

RECOGNITION
*for Cryostar supplier
excellence in China*

PREDICTIVE MAINTENANCE
*towards smart
machines*

A DAY IN THE LIFE
*No two days the
same for Liliane*

the
CRYOSTAR
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A robust approach to data management, and the right choice of software to manage it, has become vital for 21st century businesses. Current estimates suggest that almost \$6 trillion will be invested in 'internet of things' (IoT) solutions over the next five years, for example. This is an exciting time for companies like Cryostar to optimize machinery, incorporating self-learning. But why is this important for our customers?

One area we are focusing on at present is predictive maintenance. This relies on machine data collected continuously on a machine's current condition, along with data analytics that predict machine-specific malfunctions: predictive maintenance can judge when equipment failure is likely. This is a powerful optimization tool: compared to preventive maintenance that uses average statistics, and regular parts inspection and replacement, predictive maintenance avoids repairs being scheduled too soon or too late. The unnecessary costs of production outages or unneeded parts replacement are dramatically reduced. For more on our predictive maintenance programme, see p. 3.

Another area of IT that is key to Cryostar's strategy is our search for a new enterprise resource planning (ERP) system that fully meets our future needs. Until now, Cryostar has used bespoke Millennium software, introduced in the late 1990s and repeatedly expanded and updated by Cryostar's software development team.

We now aim to select a new ERP system by the end of 2018, and have two teams dedicated to

this process: a team building key job scenarios, and a team of experts to evaluate the various software solutions available. The project has already expanded beyond the planned phase 1, which initially focused on an 'extended finance' perimeter. To meet future challenges that our information systems must meet, we require strong integration between all of the ERP's features comprising Cryostar's global ERP.

Cryostar's drive to seek out and implement the best IT systems doesn't end there: further projects are underway this autumn to update the company's product lifecycle management (PLM) and customer relationship management (CRM) software, too. Together with the new ERP system, these upgrades - known collectively as project 'Hercule' - represent one of the most significant changes at Cryostar in the past twenty years.

We are looking forward to a time when Cryostar machines will monitor their own condition and performance. And through our new ERP, we will be able to monitor and optimize our own condition and performance, too. Taking on complexity and creating efficient solutions may appear a Herculean task, but will result in better ergonomics leading to greater productivity, and ultimately, higher efficiency. These systems will keep all of us a step ahead of the highly connected future we are creating together.

Samuel Zouaghi

PRESIDENT

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BIG DATA

THE THIRD INDUSTRIAL REVOLUTION ?

Today, everyone has access to computer power that can process and analyze, within a few seconds, a quantity of data that would take several lifetimes to read. In addition to rapidly executing human-written programs, this computing power also allows some problems to be solved autonomously. Even by 'foolishly' trying to find solutions at random, some algorithms will still solve problems by trial and error due to the sheer number of computations possible.

Today, connected objects flood servers with data, feeding self-learning models that will distinguish particular behaviors and, after some learning time, 'predict' the data that will be produced next.

Predictive maintenance

"The main promise of predictive maintenance is to prevent unexpected equipment failures and to allow convenient scheduling of corrective maintenance. It relies on the actual condition of equipment, rather than average or expected life statistics, to predict when maintenance will be required".

The latest evolutions in the Internet of Things (IoT) mean that computer power and data storage modify the existing industrial model and directly affect the field of machinery maintenance.

Because we don't know when a machine will need essential care, the common practice of preventive maintenance entails regularly inspecting equipment and exchanging parts, whether they need it or not, which results often in excessive costs due to repairs being scheduled too late or too early.

Predictive maintenance relies primarily on machine data and is based on its actual condition rather than time or age factors. It takes into account actual and historical data to predict the likelihood of failure in

order to schedule maintenance before equipment fails, but not before it is actually needed, avoiding unnecessary costs associated with repair and production loss.

Predictive maintenance relies on data and data analytics. Sensors that continuously monitor and collect machine data, along with analytics to determine when equipment failures might occur, can predict machine-specific malfunctions. Indeed predictive maintenance requires both hardware, to collect-transmit-store data, and software to process these data in order to monitor the equipment.

The machines will likely generate data, but the challenge is in accessing and evaluating this information, and collecting the related process data. How do we create useful information out of it? Collecting data from plant equipment has become a relatively straightforward task, but even though data crunching algorithms are readily available, analyzing the data is more complex.

