# Right place, right time

## Stéphane Desbuisson, Fives Cryo, France, and Nicolas Teyssot, Fives Cryomec, Switzerland, explain why it is vital to predict maintenance precisely to optimise equipment efficiency and extend its lifecycle.

Equipment ages daily, regardless of how often or how intensely it is used. Without proper understanding of its behaviour, maintenance can become a headache for users who are not adequately prepared.

Preventive maintenance is critical for process, cost, and equipment reliability. However, one of the main questions raised is how to verify that the right maintenance is being performed at the appropriate time. This prediction may be difficult if the customer has not put in place proper monitoring for his installation and equipment. This monitoring can be achieved with a large amount of data for an operational performance follow-up, or specifically for the prediction of the maintenance time.

Following the path of competitiveness, present and future factories will continue to deal with the challenge of cost efficiency. A broken piece of equipment can cost two to five times more than routine maintenance, resulting in totals of 10 times the original maintenance amount when all costs are included (such as emergency response, process disturbance, and stress on the production line). Therefore, it is crucial to outline proper preventive checks to avoid these failures, and be able to plan proper shutdown and maintenance times.

A cryogenic pump failure – the core of the installed cryogenic liquid transfer process, like on LNG – is already difficult to handle, despite redundancy in the process, due to the increasing risk on the back-up pump. However, would a customer feel safe if he started to see a brazed aluminium heat exchanger (BAHX) leaking?

While curative maintenance is not economical when including the emergency repairs, the customer may hesitate between a safe and easy periodic maintenance and a predictive maintenance that requires more effort.

If the interval time for maintenance is not properly set, the equipment can potentially reach the breaking point. In this case, the supposedly preventive maintenance would become curative maintenance.

Maintenance intervals are complicated to plan because of the variety of the equipment's usage (time, running conditions, start-stop cycling, etc.), and all of these usages require proper monitoring.

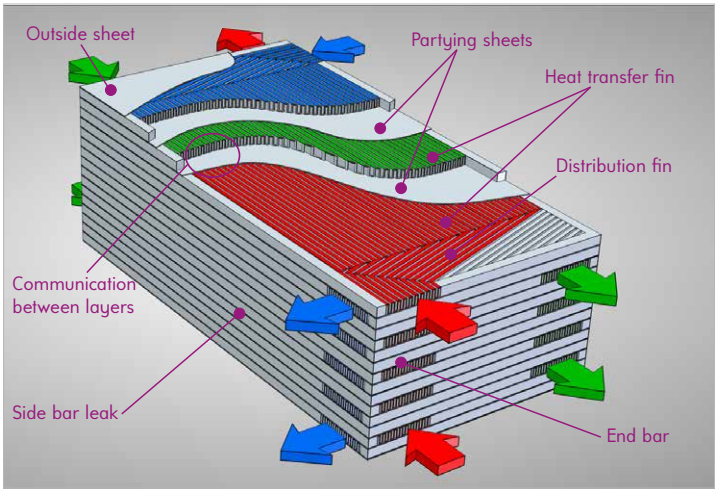


Figure 1 - Pressure-volume compression diagram for traditional and compact heat exchanger technologies.

Monitoring is the key of predictive maintenance. This is based on the collection of specific data, such as vibration, temperature, acoustic, electrical, or linked with operational performances. Data collection may also include simpler elements, such as visual checks and periodic inspection.

The generalisation of new technologies and the digital transformation of the industry represent good assets for the development of various customer-oriented interfaces and tools.

Monitoring customers' installations and equipment with new technologies will be mandatory to be able to retrieve, gather and analyse as much data and information as possible.

### HEAT EXCHANGERS AND CORE

Plate-fin heat exchanger technology is used by approximately 25% of the LNG liquefaction trains in the world, and also on

Q-Flex LNG carriers. The main concerns faced by users of BAHXs are the risks of leaks (which may require layer plugging) and fouling (Figure 1). Often, these create disturbances in the customer's processes and may eventually lead to a complete plant shutdown for a long and costly repair.

## Monitoring

While plugging may be checked by performance verification during the commissioning and operation, additional diagnostic tools and periodic maintenance should be implemented to avoid any issues. During a planned factory shutdown, three tests should be performed to assess the equipment condition:

— Leak testing to check for possible interaction between two or more streams polluting each other, along with external leaks.

— Control of distortion testing to detect possible abnormal deformations in the heat exchangers.

— Mercury testing, using x-ray techniques because it can corrode aluminium under specific conditions.

## Repair on-site

A leak can be external, stemming from sidebar leaks, or from cracks on the welds (Figure 2) causing pollution (communication between layers). When internal cracks are observed, layer plugging is often required, but new performance test simulations must be completed to understand if the performance degradation is acceptable for the customer.

