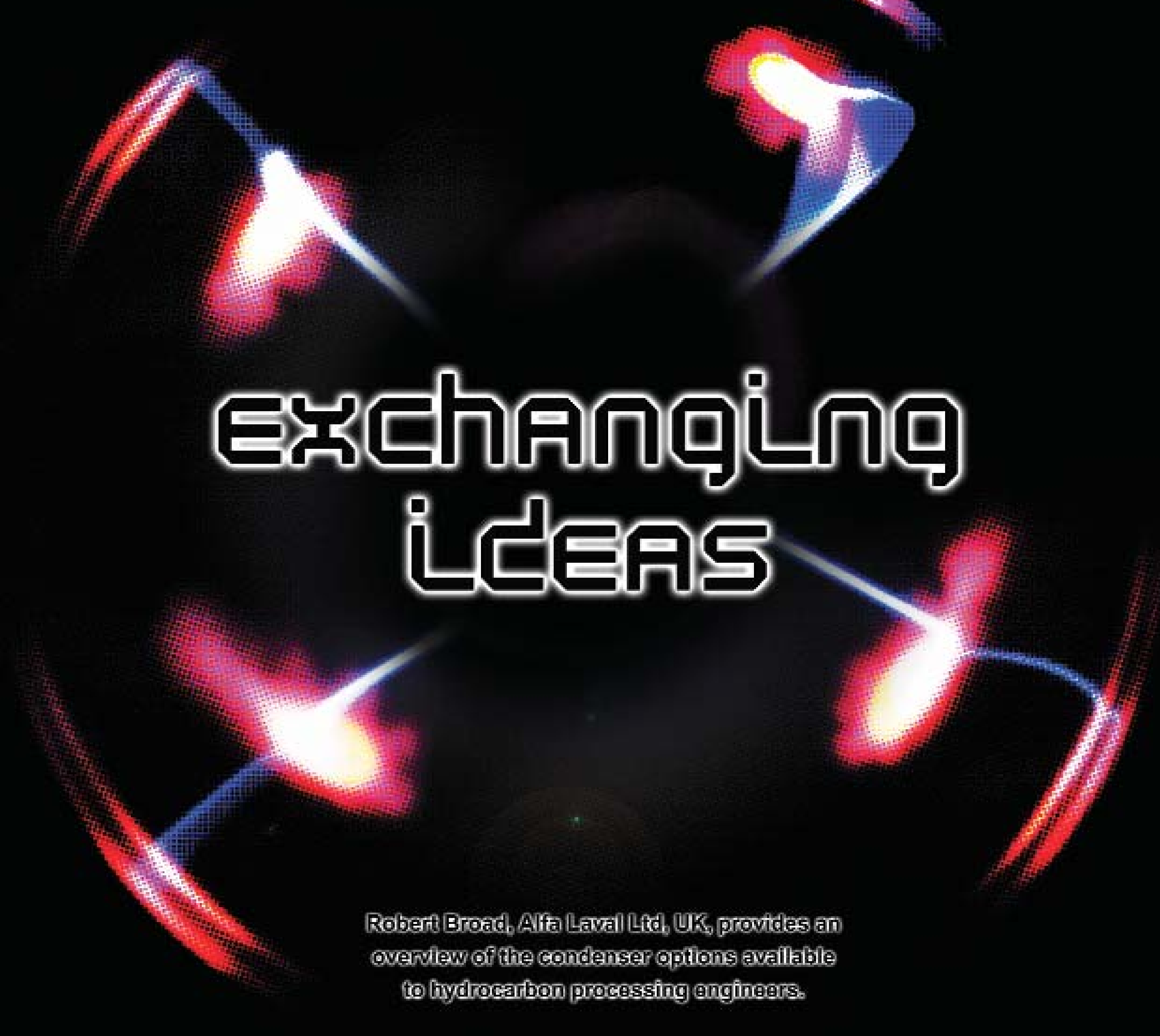


Exchanging Ideas

Robert Broad, Alfa Laval Ltd, UK, provides an overview of the condenser options available to hydrocarbon processing engineers.

