Applying High-efficiency Plate Heat Exchangers in Refinery Service

a report by

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High-efficiency plate heat exchangers have enjoyed expanded use in the refining industry over the last 15 years, with over 1,000 units currently in operation. The advantages of the technology are substantial, and refineries can enjoy the benefits if they are correctly applied and operated in the refinery process. This article will address some practical aspects of applying high-efficiency plate heat exchangers, as well as what to expect down the road when maintenance and cleaning are required.

Welded Plate Heat Exchanger

The inherent flow properties of high-efficiency plate heat exchangers make them a very efficient alternative to traditional shell-and-tube (S&T) heat exchangers, pushing the limits of what was thought practical in heat recovery services. These exchangers make it possible to achieve increased throughput in a smaller space, while significantly increasing energy recovery and lowering heater emissions. Welded technologies expand the operating limits of the plate heat exchanger, making them suitable for application in the demanding refinery industry. There are three main technological advantages to using welded plate heat exchangers (WPHEs) in refinery services.

Heat Transfer Efficiency

The main technology that differentiates the WPHE from the traditional S&T is the use of corrugated plates to form the heat exchanger channels. The corrugated plates are stacked and welded together, forming 3D flow channels that resemble a helix design. These channels induce very high turbulence and intermixing, resulting in a thermal efficiency three to five times higher than that of traditional tubular equipment. Another benefit of the high turbulence is the high shear forces on the exchanger walls, which act to keep fouling from lowering the exchanger's capacity for heat transfer. In fact, fouling rates in WPHE can be noticeably lower compared with S&T equipment under the same operating conditions.

Heat Recovery Possibilities

Another important feature of the WPHE is that it can operate very near to counter-current flow. This makes it possible to handle crossing temperature programmes (where the cold fluid is heated to a temperature that is higher than the outlet temperature of the hot fluid) in a single shell of the heat exchanger. That, coupled with the efficiency gains of the technology, will result in closer temperature approaches than is possible with traditional equipment. This is especially important in heat recovery, where the cold fluid can be heated to temperatures very close to those of the hot fluid, hence recovering as much energy as possible.

Installed Space and Installed Cost

As a consequence of the first two technology advantages, it is easily deduced that applying WPHE will save installation space and reduce installation costs. This is especially important when installation space is tight, or when the installation requires the heat exchanger to be elevated on a structure. The compact nature and efficiency of the WPHE also results in lower empty and operating weight, which will further lower the installed costs for foundations and structural steel. When estimating the installation cost, a factor of three to 3.5 times the initial investment cost is often used for S&Ts, while for WPHEs the corresponding factor can be less than two.

Welded Plate Heat Exchanger Operation in Fouling Services

The WPHE heat exchanger can be successfully used in fouling services if the nature of the fouling is understood. In fact, WPHE can significantly reduce the rate of fouling in typical crude refinery services. It is first important to classify the type of fouling into two categories, each of which is handled differently.

Deposition Fouling

Deposition fouling occurs for several reasons, but is most simply explained as a type of fouling that forms on the heat exchanger surfaces. These deposits will, over time, reduce the heat transfer performance and eventually plug the heat exchanger. The mechanism for deposition fouling can be chemical (polymerisation), temperature-dependent (solubility of carbonates, for example) or thermal degradation (cracking) of the fluids in the stream. Examples of deposition fouling include asphaltine, cooling water scale and coke formation. The best way to address this type of fouling is to design a heat exchanger with high turbulence or shear stress. Increasing the shear stress will decrease the rate at which fouling deposits on the heat exchanger walls, and is a critical factor in heat exchanger design. In an S&T heat exchanger, this means increasing the linear velocity through the equipment until a suitable value is reached to reduce fouling. Unfortunately, the S&T exchanger quickly runs into pressure drop limitations before acceptable shear stresses are reached, resulting in a design that will inevitably foul and require regular maintenance. By contrast, the WPHE can generate four to 10 times the shear stress in a reasonable design, proving to limit the fouling rate in deposition fouling services. For example, a well-designed S&T exchanger with 7ft/second velocity in the tubes generates a shear stress of 17Pa. The same service in a WPHE can generate up to 95Pa and operate much longer between cleanings.

