CONDENSERS VS HEAT EXCHANGERS

Alicia Johnson, Graham Corp., USA, highlights the strengths and weaknesses of traditional straight tube designs vs coiled tube designs in both condensers and heat exchangers.

This article will discuss both condensers and heat exchangers that utilise a traditional straight tube design and a coiled tube design. It will highlight some of the strengths and weaknesses of each design and some common applications where those strengths are utilised as an advantage. There are many types of condensers and heat exchangers in the oil and gas industry and they are not all interchangeable. There are applications where a condenser is better than a heat exchanger and vice versa. The application and the type of equipment used both matter. Certain types of equipment are more versatile and a better fit for specific applications. Common equipment used in both condensers and heat exchanger applications are the helically coiled tube design and the straight tubed design.

The difference between helically coiled tubes and straight tubes

The helically coiled tubes are made in a specific helical pattern depending on the requirements, which allows the fluid inside the coil to travel in a spiral flow path for liquid to liquid service. The tubes are tightly fit in the case or shell side, which can be a casting or fabricated. The tight fit forces the fluid on the shell side to flow in a spiral pattern opposite the tubes. This design creates a true countercurrent flow resulting in a better heat transfer rate. The helically coiled tubes average more than 40% better heat transfer than a typical shell and straight tube unit, as the coiled tubes make the helically coiled tube unit very compact. Another advantage with the helically coiled tubes is that no flat plate tubesheets are used, unlike the shell and

Figure 1. Turbine exhaust steam surface condenser (straight tubed vacuum condenser).

Figure 2. Multiple stage process vacuum condensers with ejectors.

and straight tube units. The helical design can handle large changes in temperatures of approximately 500˚F difference between fluids, as well as higher pressures of up to 15 000 psig. Another advantage of the compact helically coiled tube design is that it is easy to clean on the shell side. The casing can be easily removed without breaking the piping connections on the shell side or tube side, as the connections are located on a singular baseplate for most applications.

The advantage of the straight tube design is that it can handle more flow rate than the helically coiled tube option. The helically coiled tube design surface area only ranges from 1 to 650 ft^2, while the straight tube design can reach over 50 000 ft^2. The straight tube design allows for additional connections or fluids to be added, as the size of the unit can be large compared to the compact helically coiled tubes. Unlike the helically coiled tube, some straight tubes do have the option to have removable bundles to allow for cleaning. Due to the larger sizes of the straight tube units, it typically takes a lot more effort to remove and clean the bundle.

Condensers

Condensers are designed to facilitate a phase change from a vapour to a liquid. For example, vapours such as steam enter the condenser shell side and liquid condensate exits the condenser shell side, typically with a cooling water source on the tube side. Another way to differentiate condensers is that they operate with a lower pressure drop on the process side. There are two main locations in which condensers are used: a vacuum service or an atmospheric service. Condensers in vacuum service tend to see a large amount of flow, therefore shell and straight tube condensers would be the best fit. For some smaller flow vacuum services, a helically coiled tube condenser may be better suited. In an atmospheric service, there are some larger flow services for shell and straight tubes. A helically coiled condenser is the better option for lower flows, higher temperature differences and high-pressure applications.

Applications

An example of an application with a larger flow would be a turbine exhaust vacuum condenser or surface condenser. This type of condenser is used in vacuum service to condense steam from a turbine in turbo generator, compressor drive and pump drive applications. In these applications, a large amount of steam enters the shell side and is condensed with cooling water on the tube side. This application would be ideal for shell and straight tubed condensers (see Figure 1). This application requires the non-condensable to be removed, which is typically air. To accomplish this, an air removal package is used. This is typically made up of ejectors and condensers, but can also include liquid ring vacuum pumps. The majority of the time, the air removal condensers are at a flow rate where a straight tubed condenser would be a better fit. However, there are some applications where a smaller flow rate is used and a helically coiled condenser would be a better fit.

Another example of an application with larger flows would be a process vacuum condenser for crude oil vacuum distillation, petrochemical process for plastics, resin, fibres, etc. In process type applications, the vacuum condenser has a wide range of vapours entering the vapour inlet or process side, which is typically the shell side that is condensed into a liquid. For example, in a crude oil vacuum distillation tower, the load entering the condenser is a mixture of hydrocarbons, steam and non-condensable gases using cooling water on the tube side to condense the mixture. As this is a large amount of load, a straight tubed condenser would be a better fit than a helically coiled tube condenser. The process vacuum condenser takes the load that comes in and condenses the condensable load, and the non-condensable load will enter downstream equipment. In some cases there are multiple stages. For example, there may be a pre-condenser at the tower top that condenses the load mixture. Then, there is typically an ejector to compress the load with added steam, causing additional load to the next condenser, which is an intercondenser. Figure 2 shows an example of a multiple stage vacuum condenser with an ejector system. In this application, the load is too large for a helically coiled tube condenser. As such, the straight tube condenser would be used. In some cases, depending on the pressures, more than one intercondenser is used with an ejector to handle the specific loading mixture. At the end of the system there is an