No matter how adventurous a process engineer may be in private, if it really matters to his or her work, conservatism tends to be the order of the day. This is perfectly understandable. When the result of failure could be the loss of millions of dollars worth of production, proven performance becomes a major factor in specifying new equipment.

This inherent conservatism sometimes makes it difficult for alternative technologies to become established. When it comes to specifying key process components such as heat exchangers, hydrocarbon process engineers have a history of depending on traditional shell & tube (S&T) exchangers, particularly for duties such as condensing, evaporating and reboiling. Solid, dependable and familiar, S&Ts are the workhorses of the process industries.

Having said that, there is also now, undeniably, a trend towards more compact units. Around the globe, the number of compact heat transfer installations is growing, prompted by the need to achieve higher production levels without increasing the overall size of the plant, and the desire to reduce capital and running costs to increase profitability. These compact heat exchangers perform the vital role of condenser, evaporator or reboiler and provide levels of efficiency and dependability comparable with traditional tubular units, but with significant savings in size, weight, civil works and operational costs.

Of course, the word compact means different things to different people. However, the important relationship that this article intends to address is that between the traditional S&T and modern units, such as the welded block plate heat exchanger. Put simply, to match the heat transfer capability of a welded block unit measuring 3 m^3 a comparable S&T exchanger would need a capacity of 1000 m^2. Quite apart from the enormous saving in size, weight and materials the compact alternative represents, it also delivers savings in space, civil works, pipes and associated engineering.

The welded block plate exchanger is just one of a number of different types of compact exchanger to appear in the last decade or so. Despite the above advantages,

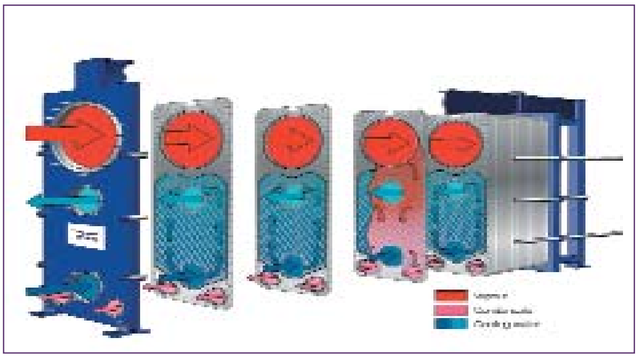


Figure 1. In this exploded view of a plate condenser, the size of the connections has been designed to fit the condensation duty and maximise effective heat transfer area.

Figure 2. In this installation, the column mounted spiral condenser is on a stripping column.

Figure 3. One of two welded block plate condensers on the vacuum column. The pressure is approximately 0.3 bara.

however, the S&T is still the benchmark against which all of these newcomers are, ultimately, measured.

The shell & tube

Among the most familiar of all process engineering components, the design of the basic S&T exchanger has changed very little for more than a century. The reason is that it works very well at what it is intended for; is fairly simple to design from both the thermal and the mechanical standpoints; and most important of all, is solid, dependable and predictable. When it comes to applications such as condensing, the principal choice to make is between a unit that uses either the tubes or the shell for the condensing. If the process involves high pressure vapours, the best choice is for condensation to occur within the tubes since this will enable a lower design pressure to be used on the shell side. Using the tubes for corrosive vapours also makes sense, since the tube can be fabricated from less expensive materials.

On the other hand, condensation should take place in the shell for vacuum service or duties slightly above atmospheric pressure, because it tends to be more efficient than condensing in the tubes. S&Ts are principally designed for cross flow heat transfer and this does not lend itself to all duties, particularly those involving the cooling of non-condensed gases (NCG).

Strangely, for such a long established piece of kit, the S&T still manages to exhibit a great deal of adaptability. The basic concept will accommodate a large range of duties, from a combination of extremely high pressure and vacuum to relatively small capacities right up to the enormous. However, most S&Ts are engineered for a specific duty. Once installed, they are difficult to adapt in terms of increasing or decreasing capacity, or to accommodate a change in duty.

