



Adam McNeilly and Paul Shields, Chart Industries, USA, introduce a passive system that provides early detection of end of service life for brazed aluminium heat exchangers.

A SMARTER SYSTEM

The lifespan of a brazed aluminium heat exchanger (BAHX) depends entirely on the care with which it is operated and maintained, especially with respect to thermal gradients. Where there is a high frequency of temperature excursions beyond Aluminium Plate-Fin Heat Exchanger Manufacturer's Association* (ALPEMA) guidelines, the gradual accumulation of stress events can lead to leaks in the field. Unfortunately, because BAHXs do not wear like brake pads or tyres, it is notoriously difficult to predict when these will occur.

Leaks to atmosphere cannot go unchecked as they pose a danger to property and life, which means an unplanned shutdown where loss of production is likely to add significantly to the overall cost of remedial action.

Chart has introduced a new technology that is capable of providing early detection of end of service life for BAHXs and is entirely passive from a plant operator's perspective. Patent pending Smart Layer™ technology can provide advance warning when a critical threshold of the operational life of a BAHX has been consumed, such that the operator can plan ahead for the unit's repair/replacement and significantly reduce the instances where unexpected external leaks require unplanned shutdowns and expedited delivery of a replacement BAHX.

Brazed aluminium heat exchangers

The BAHX is generally an incredibly robust and reliable piece of equipment and the typical industry service life expectation is

around 20 years, although units that have been operated diligently with respect to ALPEMA guidelines can enjoy service lives of 40 years or more. However, leaks can occur. The majority of these are small, and a leak between process streams (internal leak) may even go unnoticed. However, a leak to outside the BAHX (external leak) is a larger concern, as the loss of containment may lead to explosive vapour clouds or environmental pollution.

Predicting external leaks and loss of containment in BAHXs before they occur is notoriously difficult. Chart's new technology is intended to serve as an early warning system to alert operators when continued operation is likely to lead to cracks and loss of containment. It provides an indication that remedial action is required. Crucially, this technology allows continued operation without loss of containment for a sufficient period of time until process and control system improvements can be implemented, and/or BAHX repair/replacement arrangements can be made.

What is a BAHX and how does it work?

BAHXs are highly efficient, custom designed compact heat exchange devices that offer distinct advantages over alternative heat exchange methods. They are manufactured as all brazed and welded pressure vessels and designed in accordance with major pressure vessel codes throughout the world. BAHXs are applied in a variety of cryogenic and non-cryogenic

heat transfer applications, including processing and liquefaction of natural gas, natural gas liquids recovery, nitrogen rejection, helium extraction, separation of atmospheric gases and in the petrochemical industry for the production of ethylene, propylene and hydrogen. Given their high surface area, compactness and the superior heat transfer capability inherent to aluminium, they are a cost-effective solution for processing of non-corrosive liquids and gases when compared to alternative heat transfer technologies.

Construction

The principal components of a BAHX (Figure 1) are:

- Parting sheets (primary heat transfer surface).
- Fins (secondary heat transfer surface and pressure retaining component).
- Side bars (pressure retaining wall).
- Cap sheets, the outermost surfaces; similar to parting sheets except thicker and with the brazing alloy on one side only.

The components are stacked in an alternating pattern of hot vs cold.

The key to bonding the structure together is the brazing process. An aluminium alloy is applied to the surface of the parting sheet. Once the core is stacked and heated in the vacuum brazing furnace, the alloy melts, wetting the surface of adjacent components. When cooled, the alloy returns to solid state, effectively sealing the components together.

A major milestone in the development of BAHXs occurred in the 1980s with the introduction of vacuum brazing, which replaced the previous salt bath process. Vacuum brazing has enabled manufacturers to develop the size, complexity and upper pressure limits of the plate fin units needed in industry today.

BAHXs are generally oriented with the warm end up. This is a preferred arrangement because it reduces thermal stresses during shutdown by preventing cryogenic fluids flowing to warmer surfaces.

