Brazed aluminium heat exchangers are still often viewed as a black box technology in some quarters. **Paul Shields, Chart Industries, Inc., UK, and Sam Thigpen, Chart Lifecycle, Inc., USA,** introduce a new approach for optimised performance and longevity in the downstream processing industries.

LIFTING THE LID ON BLACK BOX TECHNOLOGY

Originally adapted from the aerospace industry to the cryogenic separation of air in the 1950s, there are now many thousands of aluminium plate fin heat exchangers (PFHE) in operation throughout the world. Also referred to as brazed aluminium heat exchangers (BAHXs), their use has been extended so much so that BAHXs are mission critical across a wide variety of cryogenic fractionation and processing applications, where reliability and thermal efficiency are paramount. Simply put, if a BAHX is suitable for the service and duty to be performed, it will inevitably be the most efficient heat exchange solution.

However, despite the long heritage and wide use, BAHXs are still viewed in many quarters as little understood black box technology. Through education by manufacturers and commercially available software that perception is slowly changing. However, to date, most efforts have been focused at the front end, helping engineers to identify the optimisation of process design specifications and when BAHXs can be deployed. Once delivered to site, PFHEs, often built inside the mysterious 'cold box', will typically provide many years of trouble free performance, and will only attract the attention of site operation and maintenance personnel on the rare occasions a problem occurs. At

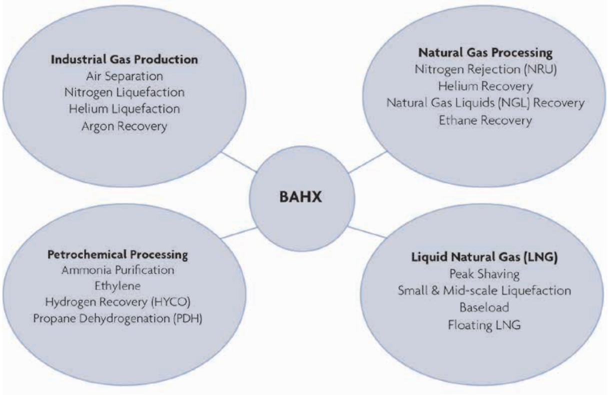

Figure 1. BAHXs are at the heart of cryogenic processing.

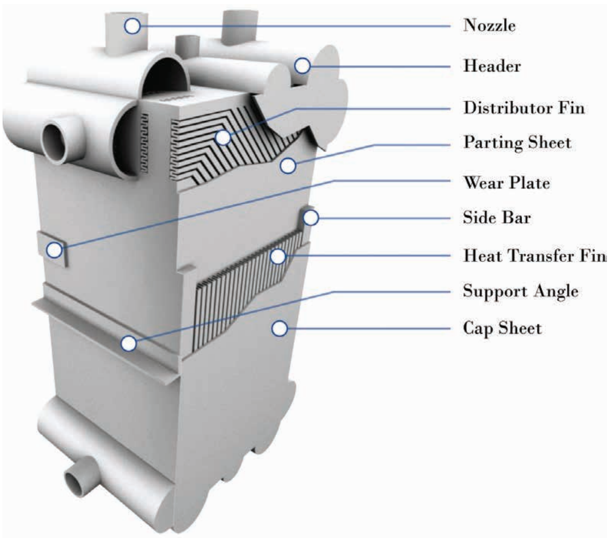

Figure 2. BAHX cut away and nomenclature.

that point, there is assistance and information available from the manufacturers and the Aluminium Plate-Fin Heat Exchanger Manufacturers Association (ALPEMA).

In the middle, though, there is a relative void, and an opportunity to assist plant personnel in optimising the performance and lifespan of this important equipment through the identification of key lifecycle stages.

BAHX applications

Shale gas and LNG are currently grabbing the headlines, and BAHXs play a fundamental and increasingly important role in both. A long time staple in the processing of raw gas to pipeline quality standards, BAHXs are the principal mechanism in the separation of the natural gas liquids (NGLs) from shale gas, which is driving the industry in the US. Furthermore, the plants that use the NGLs as feedstock, such as those involved in ethylene manufacture and propane dehydrogenation, use BAHXs within the cryogenic separation and purification stages. The majority of the world's helium is produced as a result of gas processing, again using BAHXs. In the process where high levels of nitrogen have to be removed from raw gas to meet pipeline quality standards, or to reduce total nitrogen content further for liquefaction, the nitrogen rejection units (NRUs) all have BAHXs at the core.

In LNG, BAHXs are widely employed in liquefaction plants of all sizes; from standard plant solutions providing LNG for vehicle fuelling and other applications in the small scale LNG space, through peak shavers and mid-scale plants, all the way to world scale baseload facilities.

