Compact heat exchangers in ammonia/urea production

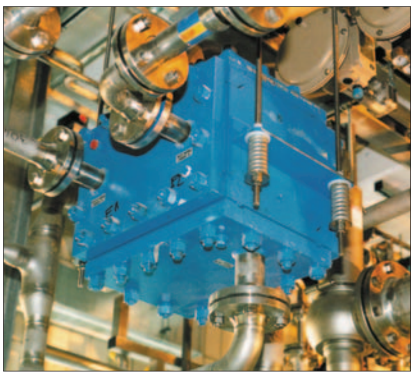
In ammonia and urea plants the predominant heat transfer equipment has traditionally been the massive shell-and-tube heat exchanger. Jakob Liedberg, of Alfa Laval, shows how compact plate heat exchangers have made inroads in even these exacting applications

The shell-and-tube heat exchanger is the most tried and tested of all heat exchanger designs. It dates back to the beginnings of the industrial revolution, when it was the basis of some of the earliest industrial steam boilers. It was the centrepiece of almost, if not absolutely, every steam locomotive that was ever built. It is still the most widely used single design type for heat exchangers. Its biggest advantage was its robustness and durability. But in relation to its heat transfer capacity it is both bulky and exceedingly massive.

Plate heat exchangers are now a fully accepted alternative in liquid/liquid heat transfer applications in the ammonia and urea processing industries. Conventional gasketed plate-and-frame heat exchangers are widely used in applications such as secondary cooling systems, where sea water is used as the cooling medium. These heat exchangers are also used as interchangers in absorption/stripping systems for gas cleaning, where they recover energy and thus improve the overall operating economics of the plant. Gasketed heat exchangers are also easy to clean and repair, since they can be completely disassembled.

The most notable advantage of the plate heat exchanger is that it takes up far less space and is much lighter than the equivalent shell-and-tube exchanger. Therefore, in an application for which it is inherently suitable, a plate heat exchanger is an obvious debottlenecking option for replacing a shell-and-tube exchanger that may have become capacity-limiting.

The main limitation, however, is the gaskets, which are subject to attack by aggressive media and wear by expansion and contraction of the plates where temperature cycling occurs, and they place a limit on the pressure and temperature under which the exchanger can operate. The shell-and-tube exchanger, on the other hand, is an all-welded construction.



Suspended Compabloc welded plate heat exchanger for condensation duties.

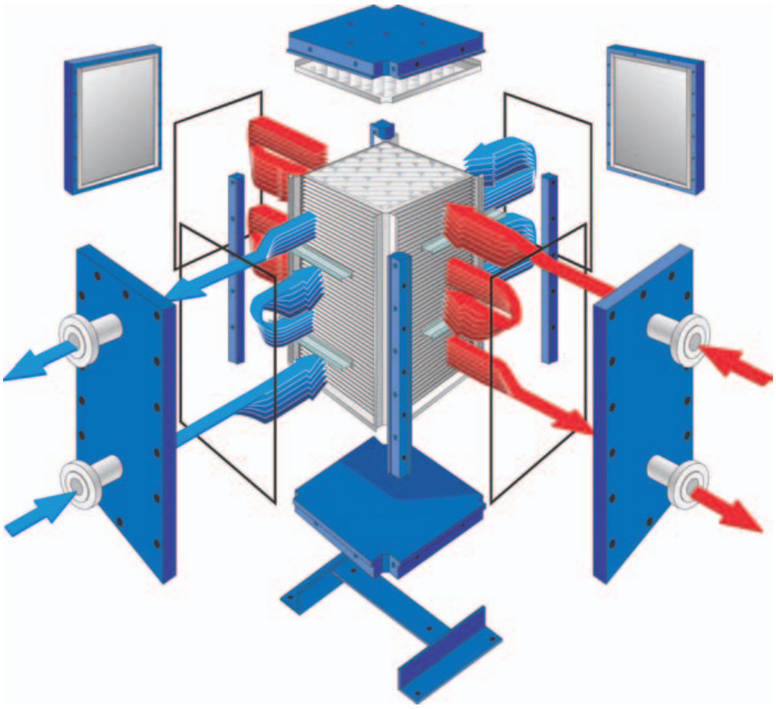
The solution to this problem is to replace every gasket by an all-welded joint. Clearly such a unit can no longer be disassembled for maintenance, but the limitations imposed by the gaskets in the conventional design are all eliminated. Alfa Laval currently supplies three types of welded compact heat exchangers, one of which is a welded block plate heat exchanger known as Compabloc.[1]

Compabloc all-welded heat exchangers

Compabloc welded plate heat exchangers reach peak performance under conditions which are at the limits of endurance for more conventional designs of heat exchanger.