Particulate Fouling

Particulate fouling is defined as some classification of suspended solids that exist in a heat exchanger inlet stream. In a refinery, these solids can be anything from pipe scale, desalter sludge, catalyst or fouling from other heat exchangers that make their way downstream. If these particles are large, or exist in large concentrations, they will accumulate inside any heat exchanger with multiple flow channels; the WPHE is no different in this regard. If particulate fouling from foreign matter is expected on an upset basis, a basket strainer with 3.5mm mesh holes is recommended to protect the WPHE from particle accumulation. If particulates are expected on a continuous basis (heavy solids loading), a single-channel device such as a spiral heat exchanger may be the best fit for the service. Examples of heavy solids loading include fluid catalytic cracking (FCC) slurry, desalter effluent, and visbreaker feed/bottoms services.

Application of Welded Plate Heat Exchanger Technology

Crude Pre-heating Case Study

In 2008, a major US refiner installed and commissioned nine Alfa Laval Compabloc® WPHE heat exchangers in the crude pre-heat train of their refinery as part of a revamp project. It was the desire of the refiner to increase the heat recovered in the pre-heat train, while also using alloys that allowed the refiner to process more advantageous crude oils. The optimal location of the Alfa Laval heat exchangers was determined through a pinch analysis of the pre-heat train, and this performance was compared with another pinch analysis using conventional S&T technology. The results of this analysis showed that the WPHE technology would allow the refiner to increase the inlet temperature to the heater by an additional 100°F, saving millions of BTU in energy as well as enjoying a significant emissions reduction. Compabloc WPHE were put into service in several locations in the pre-heat train: atmospheric column OVHDS, naphtha, kerosene, and vacuum tower bottoms versus crude positions. Actual operating data from the crude unit confirms the pinch analysis performance expectations. In addition, the performance and temperature of the Compabloc WPHE have remained steady throughout the operating period, also proving that low fouling can be expected with WPHEs when designed correctly. It can be learned from the above example that the best utilisation of WPHE technology can be realised only when the performance of the equipment is evaluated at the initial process optimisation stage of a project. Only then can the full effect of increased efficiency be seen in process improvement, emissions reduction or lower cost of downstream equipment.

Steam Generation

A refinery in the US needed to cool vacuum tower bottoms (VTBs) from over 700 to ~350°F before sending the product to storage. It was decided that heat would be recovered by generating steam in two steps. When looking for heat exchangers to perform this duty, it became apparent that the WPHEs would be able to generate higher pressure and more valuable steam than a typical tubular steam generator, due to the ability of WPHEs to have tight temperature approaches down to 5–10°F. In addition, the boiler feed water chlorides demanded a Hastelloy C alloy of construction, something that WPHE would be able to provide at half the cost of conventional tubular equipment. Since February 2007, the WPHEs have performed well, with no cleaning needed so far.

Other Processes

A major mid-west refiner was expanding an existing sour water stripper (SWS) in the refinery. One of the pieces of equipment to be replaced was the SWS feed/effluent heat exchanger. In this project, going with a more efficient design would allow the existing reboiler to handle the increased load, saving capital and installed cost. This refinery also selected an Alfa Laval Compabloc for SWS service. This heat exchanger was designed with a 700BTU/ft^2*hr*°F coefficient, and after three years of operation the feedback from the unit is positive, with no cleaning required to date.

