programme of rigorous mechanical, electrical and software testing at the Cryostar factory test facility.

The outcome was Cryostar Automation solutions provided many new capabilities to IJS Fabriek StromBeek's installation, but above all the entire design was achieved with Cryostar's main priority in mind – safety.

Cryostar secured the safety of operators through three redundant levels – electrical, mechanical and software. Plus, the software system is also secured by limiting access to password and log-in.

This is further enhanced by designating a certain level of access to individual operators, ensuring the system provides the right information to the right person. Further more, there is a permanent check between the technical configuration of the filling systems – through the supervision PC – and the actions selected by the operator. Thus negating 'human error' as a source of fault.

The filling station reconstruction was completed during the summer of 2003 and to ensure ongoing support – first level assistance – a permanent link via modem exists to Cryostar engineers.

Cryostar configuration

The new plant installed for IJS Fabriek Strombeek includes:

> four Systems including: Monogas filling systems (N_2O, CO_2, O_2,) and mixtures systems (CO_2, O_2, Ar, N_2 and He). These systems are filling industrial and medical gases. Each system has its own interface;
> five vacuum pumps;
> seven cryogenic pumps;
> one Supervision PC; and
> five wireless barcode readers.

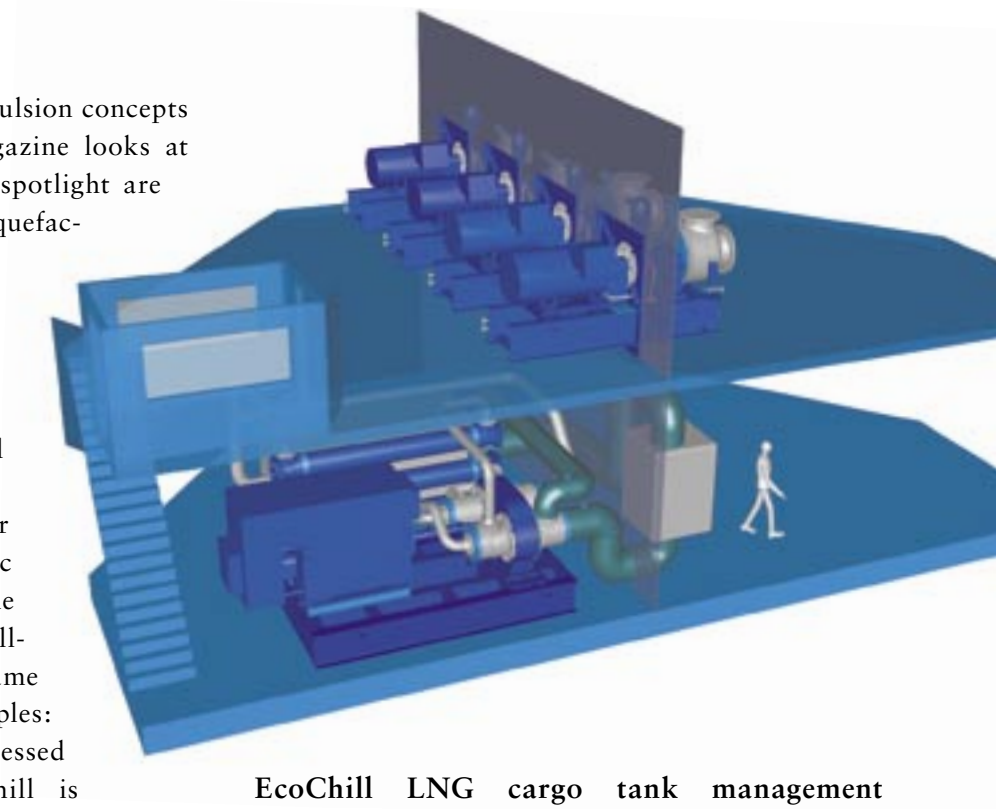
Cryostar added value

Some of the new capabilities brought to IJS Fabriek Strombeek's process are:

> multitask facility;
> synchronisation function to minimise the gas losses and therefore increase the productivity;
> barcode traceability (filling and delivery process);
> supervision software;
> production reports software: results, time date, time spent;
> maintenance support software: preventive and curative, traceability of the defaults; and
> link with existing AS400 software that controls the whole fill plant (filling and delivery traceability, work orders).

LNG transport - the future here today

Innovation is one of Cryostar's main strengths. Our engineers have been developing new technologies and new propulsion concepts for LNG carriers ... here we unveil EcoRel and EcoChill.