An algorithm models time series from currently available data and compares the measured parameters with the 'predicted' data provided by the trained model.



When the measured data deviate from the calculated parameters it generates a warning. But only if all conceivable states of production are depicted can a consolidated forecast be made. Included in these conditions are also those preferably avoided in practice: failures, and breakdowns. Maintenance engineers must define a deviation threshold for each calculated parameter. For some parameters it is complex since criteria are not fixed and vary with the potential algorithm 're-learning' that takes place when the machinery encounters new operating conditions. However not all algorithm evolution can be based on machine self-learning: human guidance control and evaluation may be required in some instances.

Over the last few years the potential of predictive maintenance has generated great excitement, and commercial solutions offerings are blooming. These solutions use non-supervised statistical models based on operating data, and require an initial learning period.

The use and benefit of such an analysis method are limitless in principle. The availability and quality of data, processing power, and the knowledge of how to combine these elements are the limiting factors. Despite many claims, not everyone who knows how to use a predictive analytics tool can contribute the necessary expertise to the analysis. The skill level and experience required to accurately interpret condition monitoring data is also high.

In addition to these limiting factors, data access is also a specific concern. Indeed the exchange of data between machine operators and machine suppliers generates security as well as confidentiality issues that must be contractually defined.

Cryostar's vision

Cryostar is evaluating a concept in which as a basic functionality, the Cryostar machines will be able to monitor and evaluate their own condition/performance, with the objective that they periodically issue a status report solely to the operator.

In addition to the status report, when needed the unit will issue a 'recommendation' for the required replacement parts linked to its actual status, listing for example the original spare parts numbers. This will take place without any human interaction, and early enough to provide enough time to schedule a future service intervention.

Among the few failures that may take place over the life of a machine, a large proportion of failures may take place early during the initial startup period of the plant in which the machine is installed. At this stage, predictive models based on pure statistics have not collected much operating data to be trained on. However, at this stage, Cryostar, as the OEM, does already have an 'enriched' model based on the 'reference machine signature' collected during the factory acceptance test and, due to the Cryostar access to a large installed base, on the

knowledge gained over the maintenance, repair and operational behavior of multiple similar machines.

The Cryostar concept is based on a standalone monitoring box installed locally on the machine, while not interfering at all with the machine control and protection system. It contains all the dedicated machine-specific information (model, serial number, set point list, reference signature, etc.) along with multiple sensors and signal processing capabilities able to perform vibration analysis, which is required on high-speed rotating equipment.

Cryostar considers that valuable information is included in machine behavior during transient conditions (start/stop sequences, speed or load increase, etc.), which require fast signal acquisition. This implies local signal treatment to limit the amount of transferred data, which would be too large when considering raw vibration data for example.

Within an optional dedicated service contract, the report will also be sent to Cryostar for an evaluation of the machine's status. In return the customer will receive tailored recommendations from the experts based on operating practice feedback collected over a wide range of similar units.

In addition to the specific preventive maintenance recommendations, since Cryostar designed the machines, Cryostar will be able to evaluate whether the operating conditions fit the actual design and if not, assuming that similar operating conditions will be maintained, to propose machine improvements that match the real conditions in order to improve efficiency.

Cryostar's wide range of machines is, most of the time, engineered to order and they are not series products. A given machine type may be in use in different applications, for a given application under different process conditions and for a given application under given process conditions under different or varying operational patterns.

No turnkey preventive maintenance solution is adapted to the Cryostar concept that mixes machine site data with site data from other similar machines as well as with design, factory assembly and test data. Cross-analyses of such a large amount of data require the development of a dedicated application, which requires specific means and specific skills based on data science technologies commonly known as 'Big Data'.

Proof of concept

Cryostar dedicated a specific team to develop a predictive maintenance proof of concept, focused on an industrial gas turboexpander and one type of cryogenic process pump.

The team has sought external support since multiple disciplines and fields of expertise are necessary.

These include:

- statistics
- data analysis
- relational algebra
- SQL language that deals with relational databases
- cleaning and management of unstructured data
- data visualization
- network infrastructure
- data communication and associated security
- Python and R programming languages

But nevertheless Cryostar considers that perhaps most importantly, the 'Data Scientist' must be a practicing expert in their field and must remain pragmatic in order to assure that the data processing stays relevant and grounded in the practical application.