Figure 1: Turbulent Flow Through Heat Exchanger Channels Generated by Corrugated Plates

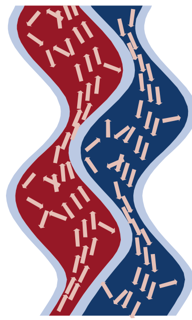
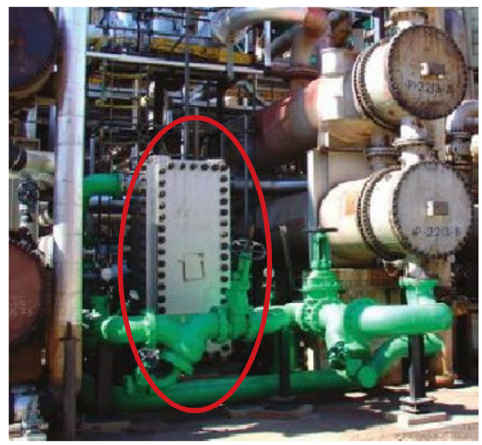


Figure 2: Difference in Heat Transfer Area and Ground Space for a Shell-and-tube versus a Welded Plate Heat Exchanger Installation in a Heat Recovery Duty



The single Compabloc welded plate heat exchanger circled replaced the two shell-and-tubes to the right.

Cleaning and Service

Fouling is prevalent in the refining industry, and cleaning equipment to restore performance is critical to the success of the plant. The Compabloc WPHE referenced in this paper is mechanically cleanable on both the hot and cold circuits. Access is allowed through bolted panels, and mechanical hydroblasting is an effective means to clean the equipment. It is also important to note that service work, when needed, is completed more quickly, which saves money on both maintenance costs and production downtime.

Mechanical Cleaning

If thorough cleaning is needed, or if chemical cleaning does not achieve the desired result, the channels in a WPHE can be cleaned by hydroblasting. The unit can be disassembled by removing four panels, and high-pressure water or steam can be orientated down the heat transfer channels. In many cases, the unit need not be removed from the foundation to be cleaned on both sides. Also, since a single piece of equipment is being maintained, compared with multiple S&T in series, maintenance can be performed in a fraction of the time of traditional heat exchangers. Please consult with the heat exchanger manufacturer for detailed procedures or service support.

Conclusions

It has been proved with service experience that WPHEs can dramatically increase the efficiency of heat transferred in refinery processes. It has also

Figure 3: Alfa Laval Compabloc Welded Plate Heat Exchanger Installed in Vacuum Tower Bottom Steam Generation Service

Figure 4: Welded Plate Heat Exchanger Cleaning with High-pressure Water

been proved that, when applied correctly, the WPHE can offer extended run times between cleaning and lower fouling rates than S&T equipment. This is especially important in heat recovery, where the use of WPHE allows the refiner to push the envelope of what was historically deemed feasible with traditional equipment. In fact, it is economical (with a reasonable payback) to install WPHE in services that would need 10 S&T heat exchangers installed in series to perform. Increased heat recovery means substantial savings in terms of both fuel savings and savings on fired heater emissions. Because of the compact size of our equipment, installed space can be one-tenth of the floor area of traditional equipment. This is especially important when installation space is tight (such as in a revamp situation) or when the exchanger is required to be installed high on a structure, where space and weight are very valuable.

The WPHE can also offer substantial cost savings over traditional equipment. This is because less surface area is required to perform heat transfer, and also fewer shells. The competitiveness of the WPHE increases dramatically when higher alloys are considered, but can also be attractive in heat recovery services with carbon steel construction. Deposition fouling in a WPHE can also be lower, due to the high turbulence and shear stresses that exist between the heat exchanger plates. In fact, shear forces on the walls of the WPHE are at least five times the shear forces of an S&T with 8ft/second velocity. WPHEs have been installed by refineries in critical roles, with excellent results. Many refiners are using the technology as a tool to increase heat recovery and reduce greenhouse gas emissions in line with their strategic long-term cost reduction strategy. Over the years, Alfa Laval has gained the experience and know-how to correctly apply WPHE technology to specific operating challenges, with the testimonials and operating performance to prove it. ■