Like the work horses to which they are frequently compared, they also provide a relatively poor return for their enormous size in terms of efficiency or, in this particular case, heat transfer coefficient. Consequently, their surface area, weight and volume tend to be much higher than for equivalent compact units.

To a degree, this can be improved by the use of finned tubes or tube inserts. However, not only do these additions crank up the initial design costs but they also add to the overall materials and installation bill. Since the sheer scale of the average S&T means large materials costs, this is not an insignificant consideration.

The compact alternatives

Plate-fin condensers

Based on a core of self supporting plates and fins, this type of unit typically provides cross flow heat transfer and is suitable for multistream duties.

The construction is brazed and consists of fins fixed within parting sheets, also generally of aluminium, which is completed by the addition of headers and side-plates. The fins themselves perform two functions:

- To provide structural support between the plates.
- To increase the available surface area for heat transfer.

Plate-fin exchangers are used principally in hydrocarbon processing duties, air separation and natural gas liquefaction. Most of these duties are cryogenic in nature. If the unit is used for applications involving higher temperatures the standard aluminium plates are replaced with stainless steel or copper.

As previously mentioned, this type of unit is suitable for multistreaming whereby one exchanger can be used to heat, cool, condense or vapourise multiple streams, providing a compact alternative to a more conventional arrangement where a number of exchangers are connected in series.

Plate and frame condensers

Based on the standard plate heat exchanger (PHE), the plate and frame condenser consists of a pack of thin plates assembled between two, pressure retaining end plates. When the pack is assembled, corrugations in the plates match up to form two separate flow channels for the hot and cold media. Depending on the specific duty for which the condenser is intended, these channels can be sealed using either gaskets or welded seams. In use, vapour flows in via an upper connection, through a manifold duct and then into every alternate channel. The coolant flows through the remaining channels in either co-current or counter current flow, depending on the duty.

The PHE was originally developed for liquid/liquid duties but it is still suitable for vapour condensation and, for pressures above atmospheric, can be a cost effective solution compared with more conventional condensers. This is due to its true, counter current flow characteristics; very close temperature approach (1 - 2 ˚C); and excellent NCG cooling. In addition, because it is basically modular in design, it is very simple to adapt for new or different duties, simply by adding or subtracting the requisite number of plates. If it has a disadvantage it is in duties below atmospheric pressure when the narrow plate channel gap creates a relatively high pressure drop. The simplest way to tackle this problem is to add more plates, but this can lead to over sizing and, as a consequence, reduce or eliminate the exchanger's inherent cost benefit when compared to more conventional condenser types.

Issues of chemical compatibility, temperature or pressure can restrict the use of the gasketted version of the plate and frame condenser. Consequently, within the hydrocarbon industry, more general use is made of the semi-welded version of the condenser, in which alternate pairs of plates are welded to provide a safe channel for the aggressive medium, or the fully welded model in which all the seam gaskets are replaced by welds. In addition to eliminating worries about chemical or thermal incompatibility, the welded condenser also widens the scope of application in terms of both temperature and pressure. Whereas, on the gasketted version, the upper temperature limit is approximately 180 ˚C, on the welded version this climbs to 350 ˚C.

Figure 4. An absorption/stripping system used to clean a C1-C4 gas coming from the cracker of H_2S. This column has a welded block condenser designed as a top mounted partial reflux condenser. There is also a welded block plate reboiler installed where a 15% MEA solution is evaporated at 127 ˚C using steam at 170 ˚C.

The plate condenser

Although it shares many similarities with the standard plate and frame heat exchanger from which it was developed, the plate condenser should really be considered as a separate species. It was developed specifically as a low pressure condenser (below 0.2 bar) and the plates are welded in pairs, both to eliminate the need for gaskets and to enable the condenser to handle aggressive vapours.