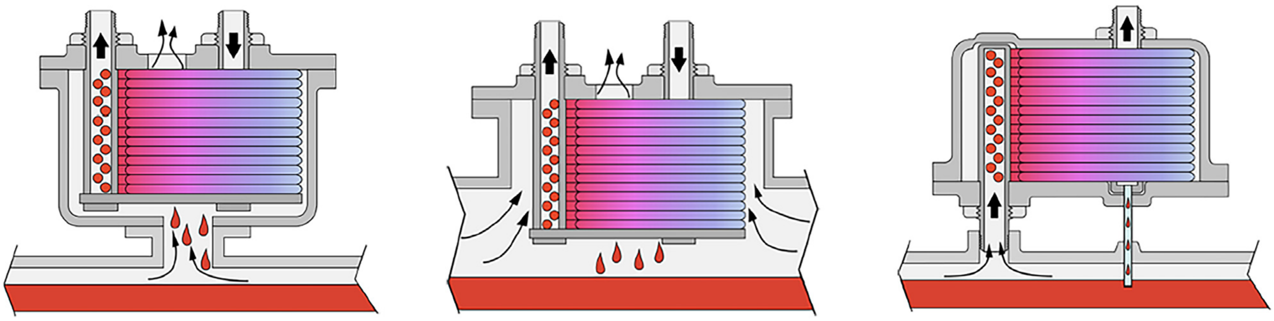

Figure 3. Left: a vent condenser on nozzle (VCON) is mounted on a nozzle. Middle: a vent condenser in nozzle (VCIN) is installed inside the tank's nozzle (middle). Right: a vent condenser tube side (VCT) condenses on the tube side.

aftercondenser. As this is still a large flow, it is a better fit for a straight tubed condenser.

A unique application for condensing vapours is a vent condenser. Unlike the turbine exhaust and process condenser, which are under vacuum, the vent condenser operates at atmospheric pressure and lower flows. The vent condenser is used to reclaim vapour from a product in a tank that has stored liquid by using cooling water to condense vapours into the liquid. The vent condenser prevents a vessel or tank from building up in pressure or collapsing in vacuum with the change in weather. The vent condenser also reclaims vapours when the vessels or tanks are being filled. Since this is a smaller amount of flow compared to other condensers, there is a larger amount of temperature change or thermal growth, and space is usually limited. A helically coiled tube condenser is ideal for this application. The straight tubed condenser or shell and tube would be bulky to put on a tank or vessel to reclaim vapours and is more complex to design for larger changes in thermal growth with fixed tubesheets. The helically tubed condenser is also versatile as it can easily be modified to this application either by being on top of the vessel or tank (see Figure 3, left), or inside the vessel or tanks without a casing for shell side condensing (see Figure 3, middle) due to the compact design. Another option would be placing the helically coiled condenser on top of the vessel and using the tube side to do the condensing (see Figure 3, right). The tube side condenser would be ideal for corrosive vapours as it would be easier to use special metals for the tubes.

Heat exchangers

Heat exchangers are designed to transfer as much heat as possible from one flow to another. An example is when a high temperature process fluid enters the heat exchanger on the shell side and the other fluid, such as water, is colder when entering the tube side, causing the heat from the process fluid to be transferred to the colder water, cooling the process fluid as a result. A heat exchanger has more tubes compacted in the bundle in order to get as much heat transfer as possible compared to a vacuum condenser, which has an open dome space in the bundle. Therefore, the process side pressure drop is typically higher in a heat exchanger.

Applications

The shell and tube heat exchanger is used in different applications, but mainly in applications that are liquid to liquid and that require heat to be exchanged. This can be larger flows or smaller flows, depending on what is trying to be achieved. For a larger flow, it would be preferential to use a straight tubed heat exchanger. For lower flow, higher pressure, greater temperature change, special materials, or space restrictions, a helically coiled heat exchanger would be more suited.