When sampling at high frequency, each sensor produces billions of data within a few hours. Over years, even low frequency sensor signal sampling produces billions of data per sensor; and since multiple parameters are collected per machine they cannot be handled/treated by a conventional computer. Unprecedented computing and storage capacity is needed and the chosen solution must be scalable to cope with the continuously growing amount of data. To analyze machine operating and test data, Cryostar will use, on a small scale, open source distributed computing and storage solutions that have already been developed.

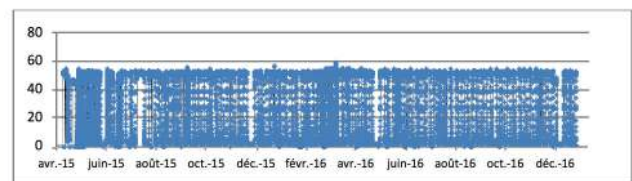
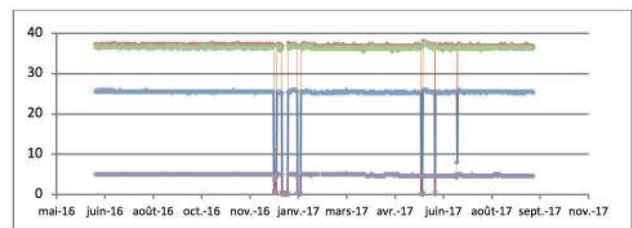
Conclusion

Cryostar is working on a predictive maintenance proof of concept, based on supervised machine learning.

Data access is key for any predictive maintenance activity and Cryostar has the exclusive access to both operating as well as design testing, maintenance and repair data over a wide range of units operating under various conditions to develop its model. Cryostar believes that machine expertise and knowledge, especially for non-series products operating under different conditions, will remain a requirement to train predictive maintenance models.

Even though turbine, compressor and pump failure case data are rare and statistically underrepresented, Cryostar expects that its model, borrowed from Artificial Intelligence, fed by the combination of on-site operating data, by OEM exclusive, design, factory assembly and test data will provide early, robust and relevant machine status change warnings.

Two different operating schemes for two turbo-expanders (same type, frame size and application).





NO TWO DAYS ARE THE SAME

We begin our new series of 'a day in the life' articles with Liliane Hell, a Cryostar employee of 41 years, who is presently in charge of shipments of machines (compressors, exchangers, and liquefaction units) in the LNG Transport and Terminals Business Unit.

For Liliane, no day is the same, each is one special, even if they all start by reading emails that have arrived during the night due to the time difference, as most customers in this market segment are in Asia. The next step is to analyse and prioritise these in order of urgency.

In fact, Liliane's team prepares a shipment of this type of equipment at least three weeks in advance, as it is necessary to reserve a ship able to take the load

within the desired timeframe, after obtaining customer approval for the selected transport date. During these three weeks, the project manager or their assistant meet bi-weekly with logistics for a project follow-up, to coordinate activities internally so that the material is packed and ready for delivery on D-day. The team will also use these three weeks to prepare all the documents and information necessary for the shipment, in collaboration with the freight forwarder, Schenker; to monitor the packaging with our partner Embalsace; and for marking boxes and packing. Next comes customs clearance, even though Cryostar is allowed to use a simplified procedure. The invoice is issued and the equipment can leave. Except that...

All that seems a little routine, but that is without accounting for unexpected problems. And there are many! The most difficult to manage are changes to the means of transport. If everything is prepared for maritime transport, and then the customer requires a



shipment by plane, Liliane must go back to square one and start again. Other events can affect us moving forward through the necessary steps, such as the obligation to obtain an extension to the letter of credit (the title of payment) or a crate not being taken on board the ship! As we know, the captain is the only master on board of the ship and they can use their authority to leave one crate on quay, if it suits them. This can happen particularly if the crate is oversized and does not allow the load to be maximised. Consequently, the single invoice will then need to be transformed into two invoices with all the other documents modified for two shipments, instead of one.

Among the additional tasks, the most delicate is that of tracking letters of credit with a great deal of back and forth with our banks to present a compliant set of documents and to avoid the letter of credit being rejected, which would result in non-payment of the invoice. There are also requests for tenders on future projects, so that sales engineers can consider the cost of transport in their quotes to customers. Or the

opening of the shipping file from the customer's order with a check-list to be followed, processing disputes, upstream work on letters of credit in collaboration with the legal department, and compliance with customs rules and embargos depending on the country.