Essentially, the Compabloc exchanger (Fig. 1) is a stack of corrugated rectangular heat transfer plates in stainless steel or a more exotic material, welded to their neighbours alternately at their top and bottom edges and at their side edges so as to form a series of alternating perpendicular channels. The block is supported in a frame comprising four girders running along the corners of the welded plates, to which are bolted side, top, bottom and end panels. The space enclosed between each side

Fig. 1: **Exploded view of multi-pass Compabloc exchanger, showing flow patterns.**



panel, the girders to which it is attached and the heat exchanger block assembly forms a header chamber for the channels opening into it. The heat exchange media enter and/or exit these header chambers through nozzles in the side panels.

In a once-through configuration the two media flow in alternate channels in a cross-flow arrangement, which means that the temperature approach is not uniform across the whole area of the plates and the exhaust temperature of the medium leaving the header chamber is an average of the exhaust temperatures from each channel. A true counter-current performance is obtained by dividing the header chambers with baffles (Figs. 2 and 3) so that each medium flows alternately in one direction through a group of channels and in the opposite direction in the next. The number of passes depends on the application.

To gain access for inspection and hydroblast cleaning, the side panels are simply removed. In contrast, to inspect or service a shell-and-tube exchanger requires its own length in clear space to allow the internals to be withdrawn from the shell.

Applications

Compabloc heat exchangers are not only used for liquid/liquid duties but also for a wide range of condensing and reboiling applications in the process industries.

Compabloc heat exchangers are extremely compact, and the inherent integrity and rigidity of their structure means that the wall thickness of the heat exchange elements can be much less than in a shell-and-tube design. Their resulting high heat transfer coefficient reduces the surface area required. And, because they contain so much less material than their shell-and-tube equivalent, they can be fabricated in exotic

Fig. 2: **Use of baffles to establish counter-current flow pattern.**

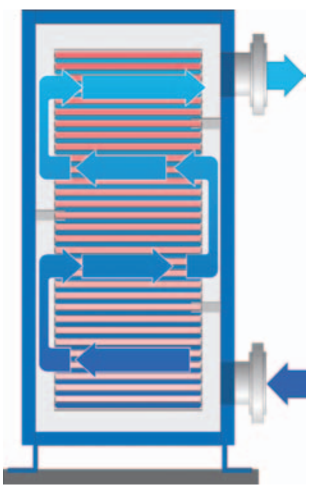
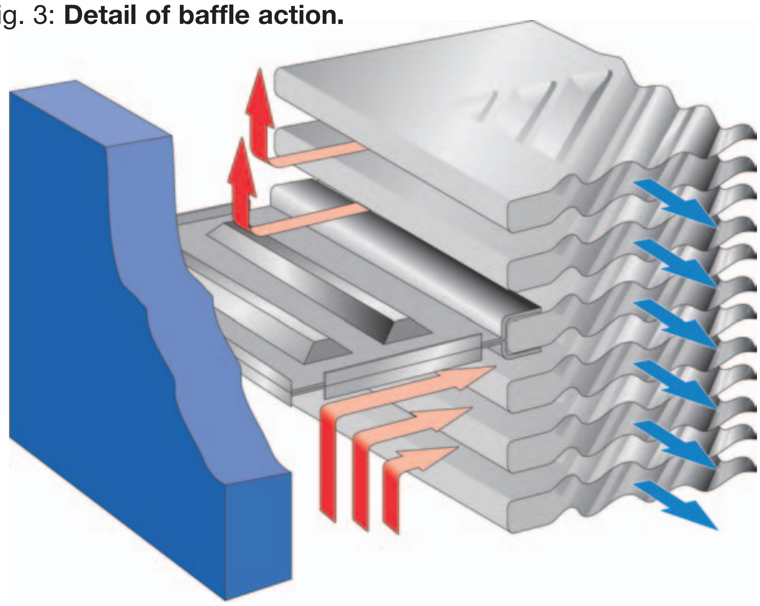