Unlike the regular PHE, whose connections are not really suited to low pressure vapours, the plate condenser's connections are sized to match the volumetric flow rates of the inlet and outlet streams. Being larger, they can accommodate large volumes of low pressure vapour at a moderate velocity and with a small pressure drop.

Plate condensers are particularly suited to high vacuum duties. A wide gap channel on the vapour side combines with a relatively short flow path to keep the pressure drop

Figure 5. S&T condensers are shown on the lower left, and three welded block plate condensers are shown on the top right. Despite their small size, the block condensers have 50% greater capacity than the S&T units.

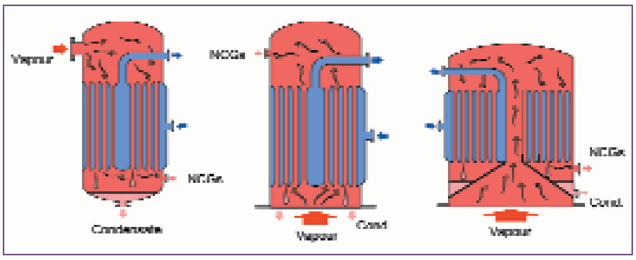


Figure 6. Schematic of a stand alone spiral condenser, the vapour channel is completely open both at the top and bottom to achieve a very low pressure drop.

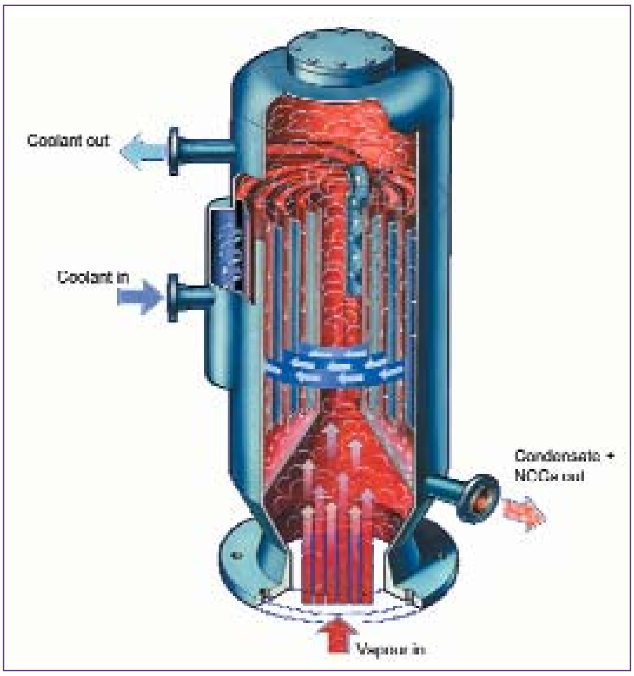


Figure 7. Column top mounted spiral condenser. The vapour channel is completely open both at the top and the bottom to achieve a very low pressure drop.

in the vapour channels very low. Thanks to the channel configuration, which is designed to promote turbulence, the condenser achieves very high rates of heat transfer while

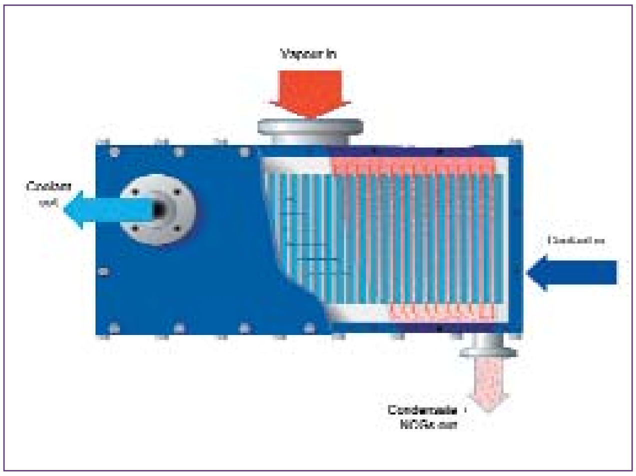


Figure 8. The plate condenser.

keeping the vapour pressure losses low.