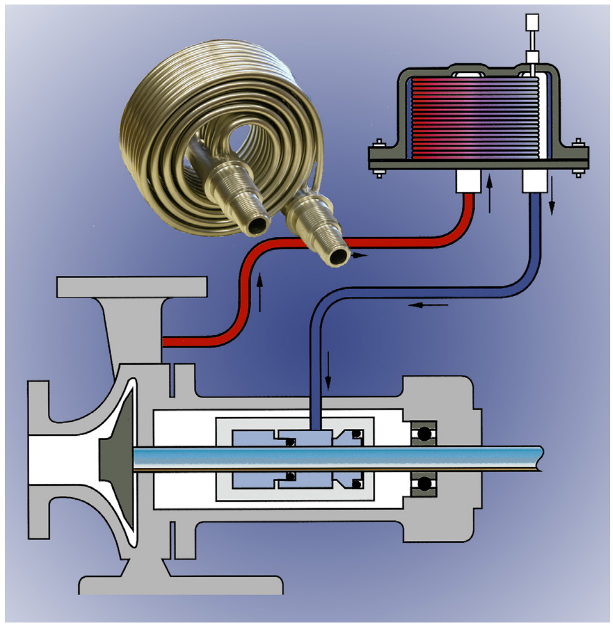

Figure 4. Example of a pump seal cooler.

A common heat exchanger application is the seal cooler. A seal cooler cools the liquid that is supplied to the mechanical seals of a pump (see Figure 4). A pump seal cooler exchanges the high temperature flush fluid from the mechanical seal of the pump to the secondary fluid typically on the tube side, which is generally water at a cooler temperature. Given that a pump usually has only a certain amount of space, a compact design is ideal, so a helically coiled heat exchanger would be better suited for this application. In addition, the countercurrent flow path improves the thermal efficiency, which also reduces fouling and allows incomparable mechanical seal cooling in the compact size. This application has large temperature changes with close approach temperatures, which is best done with true countercurrent flow configuration of the helically coiled tube heat exchanger. A straight tube exchanger would require more surface area and take up more space.

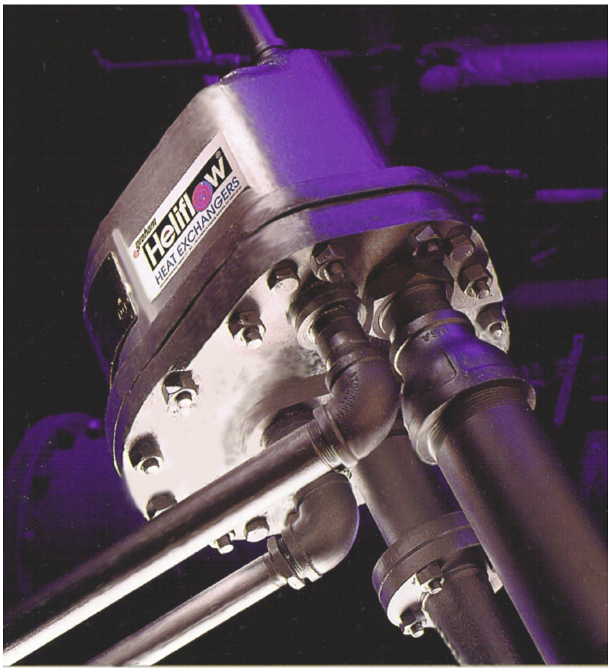

Figure 5. Example of a helically coiled heat exchanger.

A sample cooler is another application where a heat exchanger is used, as a process sample often needs to be cooled and is usually done with cooling water. Therefore, the heat from the sample liquid is transferred to the cooling water. A sample cooler is typically located at the boiler, distillation column overheads, condensate drums, distillation column cut-points, reboiler bottoms and deaerators. Typically, only a small sample is needed. It may be higher pressure; the fluid sample may be corrosive, requiring special materials and a requirement to be easily cleaned; it may be periodically or continuously run. A helically coiled heat exchanger would be the best fit for this application (see Figure 5). The helically coiled heat exchanger is compact in design and the true countercurrent flow pattern can handle the different pressures, significant changes in temperature or demanding thermal growth and can be easily cleaned by simply removing the casing or shell without affecting the connections. It would be difficult for the straight tubed heat exchanger to handle higher pressures and large changes in thermal growth due to fixed tube sheets. It is also larger in size, which is not ideal for a sample cooler application.

Conclusion

The applications mentioned in this article are only a portion of what a condenser or a heat exchanger can be used for. There are specific applications for a condenser and a heat exchanger and they are not interchangeable. A condenser changes the phase of the load by taking a vapour and changing it to a liquid, while a heat exchanger does not change the phase of the load and takes a liquid and changes the temperature by exchanging the heat by cooling one liquid and heating the other.

When looking at a new system, it is best to look at what needs to be achieved along with the type of equipment. A helically coiled tubed unit may be a better fit, and other times the straight tubed unit may be ideal. It is also important when replacing equipment to understand what needs to be achieved.