Fig. 3: **Detail of baffle action.**



materials of construction much more economically than shell-and-tube exchangers. On account of the high cost of fabricating shell-and-tube heat exchangers in exotic materials of construction, the less expensive but less elegant alternative of using a lower-grade material and building an appropriate corrosion allowance into the design is often adpopted. So Compabloc is particularly attractive for application in corrosive environments.

The corrugations in the surfaces of the heat exchanger plates mentioned above are there to promote turbulent flow, which reduces the fouling tendency. Where fouling does occur, the same turbulent flow enhances the effectiveness of chemical cleaning in place.

Because of the large cross-flow area and short flow paths, the pressure drop through a Compabloc unit is very low, making it very suitable for low-pressure condensing duties, for example. Where it is to be used as a condenser, it is advantageous to design it in a two-pass configuration (downwards, then upwards) on the condensing side, as the condensate can be drained from it directly without any need for a separate dedicated separator.

The following are some specific applications in which Compabloc exchangers have already been used to advantage.

CO_2 cooling

A Ukrainian fertilizer manufacturer which needed to replace two old shell-and-tube carbon dioxide coolers selected Compabloc from the various options. Alfa Laval advised the company that a single Compabloc unit would be sufficient for this purpose. In addition, the improved thermal performance of the Compabloc heat exchanger would lower the carbon dioxide gas exit temperature and, consequently, its moisture content. Since the transformation of ammonium carbamate into urea is an equilibrium reaction and water is one of the reaction products, reducing the moisture input to the process has a favourable effect on the conversion efficiency.

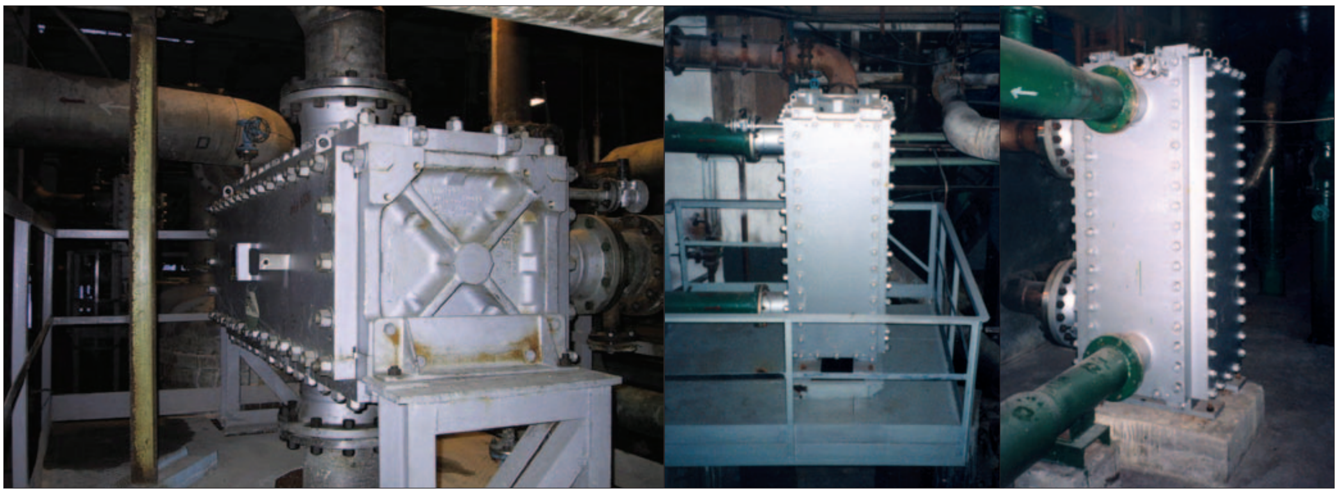
Syzran refinery MEA stripping tower, with twin Compabloc reboilers at the base of the column and a Compabloc reflux condenser atop it.