In sharp contrast to the wide gap employed on the vapour side, the channel for the cooling medium is kept deliberately small to encourage velocity and turbulence and maximise heat transfer performance. As a consequence, NCGs are cooled very efficiently which reduces the load on downstream vacuum systems. This combination of features and benefits make the plate condenser the most cost effective choice for most low pressure condensation applications.

Welded block plate condensers

Similar in concept to the plate condenser, the welded block plate condenser is built around a central core in which alternate corrugated plates are welded together to form channels. This plate core slides into a carbon steel frame with pressure retaining plates at the top and bottom. Removable side panels, which accommodate fluid inlet and outlet nozzles and baffles to direct the fluids back and forth through the channels, complete the structure. These baffles make it into a multipass unit capable of cocurrent or counter current flow, which is readily accessible for inspection and mechanical cleaning.

Generally, the welded block plate condenser is mounted horizontally so that the vapour enters through the large top nozzle and is distributed through the parallel channels while the cooling liquid enters through a side nozzle. Depending on the temperature programme, the coolant flows in a single pass or in multiple passes through the condenser. Condensate and NCGs can either exit the unit through a nozzle located in the bottom panel or a second pass can be used to remove them via a separate connection to a vacuum system, which cools them further and reflux condenses even more vapour.

Although the plate channels are reasonably narrow (typically 5 mm) the natural tendency for this to create high pressure drop is balanced by a relatively short flow path so that pressure drops are kept low, even at high vacuum. Close temperature approaches are a feature of this particular type of condenser, thanks principally to the use of baffles on the coolant side and its inherent thermal efficiency. In terms of design flexibility, the welded block plate condenser falls somewhere between the S&T and the PHE. Although the basic approach is modular, the fact that it is totally welded makes it much less easy to adapt to a new duty than a PHE, although it is true to say that the baffles can be moved for a new duty.

However, like the PHE, it does offer a degree of compactness that provides the potential for significant savings com-

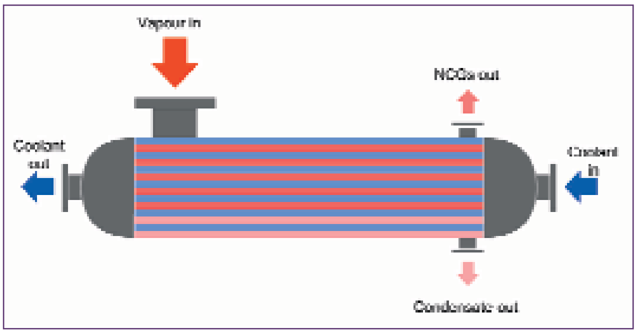


Figure 9. This S&T system operates with one pass on the condensing side and one pass on the coolant side.

pared to the S&T as mentioned at the beginning of this article.

Spiral condensers

The spiral condenser has evolved from the basic spiral heat exchanger and shares its principal benefits and features. Chief among these is its excellent thermal performance, achieved through the combined effect of high turbulence and the curvature of the internal heat transfer surfaces.

The condenser is formed from a series of concentrically wound metal sheets, which are separated by welded studs to form flow channels. The sides of these channels can either be left open to achieve lateral flow or welded on either one or both sides. This spiral wound core is fixed inside a cylindrical vessel to which connections are welded on the external walls to provide inlet and outlet points for the media. The use of open flow channels for the vapour makes the spiral condenser particularly suitable for condensation duties at very low pressures (below 0.1 bar) and for handling high volumes of NCGs. Purely in terms of heat transfer efficiency, it also outperforms the conventional S&T, particularly when the cooling side of the process is the limiting factor, thanks to the previously mentioned combination of turbulence and internal geometry.

Vapour enters the condenser at the top of the vessel and flows through the open channel. At the same time, coolant flows through the sealed, spiral wound channel and condenses the vapour. The resulting condensate and noncondensed gases exit through the bottom of the vessel through separate nozzles.