There are four main fin types that form the secondary heat transfer surface: plain, plain perforated, herringbone

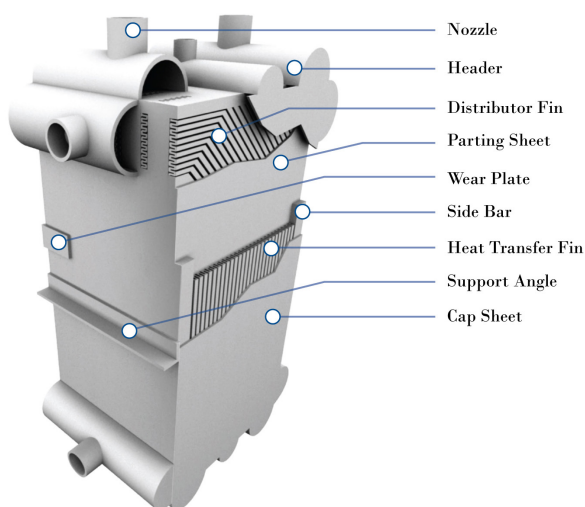


Figure 1. BAHX components and nomenclature.

and serrated. This variety is one of the main contributors of the high thermal efficiency of BAHXs compared to other heat exchanger types.

Dealing with thermal fatigue

The typical cause of BAHX loss of containment is small external leaks due to cracks that have formed on the surface of the cap sheet. These hairline cracks usually appear at the edge of the cap sheet near inlet or outlet headers, are under 6 in. long, and less than 0.01 in. wide.

The majority of external leaks are caused by thermal fatigue, which is the accumulation of damage that occurs as a result of changing temperature gradients within the metal matrix of a core. This is caused by operation outside ALPEMA guidelines.

Smart technology

The premise is that thermal fatigue stress will accumulate in Smart Layer faster than in other parts of the core. Crucially though, damage will manifest in the technology before loss of containment occurs, providing an indication that a significant portion of the life of the BAHX has been consumed.

This early warning gives owners and operators the opportunity to take action through analysis of the operating data to determine the root cause of the damage, followed by appropriate remedial action including adjusting operation to mitigate further damage to the BAHX and making arrangements for repair or replacement. Since operators are alerted without loss of containment having occurred, the BAHX can continue to operate for some period to allow these actions to be completed on a more flexible and convenient schedule.

There are three stages to the technology's damage indication:

- Stage 0: new condition, no cracks or leaks.
- Stage 1: damage indicated, no external leaking of process fluids.
- Stage 2: external leaking of process fluids.

The BAHX leaves the factory at stage 0. It experiences operating/upset conditions outside of prescribed guidelines and at this point fatigue damage crosses a critical threshold at stage 1. If the BAHX incorporates Smart Layer, an alert is triggered that enables remedial action to be taken: operating conditions can be analysed and adjusted; provision can be made for a planned repair; production continues and there is no loss of containment. As such, stage 2 is never reached, and the eventual repair can be completed expediently, returning the BAHX to stage 0.

If the BAHX does not incorporate this technology, no alert is triggered, which means the non-ideal operations continue: damage accumulates, resulting in stage 2; the plant shuts down; emergency repairs are carried out, which are expensive and time-consuming; revenue is also lost through an unplanned shutdown (Figure 2).

How it works

The new technology is an inactive layer on the top and bottom of a core that has been pressure tested and rated to hold the full operating pressure of the outside active layer

that is adjacent to it (Figure 3). Prior to start-up, the layer is pressurised with an inert gas and sealed to create a positive pressure.

Pressure sensors are installed in the technology and integrated into the plant's distributed control system (DCS) so that the pressure can be continuously monitored.

Operation outside ALPEMA guidelines will induce stress and fatigue in the layer, and eventually a crack will form, either on the cap sheet, or on the outside parting sheet separating Smart Layer from the outermost active layer.