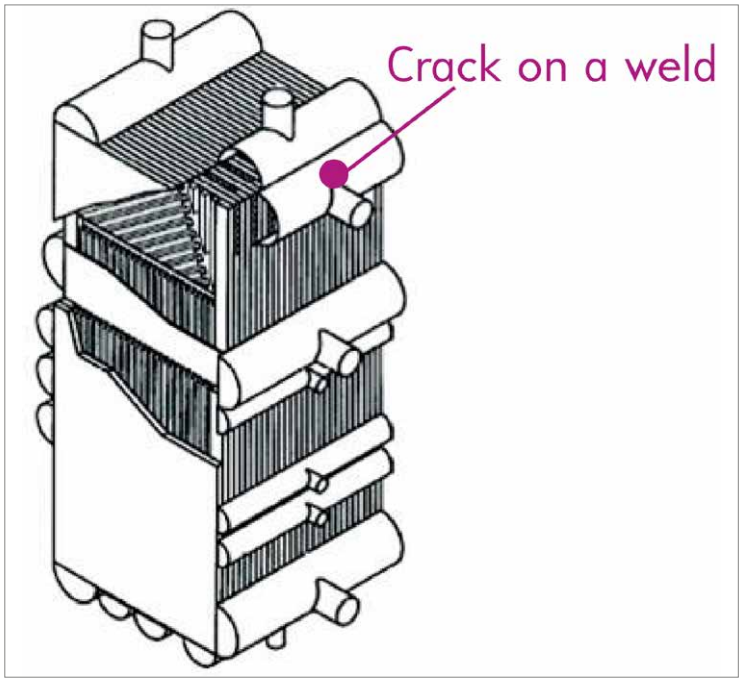


Figure 2 - Multi-staged gas compression system principle

Providing optimum efficiency of the equipment is the objective, and means that only reasonable pressure drops are acceptable. Such repairs can be done on-site using experienced field service engineers and technicians that will seal leakage by welding, and perform tightness tests to confirm plugged leaks and optimal efficiency.

Additional non-destructive tests (NDTs) are also required, including the radiographic and dye penetrant tests performed by experienced field service technicians.

Aluminium is the main material of Fives' BAHX. It is one of the most difficult alloys concerning welding and requires several different qualifications, such as ASME and European PED codes. To support customers on these complex requirements, Fives created its own internal welding school aimed to improve welding skills and develop new welding procedures to ensure the highest quality of welds on-site and at its workshops.

By the way, in partnership with Licensors and End Users, Fives is involved in the 10-year maintenance of Q-Flex LNG carriers in dry dock (see Figure 4), to ensure the lifespan of the re-liquefaction system. Thanks to the reliability of the plate-fin technology, repair operations to be performed by Fives remain rare, and do not exceed one week as an average. Such repairs, when needed, are