Since 1977, Liliane has not had a dull moment in her work because it is so varied - no two days have ever been the same!





CRYOSTAR CHINA WINS THE 2018 LINDE SUPPLIER EXCELLENCE PRIZE

At a reception held in Shanghai at the Linde Technical Center on 14 June 2018, Cryostar China was awarded the '2018 Supplier Excellence Prize' by Linde Gas China, from among nearly 3000 suppliers listed in the 'Strategic Supplier' category.

Cryostar China has taken a more proactive approach to service over the past fifteen months, significantly improving the level of service provided to its customer, Linde Gas.

Antoine Jacques, head of Cryostar China, elaborates on his approach to service: "We are particularly proud to be recognized by our client as we constantly search for ways to improve our services to our customers. Our new service approach includes (subject to project prerequisites) dedicated teams of intervention technicians on-site who are easily identified and already known to our client."

According to Jacques, Linde Gas greatly appreciated this quest for proximity and team spirit. Meetings are scheduled every two to three months between Cryostar China and

Linde's Chinese team for troubleshooting, to review spare parts stocks at Linde sites and to discuss general follow-up issues. "These sessions have been held successfully at both Linde Shanghai and Cryostar China. Regular meetings have encouraged communication between the two companies, in a spirit of transparency and openness," he adds.

"We were also keen to appoint dedicated technicians to work on each of the Linde sites concerned, who would be responsible for solving technical problems on site. This will help to ensure better monitoring and provide practical solutions to any problems which arise." The success of this approach has been made possible thanks to the strong commitment of the Service Manager, the Business Center Manager and Cryostar's after-sales services department, Jacques says.

"This award is a clear acknowledgment of Cryostar China's achievements and efforts. As an additional honour, Cryostar was the final award winner at the ceremony, something of which we are particularly proud."



The recipients

Cryostar China

Based in Hangzhou near Shanghai, Cryostar China was established in 2002. Since its formation, Cryostar China has fully participated in the growth of industry in China, moving and expanding its premises to provide ever better services to its customers. The company supplies equipment and services to the largest gas companies in China and internationally, as well as gas distributors in the industrial gas, green energy and LNG markets. It has 35 employees.

Cryostar China
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Yaogu LIU, Service Manager and Antoine JACQUES, head of Cryostar China representing Cryostar at the ceremony



A long term partnership

Petrofac has been an important partner in Cryostar's successful move into the hydrocarbons marketplace in recent years. We take a closer look at Cryostar's role in the evolution of a major project in Oman.

In 2014, Petrofac and BP awarded Cryostar a contract to supply two turboexpander-compressors for BP Oman's tight gas project, known as Khazzan. Earlier this year they also chose Cryostar to provide a third turboexpander-compressor for the Ghazeer project, the Khazzan project's second phase.

Together with Petrofac, Cryostar has executed seven projects to supply hydrocarbon turboexpander-compressors for gas processing projects between 2005 and 2013. These machines have been destined for Algeria, Tunisia, Syria, Turkmenistan and the Sultanate of Oman.

Petrofac, based in Sharjah, UAE, specializes in project management relating to gas processing plants worldwide. As one of Cryostar's important key historical customers, Petrofac has been a major player in Cryostar's strategy, initiated 15 years ago, to penetrate the hydrocarbon market. During this time, all of our turboexpander-compressor projects executed with Petrofac incorporated our renowned expertise in active magnetic bearing (AMB) technology.

In 2014, Petrofac awarded Cryostar a contract to supply two model MTC600/240 turboexpander-compressors for the Khazzan Phase 1 project in Oman. BP operates the Khazzan Block 61 in partnership with

Oman Oil Company Exploration and Production. The first phase of this giant gas processing plant was awarded to Petrofac and has a capacity of just over 1 billion standard cubic feet of gas per day (SCFGPD) and around 35,000 barrels per day (BPD) of condensate.

The turboexpander-compressors Cryostar supplied are equipped with AMB, and designed to develop a total maximum power of 10MW. Cryostar delivered the Khazzan turboexpander-compressors on time in January 2016, subsequently BP commissioned the plant in September 2017, reportedly ahead of schedule and under budget.