Key BAHX features

- Multi-stream capability means the entire cooling requirement can be contained in a single unit or series of single units manifolded in parallel for larger plants.
- Thermal conductivity of aluminium is much better than steel.
- Increased thermal efficiency through a tight approach to temperatures.
- The hydraulic performance of BAHXs affords excellent turndown capability.
- Superior heat transfer surface area per unit volume – typically 300 - 1000 m^2/m^3.
- Aluminium gets stronger at cold temperatures.

BAHX best practice

The lifespan of BAHXs depends almost entirely on the care with which it is operated and maintained. There are no moving parts or items that wear out during normal operation, which makes it extremely difficult to predict end of life because lifespan is generally governed by events that are unexpected, or for which no control procedures are in place to address. However, virtually all hazards to BAHXs can be prevented by applying the mantra: keep it clean, keep it dry, manage thermal gradients.

Keep it clean

Fin passages for fluid flow inside BAHXs are measured in millimetres; that is a major contributor to the thermal efficiency of the unit, but also a major factor as to why manufacturers stress that process fluids should be clean. 'Plugging' is the term used to describe full or partial obstruction of passages, with pipe scale and molecular sieve dust being the most common causes, although construction debris used during initial installation is not uncommon.

Sometimes oils, heavy hydrocarbons and waxes can enter the process fluids and solidify inside the BAHXs during cryogenic operation.

Both plugging and fouling can increase pressure drop, impair thermal performance and cause maldistribution, leading to higher thermal stresses. Measuring either the deterioration in heat transfer performance and/or abnormally high pressure drop is another way that most obstructions are detected.

Prevention is always better than cure, and the installation of upstream filters, together with a maintenance regime for molecular sieves, is highly recommended to minimise the risks of plugging. Assuming that adequate pretreatment systems are in place to condition incoming streams in normal operation, fouling is more difficult to guard against because it suggests a failure elsewhere in the system that has allowed the fouling agent to pollute the incoming fluid. A fouling factor can be applied that would down rate the fin efficiencies according to a certain level of fouling. It would result in a slightly larger heat exchanger but, more importantly, fouling factors can only be applied at the design stage, long before the exchanger goes into service.

Keep it dry

Most BAHXs operate at cryogenic temperatures, which can cause certain compounds, most notably hydrates, water and CO_2, to freeze inside the exchanger. This will cause plugging and, in the case of water, expansion as it freezes, leading to rupture of the layers. A single ice rupture will fail the heat transfer fins in the originating layer, but also damage the fins across multiple adjacent layers. Fin failure is irreparable, and often the only solution is a replacement unit.

Manage thermal gradients

This term refers to the correct control of stream temperature and flow rates to minimise temperature differences and thermal stresses within the heat exchanger structure. In Chart's experience, this is the least understood of the recommended best practices for BAHXs and the cause of most leaks and equipment failures. Succinctly, excessive thermal gradients decrease the life expectancy of a BAHX and eventual failure can be a protracted process of accumulated damage through thermal cycling, or a single catastrophic thermal shock event.

Excessive thermal gradients are most often caused by transient events, such as changes in process conditions or flow rates. Thermal fatigue is a slow accumulation of damage due to repetitive temperature cycling, each with a relatively low stress level per cycle, but cumulatively can lead to failure. Thermal shock is the term for severe thermal gradients likely to cause failure after relatively few occurrences.

Unlike the other causes of failure, there is no reliable way to measure fatigue damage before it manifests.

Optimisation of BAHX performance and longevity

Most BAHX issues can be remedied or repaired, and the major manufacturers have skilled technicians that can be deployed to a site to undertake those tasks. However, as stated earlier, prevention is better than cure and Chart is committed to education, as well as innovation, to promote a greater understanding of the products. Consequently, a series of initiatives were launched to promote best practices for the maintenance and management of BAHXs ensuring optimum performance and lifespan.

Figure 3. Post-delivery stages for optimised performance and longevity.

APEX is a series of free to attend, informative webinars, where Chart engineers share their expertise through a series of carefully researched presentations. The topics are aimed at plant stakeholders, from process and mechanical engineers, through to operation and maintenance personnel, with groups deliberately kept small for maximum interaction.

The BAHX Product Bulletin draws its contents from Chart's experience and, together with the APEX webinar series, grants access to a team of technical experts. It summarises what users should, and should not, do with respect to the operation, inspection and maintenance of BAHXs, and is intended to supplement the ALPEMA standards and Chart's installation, operation and maintenance manual.

Conclusion

The identification of seven stages – order, startup, operation and maintenance, support, monitor, optimise and upgrade – is intended to help stakeholders identify steps in the BAHXs product lifecycle, and the options that can be pursued along the path of optimised performance and longevity. At the beginning, the importance of PFHEs in cryogenic processing was highlighted, emphasising a greater understanding of their capabilities as an important tool for debottlenecking and expansion projects, as well as avoiding failures.