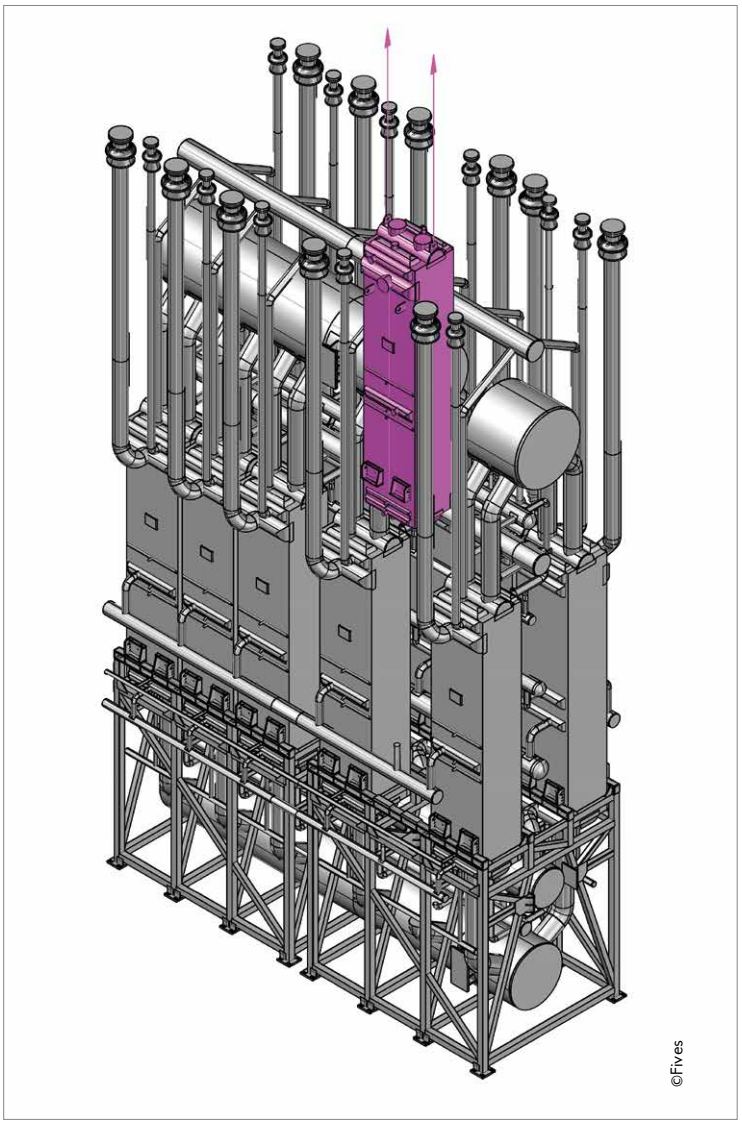


Figure 3 - Replacement of one core

performed at anchorage point or during ballast voyage.

All of the company's technicians are trained so that they can work on all types of heat exchangers regardless of the manufacturer. For example, on spiral wound heat exchangers (MCHEs), TIG and MIG welding can be performed on-site by experienced service technicians.

Occasionally, the damages are such that one of the cores is not functional anymore, and it has to be replaced. Fives' designs allow for single heat exchanger replacements instead of modifying the complete installation, whether the heat exchanger must be repaired or replaced (Figures 3 and 4).

However, most of the times when these periodic checks are performed, there remains potential internal pollutants, such as dust, corrosion debris, or perlite, that could plug and foul one or more layers. The de-plugging technique used by Fives is called back-puffing, which sends a large air quantity under pressure into one isolated layer to push particles out. It is helpful to emphasise that most plugging caused by dry particles can be de-plugged with this procedure.

However, design and study are key in the exchanger's design, by enabling the optimisation of the replacement solutions and minimisation of the welding on-site in order to reduce the shutdown period. The design and process teams play a key role in these operations. Designers calculate the sizing for the process

design and mechanical integrity, while the process engineers check the design with specifications (i.e. simulations to ensure optimal efficiency).


Figure 4 - Q-Flex LNG carrier

### Remote support

Whether for site intervention and checking or for customer support, a remote team of application and process engineers should be on call at the office. These teams will remotely support the customer to resolve the production issues, concerns, or demands in the quickest manner possible.

Fives' highly qualified technicians can easily avoid typical problems with BAHXs or MCHEs (fouling, plugging, leaks, etc.) leading to devastating effects on production losses.

## CRYOGENIC PUMPS

Heat exchangers are not the only equipment that can benefit from proper checks and verifications.

The cryogenic pump field is an area where predictive maintenance can lead to important cost savings. Such equipment, as per Fives' recommendation, is highly monitored with internal and external sensors.

### Monitoring understanding

When talking about cryogenic pumps, the variety of usage is as wide as the amount of customers worldwide. Although the same type of pumps can be used onshore for bunkering or in a trailer tank to unload its tank, it is key to understand the customer's business and its monitoring requirements.

Prior to defining the proper tools to use for monitoring, Fives always meets the customer first to ensure that data can be retrieved, whether automatically or manually. For instance, motor grease quantity and interval depend on motor usage (performance) and external temperature.

### Local monitoring and support

It is important to support customers by properly setting up the preventive maintenance (whether it is periodic, or constantly monitored), and therefore being able to spend some time on-site on a regular basis to verify that proper actions have been done.

Whether it is led by one of Fives' five service centres or by a local partner, all customers are tracked on a yearly basis to ensure the adequacy of these supports versus the latest customer objectives.

### On-site monitoring

Local monitoring through periodic check or sensor monitoring is the best way to support preventive and predictive maintenance.