The Compabloc heat exchanger has operated perfectly since it was installed in 2000. Inspections are only needed once a year. In contrast, the old shell-and-tube system had to be opened frequently for cleaning, which led to severe production losses.

Compabloc exchangers have also been very successfully used as inter-stage coolers in the compression of carbon dioxide at the start of the urea process. The company replaced shell-and-tube gas coolers with Compabloc, with only minimal space and foundation requirements. Another benefit is that the carbon dioxide gas compressor is now more stable in operation.

Reboilers

Any operation which involves stripping or desorbing a gaseous or volatile constituent from a solution through the application of heat includes a heat exchanger called a reboiler, typically heated by steam or by a hot process stream, through which the solution is cycled and then returned to the stripping column. The prime example is the regeneration section of an acid gas removal system. Usually the reboiler operates in a quite aggressive environment, yet a shell-and-tube design with a low-specification material plus corrosion allowance is most often used. Though the specific example below is in an oil refinery, such systems are an inte-



Compabloc exchangers for CO_2 compressor cooling: First stage, Second stage, Third stage.

gral part of most ammonia plants, where conditions may be just as aggressive, if not more so.

When the Syzran Refinery built a new stripping tower for an MEA H_2S removal system at its plant in Russia, the company (Yukos) installed two Compabloc reboilers, although one was considered adequate. These reboilers were installed in parallel to allow cleaning, when required, without shutting the plant down.[2]

Installing Compabloc heat exchangers also resulted in major savings in capital investment. The compact shape of the Compabloc units meant that they could be installed and still operate by thermosyphon without raising the tower, as would have been necessary if a shell-and-tube heat exchanger had been used. This also contributed to savings in terms of building foundations. A further Compabloc heat exchanger was installed in this stripping installation as a reflux condenser on top of the stripping column. The advantages of using something as small and light as a Compabloc exchanger in such a situation are too obvious to need stating.

Urea wastewater treatment

Compabloc heat exchangers can be used in various ways in the wastewater treatment section of urea processing facilities. In older plants using an ammonia stripping tower, for example, they can be used to replace vertical shell-and-tube reboilers. This simplifies the disposition of the plant, as less piping is required and minimal foundation work is needed. Compabloc is highly suitable as original equipment in new installations which use hydrolyser heat exchangers to recover energy from waste water streams.

Condensing ammonia

Compact heat exchangers are frequently used for condensing ammonia – an important procedure in the fertilizer industry, as the output of almost every ammonia plant is stored as liquid and is sent on for further processing to urea in that form.

When a major European chemical company needed to replace its

Detail of column-mounted reflux condenser.

old shell-and-tube ammonia condensers, compact Alfa Laval Compabloc condensers were the logical choice. Taking up only half the space of the shell-and-tube installation they replaced, the Compabloc units not only solved problems associated with corrosion but also reduced maintenance costs at the same time as providing a considerable reduction in the capital investment required.

These Compabloc units were inspected a year after they were commissioned in 1998 and were found to be clean. Since there were no other problems, no maintenance was required. By comparison, the previous shell-and-tube units were cleaned every two years.

A versatile solution

Compabloc technology is based on an innovative concept that is completely different from traditional condensers and reboilers. Customers are so familiar with the shell-and-tube type that they tend to take it as a fixed point and not to realise what huge strides technology has taken with designs like Compabloc, and not just from the technical point of view but also in terms of cost benefits.

Alfa Laval can document numerous examples of the cost benefits of using compact heat exchangers, not just from the initial investment cost savings but also from lower installation costs, space savings and simpler, shorter maintenance. ■

References

1. Wilhelmson, B.: "Compact heat exchangers offer sizable payback". *Chemical Engineering* **110** (7), 60–65 (Jul 2003).
2. Arvidsson, P.: "A reboiler for the space age". *Hydrocarbon Engineering* **8** (11) (Nov 2003).

The three Compabloc units on the right have half the footprint of the three shell-and-tube units on the left but 50% greater capacity!