If a crack develops through the cap sheet, no containment loss of process fluids will occur, but Chart's new layer will lose pressure. This will be detected by the pressure sensor.

If a crack develops through the parting sheet, the fluid from the active stream will flow through the crack into the Smart Layer. This will increase the pressure in the layer and be detected by the pressure sensor. This layer will contain the active stream that has leaked into it because it has been pressure tested and rated to hold full stream pressure and thereby prevent a loss of containment.

In either case, this cracking is a sign that the operating conditions are outside of ALPEMA guidelines, and damage is being caused to the heat exchanger. The new layer signals that a critical threshold of damage has been reached, and because this signal is received before loss of containment is experienced, it permits operation to continue unchanged for a limited time. This gives owners and operators the opportunity

to investigate root causes and formulate repair or replacement plans without the need for a sudden unexpected shutdown.

Implementing operational improvements

The most likely cause for fatigue damage in a BAHX is thermal fatigue caused by operation outside of ALPEMA guidelines, which are as follows:

- Maintain cool-down and warm-up rates to below 2°C/min., not to exceed 60°C/hr.
- Maintain cyclical stream fluctuations to less than 1°C/min.
- Maintain temperature differences between streams to less than 50°C for all cases, and less than 30°C for severe cases such as two-phase, transient, or cyclic conditions.

If the root cause of the fatigue damage is related to operation there may be simple changes that can be made to avoid future fatigue damage accumulation. This includes both automatic plant control response and manual operator response to events such as compressor trips, operating regime changes, and other upset conditions.

Restoring stage 0

Depending on the nature of the damage indicated, repair may be a viable solution to restore the predictive layer to stage 0 condition. The repair details will vary on the specific BAHX design and the location of the cracks. The BAHX must be taken out of service to perform the repairs, but with proper planning this downtime can be minimised. Note that repair cannot reverse fatigue damage that has accumulated in other areas of the core. This means that even though repair may be able to restore Smart Layer to stage 0, the time required to reach stage 1 may be reduced, the grace period between stages 1 and 2 may be reduced, and the new layer may go from stage 0 to stage 2 without passing through stage 1.

Any BAHX repairs should only be made following consultation with the OEM or a credible authority to ensure that a balanced thermal profile is maintained. Repairs must be made in full accordance with the appropriate pressure vessel code requirements (typically ASME) using certified personnel.

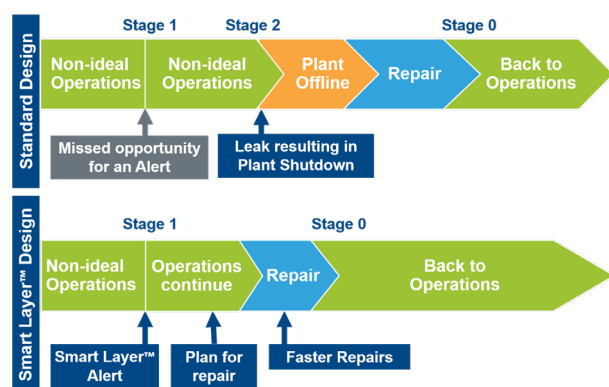


Figure 2. Comparing response options for standard BAHX design with Smart Layer technology.

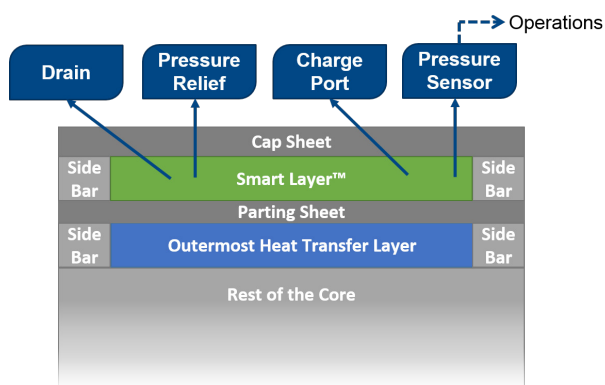



Figure 3. A closer look at how Smart Layer is configured.