In the second feature on new propulsion concepts for LNG carriers, Cryostar magazine looks at emerging technologies. Under the spotlight are Cryostar's EcoRel boil-off gas reliquefaction system and EcoChill LNG cargo tank management system for Propulsion with Slow Speed Diesel Engines

What is EcoRel and what is EcoChill and the difference between them?
The name EcoRel stands for Economic, Reliable and Ecologic Reliquefaction system and the name EcoChill stands for Economic Chilling of tank cargo. Basically, the name describes the operationing principles: The EcoRel reliquefies the compressed boil-off gas vapour; the EcoChill is sub-cooling the LNG cargo to avoid the boil-off formation.

Both the EcoRel and EcoChill are compensating the tanks insulation 'heat in-leak' into the LNG cargo by cryogenic refrigeration. This refrigeration is provided by the Brayton cycle running with Nitrogen as an inexpensive and safe operational medium.

How it works

EcoRel boil-off reliquefaction cycle

The boil-off gas is withdrawn from the LNG tank by a two-stage boil-off gas compressor, in which the temperature on the suction side is constantly controlled via a mixing device and compressed to between 4-5-bar. At that pressure it is condensed in a condenser, which is cooled by nitrogen gas from the Brayton cryogenic refrigeration cycle. After condensation it is expanded to the tank pressure and re-mixed with additional LNG to avoid nitrogen-rich gas flashing.

EcoChill LNG cargo tank management system

The LNG is pumped from the tank and circulated through a sub-cooler, supplied by nitrogen from the Brayton cryogenic refrigeration cycle. The sub-cooled LNG is injected back to the cargo tank through different headers – one in the gas phase to control the tank pressure and several headers in the liquid phase to control the LNG temperature at different locations. The flow of the LNG to the different headers is controlled by the cargo tank management system.

Brayton cryogenic refrigeration cycle

In the closed Brayton cycle nitrogen gas is pressurised at ambient temperature from low pressure (10-15-bar) to high pressure (40-60-bar) in a three stage compressor utilising water inter- and after-coolers. The gas stream is then sub-cooled in a counter-current plate fin heat exchanger and expanded in a cryogenic radial inflow turbine. The expansion further cools the gas, which thereafter is warmed in a condenser (for EcoRel) or LNG sub-cooler (for EcoChill). This is followed by

using the counter-current plate fin heat exchanger to bring the gas back to ambient temperature and allow compressor suction. The three-stage compressor and the expansion turbine are combined as a compander on a common gearbox.

EcoChill vs. EcoRel

In simple terms, with EcoChill the boil-off gas vapour does not need to be compressed for reliquefaction. In comparison, the boil-off gas compression energy for EcoRel requires a 20 per cent higher energy input to the Brayton cycle, than with the EcoChill without the gas compression.

EcoChill also has the added advantage that boil-off gas compressors can be avoided altogether. Instead, compression power is replaced in EcoChill by the very low pumping power for LNG re-circulation in the sub-cooling cycle.

The result is that the heat in-leak compensation function of EcoRel with, for example, 5,000kW total input power (this being the typical power requirement for 200 to 250,000m3 LNGC) can be achieved by EcoChill using only 4,000 kW. The 1,000kW difference corresponds to US$12-14 million in fuel cost savings during the 40-year life of an LNGC. Plus, the investment cost for EcoChill is slightly lower again.

Leading edge

Cryostar products for the current cargo handling system for LNGC's with Steam Turbine Propulsion are single stage boil-off gas and warm-up compressors, gas heaters and vaporisers. Cryostar's range was extended during 2003 to include medium pressure two-stage boil-off gas compressors for LNGC's with Diesel-Electric Propulsion. In line with Cryostar's commitment to leading edge of technology, it now offers four-stage boil-off gas compressors with up to 40-bar discharge pressure for LNGCs using Gas Turbine Propulsion.

Patent protection: The Cryostar intellectual properties for both the EcoRel and EcoChill principles are protected by patent

The new propulsion concepts for future LNG Carriers were described extensively in Cryostar magazine Spring 2003 issue

News

Cryostar France investment

Cryostar France is investing in an additional 300m² of floor space to meet the growing needs of its engineering section.

New propulsion system delivered

Cryostar delivered the world's first two-stage boil-off gas compressors to France's Chantier de L'Atlantique in January for its first LNG carrier using Diesel-electric propulsion.

Central bank rates Cryostar tops!