Apart from its thermal efficiency, compact size and low weight, one of the great advantages of this type of condenser is that it works with a very low pressure drop and is therefore able to cope with high volumes of NCGs. It can also be located directly on the top of a column; eliminating much of the pipework, pumps and other ancillary equipment that would otherwise be needed. In such a configuration, vapour enters the unit from below, is turned through 180 ˚ and then back down through the spiral body.

Condensate can be extracted through a baffle arrangement or refluxed back into the column. On the debit side, the spiral condenser's design is finite in the sense that, once fabricated, the condenser cannot be altered or modified to handle changed duties. Like the S&T, it is also not particularly efficient in cooling NCGs because of its cross flow characteristics.

Conclusion

This article started by alluding to the in-built conservatism of most process engineers (the author included). However, there are definite signs that the picture is changing. The number and variety of compact condensers, evaporators

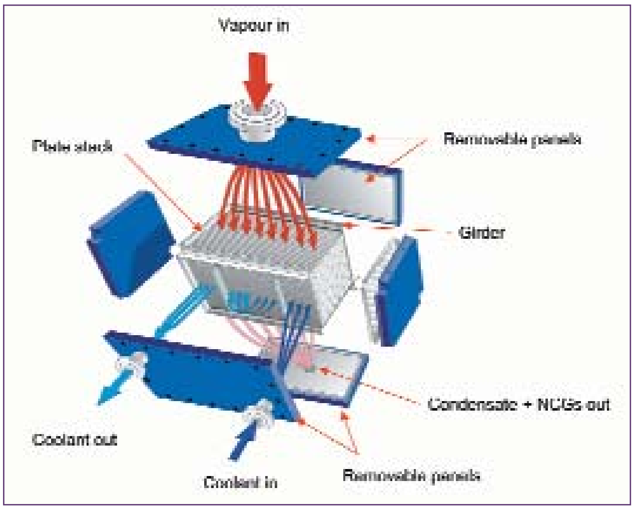


Figure 10. In this exploded view of a welded block plate condenser, operation is one pass on the condensing side and four pass on the coolant side. The four side panels can be removed for inspection and cleaning the heat transfer surface.