Replacement

In some instances, full BAHX replacement is the best course of action. After the arrival of the new unit, it can either be installed right away, or kept onsite as a spare until the existing unit develops an external leak.

Conclusion

Although Smart Layer is a technological development, it should really be considered in the context of a cost-effective insurance policy that protects plants against severe loss of production revenue through unplanned shutdowns and the potential for damage to property and life should external leaks go unchecked. Rather like any protective device, they ensure peace of mind, regardless of deployment, from the outset. 

Note

*ALPEMA produces the standards that are the authoritative reference to all the main aspects of the specification, design, manufacture, purchase and use of BAHXs.

Born and raised in La Crosse

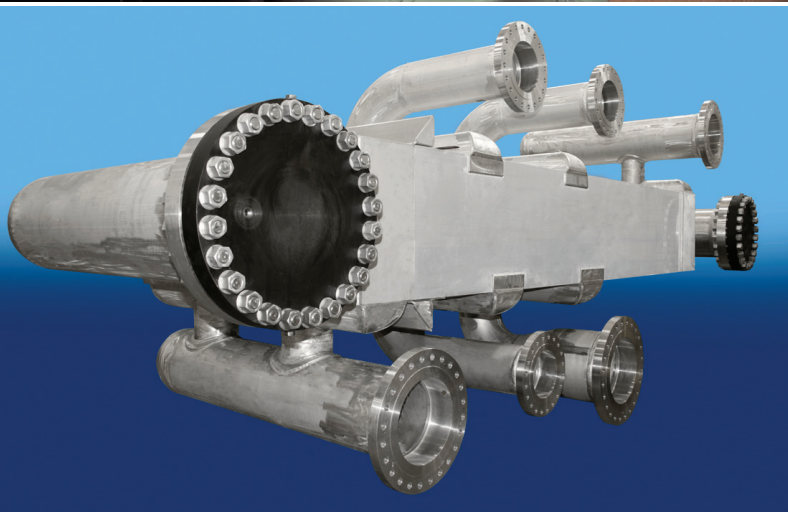
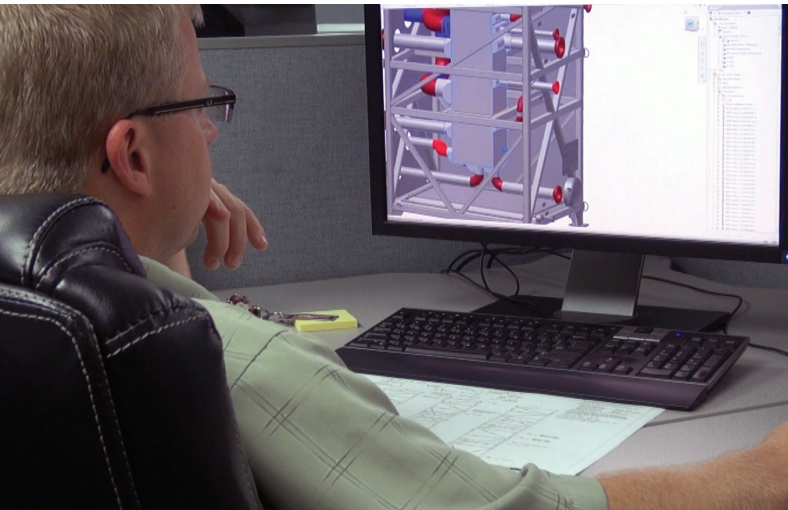


Chart specialty heat exchangers are key components in a huge range of applications across the energy, industrial gas, science and medicine industries. They were pioneered in La Crosse and more than 70 years later we're still designing and manufacturing them here today.

You may never use the products we make, but every day, people across the world rely on the products that our engineers, fabricators, welders and other specialists make possible; right here in La Crosse!



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