The French central bank, Banque de France, has awarded Cryostar with its top financial ratings. For the third year in a row, Cryostar has achieved a credit rating of three, and scored seven for payments performance. NB: A rating of 'three' reflects the highest level of excellence that can be awarded to companies in terms of quality of credit and ability to fully honour financial commitments. A 'seven' rating is the highest indicator that payments are made on a regular basis and that the company has never experienced payment incidents.

Liquid turbine generates growth

A growing number of Cryostar customers are opting for the 'liquid turbine' in combination with a conventional expander-generator or expander-compressor unit. And with reported power savings of more than 500 kW and flexibility of use, this comes as no surprise.

Liquid turbines can be used in most of the liquefaction cycles (air separation, nitrogen liquefaction, LNG liquefaction, hydrocarbon processes, etc.). They are installed in parallel to the Joule-Thompson valve and are supposed to replace them during the operation of the plant.

The growing popularity of the liquid turbine, the latest addition to rotating machinery for industrial gas plants, is another example of Cryostar's commitment to research and development in order to provide innovative engineering solutions.
Over the years, Cryostar engineers conducted a number of design studies in order to satisfy stringent customer requirements. The resulting design features of a liquid turbine include double sealing philosophy, careful cold barrier design and a comprehensive monitoring of crucial machine parameters.

It all started in 1983 when Cryostar commissioned its first liquid turbine for the BOC Widness plant. This first liquid turbine was based on a Pelton wheel design and its isentropic efficiency level was between 33-36 per cent.

Soon afterwards a Francis wheel replaced the Pelton wheel and efficiency levels soared to values higher than 70 per cent with a liquid turbine that was commissioned for BOC Scunthorpe in 1986.

What followed was a minute fine-tuning of this prototype over the next decade until the liquid turbine reached its technical maturity.

In 1999, for the first time in its history, a liquid turbine – due to be commissioned for Air Liquide – underwent a full-load, full-pressure test at Cryostar's unique cryogenic test facility in France.

The results were more than satisfactory – the turbine reached isentropic efficiencies of up to 84 per cent.

Since then, liquid turbines have become standard equipment installed in air separation plants and Cryostar has seen many customers including these in new plants, but also in existing plants since the pay back is so short!

Events

★ **April 27-30, 2004**

CRYOGENICS 2004 and CRYO-MARKET 2004, Exhibition Praha, Prague, Czech Republic.

★ **May 11-14, 2004**

20th International Cryogenic Engineering Conference (ICEC 20), Beijing, China.

★ **May 18-20, 2004**

4th Annual World GTL Summit 2004, London, UK.

★ **May 27-28, 2004**

LNG North Am Summit, Houston, Texas, USA.

★ **September 22-14, 2004**

Energie 2004, Avignon, France.

★ **October 26-28, 2004**

NGV 2004, Buenos Aires, Argentina.
For more details:
www.ngv2004.com

Tools and datas:
Carbon Dioxide Conversion Data

We have decided to dedicate this section of our magazine to include usefull tools and datas that are handy in our industry. In this issue, the Carbon Dioxide Conversion Data table.

	Weight		Gas		Liquid		Solid	
	Pounds (Lb)	Kilograms (KG)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)	Cubic Feet (CuFt)	Cubic Meters (m^3)
1 Pound	1.000000	0.453592	8.741500	0.229427	0.118149	0.447242	0.010246	0.000290
1 Kilogram	2.204622	1.000000	19.271707	0.505800	0.260474	0.986000	0.022589	0.000640
1 SCF Gas	0.114397	0.051890	1.000000	0.026285	0.013516	0.051163	0.001172	0.000033
1 Nm^3 Gas	4.358684	1.977066	38.044053	1.000000	0.514974	1.949387	0.044659	0.001265
1 Gal Liquid	8.463899	3.839160	73.987173	1.941847	1.000000	3.785412	0.086721	0.002456
1 L Liquid	2.235925	1.014199	19.545342	0.512982	0.264172	1.000000	0.022909	0.000649
1 CuFt Solid	97.599063	44.270193	853.162212	22.391862	11.531218	43.650411	1.000000	0.028317
1 m^3 Solid	3446.677978	1563.386936	30129.135546	790.761062	407.221068	1541.499516	35.314662	1.000000

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F.
Liquid measured at 21.42 atmospheres and 1.7°F.

Nm3 (normal cubic meter) gas measured at 1 atmosphere and 0°C.
All values rounded to nearest 4/5 significant numbers.

Solid measured at -109.25°F

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