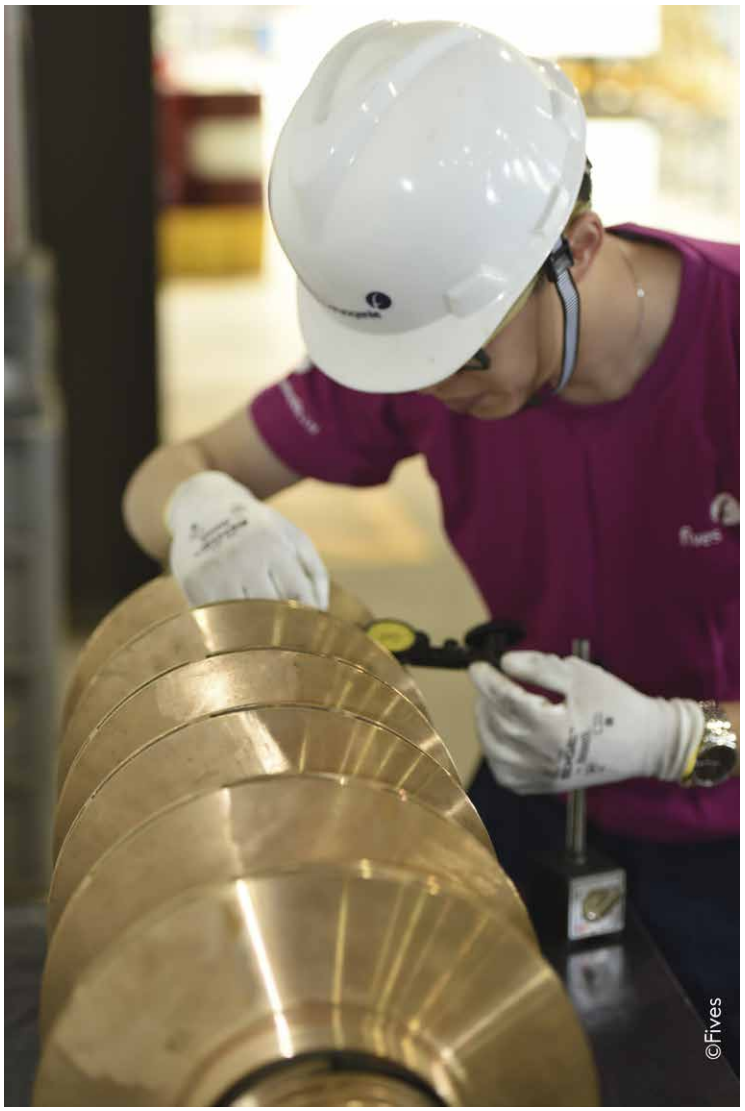


Figure 6 - Pre-alignment and concentricity check of centrifugal LNG pump.

For pump data, monitoring dœs not only mean process parameters such as pressures or flow, but means all the value chain in the equipment: motor power, motor speed, vibration, temperature and vibration of bearing, etc., and its accessories (lubricating system, seal gas, etc.).

Actual triggers are set to protect pumps from failure, and whether it is an alarm point or a stop one, reaching them means maintenance is already required. Field and remote support are both provided to reach optimum performance of the customer's pump. While visiting a customer in China, Fives' local team was able to predict the maintenance requirement for the pump more than six months prior to the customer observing difficulties.

### Remote monitoring

When equipment is working alone on a remote site, or when the customer has several ports of control, it is also important to set up remote monitoring. It helps customers to understand how the


Figure 5 - Piston head maintenance for a FGSS piston pump

pump works, but also gives the service provider more data to support his customers and help him define proper timing for his maintenance and proper actions to support his maintenance.

For example, on the Cryomec VSMP pump, product for LNG application, monitoring can be achieved through constant remote support, on bunkering applications since there is no local constant monitoring, but also for LNG fuel gas supply systems (FGSSs) to ensure people on board receive support on any actions since there is no on board specialist available at any time.

While on-site monitoring by customer's technicians and engineers is only set to review instantaneous data for live process, historical data should be reviewed in order to assess trends as well as predict the next most appropriate maintenance time.

Fives' teams have developed the expertise to analyse this data, assess trends and can predict precisely the appropriate timing of the next maintenance required.

### Repair on-site or in a workshop

The last step of good monitoring and follow-up is of course the maintenance repair itself. This should also follow strict rules to maintain high quality standards and not reduce maintenance interval.

Customers are very often willing to take care of the motor repair themselves since their maintenance team or local workshop may have experience with motors. However, motors used on cryogenic pumps are far from being generic or standard motors, and their maintenance requires very specific and detailed checks that regular maintenance shops are not aware of. In this matter, it is important for the customer to get in touch with certified repair workshops that can handle such fine-tuned motors. For example, Fives has developed a special methodology for motor repair (Figure 5) and has certified its five workshops accordingly (Figure 6), in addition to the workshop of its official service representatives. Poor motor re-assembly can decrease the motor life-time drastically. A common example would be the one Fives dealt with recently in South Korea. While last motor maintenance on a Cryomec VSMP managed by a Fives technician had made the pump last three years without any issues on 24/7 duty, the customer allowed a local, uncertified contractor to take care of the maintenance of all equipment on-site, including the Fives cryogenic pumps. While repairing the motor as a regular motor, the lifetime of the pump dropped significantly since the pump failed twice after three months duty.

Performing predictive maintenance on cryogenic equipment is key to achieve optimum efficiency and extend its lifecycle.

However, understanding the various usages of cryogenic equipment is vital to monitor it correctly and predict the maintenance adequately. This can only be achieved by building a close relationship with the customer.

## CONCLUSION

Wherever the customer is located worldwide, he should benefit from local support and experience of cryogenic specialists to determine the trigger to properly scheduled maintenance times, whether using his own system, or the one developed by the Fives service teams.

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