December 2017 saw Petrofac awarded a contract by BP for the central processing facility (CPF) at Khazzan Phase 2 (the Ghazeer Project). This was quickly followed by Petrofac then awarding Cryostar a contract in



January 2018 to supply a further model MTC600/240 turboexpander-compressor for delivery in January 2019.

The Ghazeer project is expected to come onstream in 2021 and deliver an additional 0.5 billion SCFGPD and over 15,000 BPD of condensate from the existing Khazzan plant. The Khazzan developments are expected to deliver total production of 10.5 trillion cubic feet (Tcf) of gas and around 350 million barrels of condensate through the end of concession.

news

LNG Business Unit sees large orders in 2018

Since the early 1990s, CRYOSTAR's role as a supplier of cryogenic equipment for LNG carriers has grown. As a result of the company's innovative spirit leading to significant and lasting improvements to machinery, CRYOSTAR's reputation has been elevated to that of market leader.

In 2018 to date (up to August), CRYOSTAR has booked LNG orders for an impressive total of € 108 million, which comprises an outstanding amount of 70 pumps, 90 compressors and over 300 heat exchangers and vaporizers. These orders, placed by all major Korean shipyards – Daewoo (DSME), Hyundai (HHI) and Samsung (SHI) – are for a total of 25 LNG carriers.

The company is expecting more orders through the

end of the year, with a good chance to beat the order record of € 126 million, set in 2011

A first for Cryostar

The sale of two hydrocarbon liquid turbines (LTG200/50) to SOAR (China) is a commercial success, which could open a new market for Cryostar. Destined for a Chinese petrochemical plant, these turbines will replace the valves usually utilised in the Rectisol process, operating on a licence by Hengli Petrochemical (Dalian) Co. Ltd., the end customer of the project.

The process consists of a physical wash of syngas involving a solvent to extract acid gases and raw syngas. The syngas derives from coal gasification or refinery residues.

CS India opens new office and workshop in New Delhi

To keep pace with economic growth in India, CS India (CSI) has moved to a new location. Just 200m away from its former address in Okhla Industrial Estate, the new workshop remains in a prime industrial area of New Delhi.

The new location has a covered area of 2650 sq. ft., of which the office space occupies 1800 sq. ft. on two floors and the workshop covers 850 sq. ft. on the ground floor.

Equipped with a Kone Make 2 Ton Pillar Mounted Jib Crane and a Toyota BT Staxio Stacker for moving materials, the workshop also houses a degreaser, which has been customized to our use. The CSI team is all geared up to welcome you at our new location.

Job dating at Cryostar

CRYOSTAR is currently in continuous recruitment mode in response its increasing business activity. Between January and August 2018 some 62 people joined Cryostar.

To increase our chances of attracting talented and highly qualified people, the company organised a 'job dating' event on June 18th. This event, where many potential candidates have an initial, very rapid interview, was a great success, with over 70 people attending.

Consequently, a dozen candidates have been interviewed in an in-depth phone call, of which six were then interviewed face-to-face.

At this stage, one candidate has already been hired, and will join CRYOSTAR in the coming weeks.

Cryostar employees retired in 2018

In 2018, the following people have retired. We wish them a long and peaceful retirement.

NAME		RETIREMENT DATE	JOB TITLE	SENIORITY/ YEARS
NAAS	PATRICE	30/06/2018	SPECIALIST CUSTOMER SERVICE	35,50
TRUBALUK	ADAM	31/03/2018	EMPLOYEE TECHNICAL TRAINING	27,83
BOIGEY	JACQUES	31/01/2018	SENIOR DESIGNER TURBO MACHINES	30,50
MANN	BERNARD	31/01/2018	ADVISER BU PROCESS	43,33
HANNAUER	GILLES	30/04/2018	PLANNING TECHNICIAN	13,83
MICHELUTTI	MARIO	28/02/2018	MAINTENANCE TECHNICIAN	11,50
PERICHAUD	BRUNO	31/07/2018	OPERATOR	11,33
SCHMITT	BERNADETTE	28/02/2018	ACCOUNTANT	7,42
SUTTER	PHILIPPE	31/03/2018	BUYER RESPONSIBLE MARKET SEGMENT	4,58
KUENEMANN	JEAN	31/03/2018	TECHNICIAN ON SITE SERVICE	3,25



BRAZIL

CHINA

FRANCE

INDIA

RUSSIA

SINGAPORE

UNITED KINGDOM

UNITED STATES

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