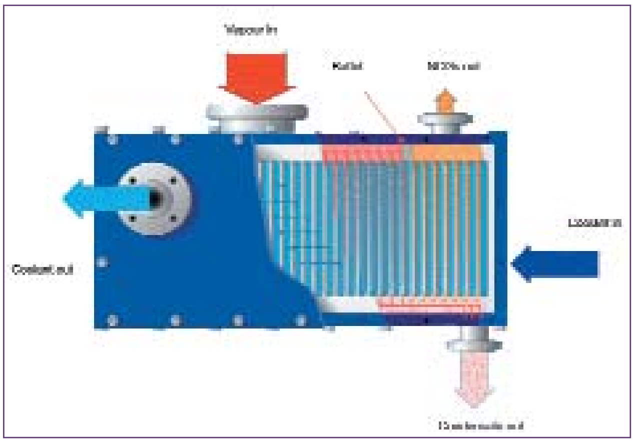
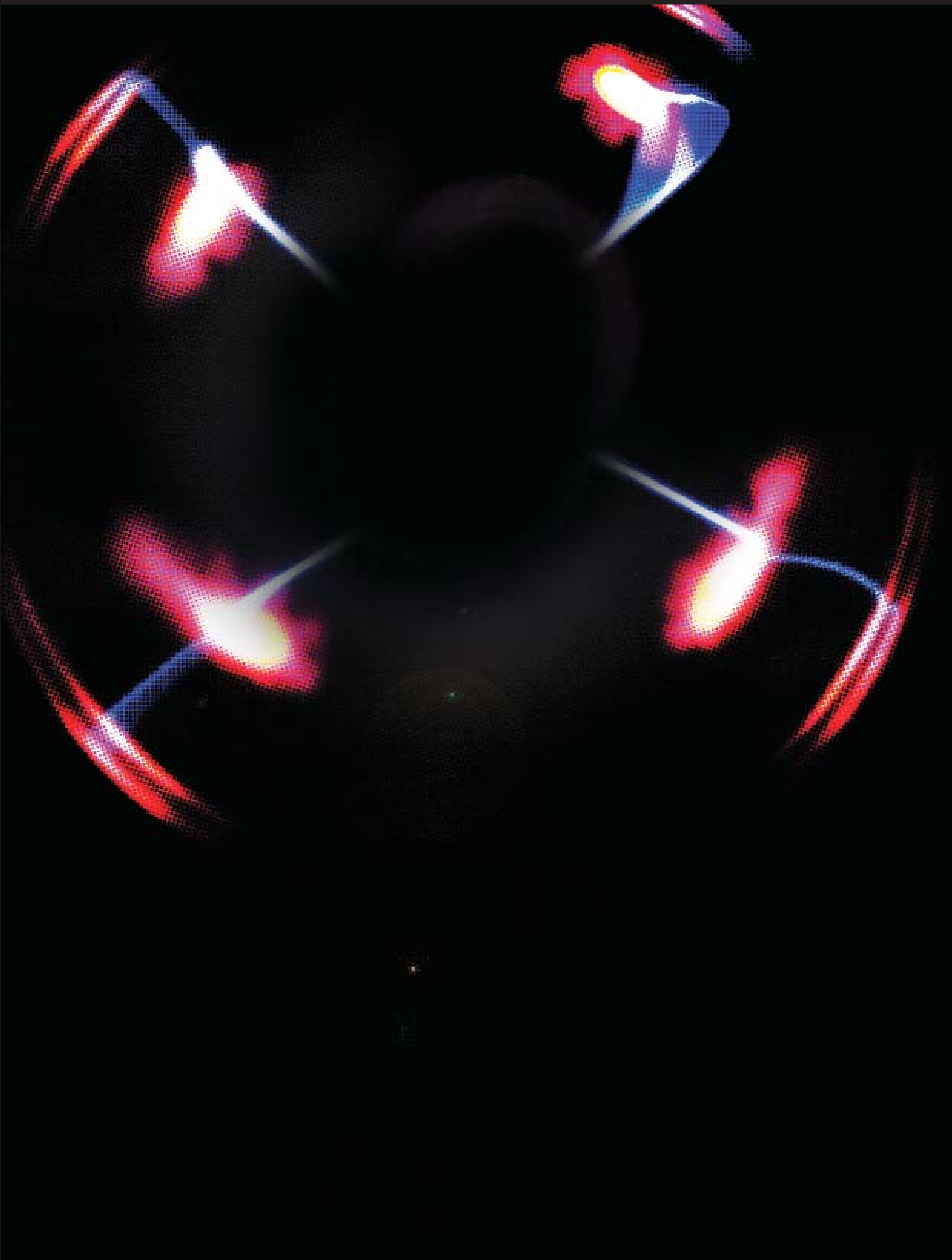


Figure 11. The welded block plate condenser with two passes. A baffle is utilised to create a disentrainment section to enable NCGs to be removed without a knock out pot. This also further cools the NCGs, reducing the vacuum system loading and recovering more product through reflux condensing.

and reboilers now installed around the world is testament to that. Although none of them quite matches the S&T in terms of its universal scope of application, they do provide distinct performance and cost advantages in most applications involving temperatures below 300 ˚C and pressures of 30 bar or less.

Obviously, there is a long way to go before compact condenser alternatives win the same degree of universal acceptance. However, the introduction of advanced welding and manufacturing techniques, and exotic materials, allied to a better understanding of the boiling process, has certainly increased the scope of application.

This will be further improved as manufacturers concentrate their efforts on developing discrete units, rather than simply adapting or altering existing heat exchanger designs. When these disparate factors come together, the compact condenser will be even better placed to deliver process improvements and significant cost savings that, in turn, will provide rapid payback for hydrocarbon process engineers.



Reprinted from HYDROCARBON ENGINEERING DECEMBER 2004