New Applications for Spiral-Tube Heat Exchangers

A decades-old, yet less well-known type of heat exchanger offers ad new and emerging applications

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Spiral-tube or helically-coiled heat exchangers have been around for decades addressing sample cooling, mechanical seal cooling, vent condensers, vaporization and general heating or cooling requirements. They serve niche or unique applications and are not as well known or understood as are ubiquitous shell-and-tube or gasketed-plate heat exchangers are used.

This article introduces — or for some, reintroduces — spiral-tube heat exchangers and provides an overview of new applications where they are being used or are specified for emerging or developing markets, such as the hydrogen economy, botanical extraction, compressed natural-gas systems, cryogenic vaporization and vent-emission reduction.

Spiral-tube heat exchanger

A spiral-tube heat exchanger consists of a number of tubes stacked and helically coiled (Figure 1). The coiled tubes at each end are welded, soldered or brazed into manifolds or piping that permit fluid to enter and exit the coil. In heat-exchanger parlance, this is referred to as the tube side of the heat exchanger. The coil is placed inside a casing or housing where a baseplate provides for a sealed enclosure, creating the shell side, or casing side, that permits fluid to enter and flow along a pathway exposed to the exterior of the coil and then exit the heat exchange area.

A number of advantages are present with such a configuration [3]:
Compactness. The straight length of tubing, which can be 45 ft long, is coiled, resulting in a smaller footprint as compared to a corresponding shell-and-tube heat exchanger. This attribute is ideal for heat-exchanger integration within a packaged system. For example, a spiral-tube heat exchanger with 380 ft^2 of heat-exchange area addressing a 3,000 psig operating pressure occupies a volume of 5 ft 4 ft 4 ft. In contrast, a shell-and-tube heat exchanger with high pressure on the tube side occupies a volume of 15 ft 3 ft 2 ft. The 15-ft tube length for a shell-and-tube exchanger causes integration complexity and an increase in floor space needed for the overall packaged system by approximately 10 ft.
High pressure capability. The coil

copper, copper-nickel, titanium, Hastelloy, Inconel and Incoloy. The casings are commonly in cast iron, cast steel, fabricated steel or stainless steel. Although any material that can be cold worked (rolled) and welded may be used for the casing or shell side.

High-pressure applications

When fluid operating pressure is elevated, above 750 psig, as an example, a spiral-tube heat exchanger is an ideal candidate. New energy applications, such as hydrogen-fueling systems or remote natural-gas delivery systems, create new demand for this type of heat exchanger. Similarly, developing markets, such as supercritical CO_2 for botanical extraction or shelf-stable alternatives to traditionally frozen foods and also mature markets for industrial gases, like helium systems, also require these specialized heat exchangers.

Hydrogen fueling systems. The energy transition and search for non-fossil-based transportation fuels has brought hydrogen to the forefront as a fuel for fuel-cell electric vehicles. The Society of Automotive Engineers Standard SAE J2601 governs fuel-station requirements for light duty vehicles and buses. Dispensing pressure to the vehicle is either 10,000 psi (70 MPa) or 5,000 psi (35 MPa). These are extremely high pressures. Diaphragm compressors are used to increase hydrogen pressure to the required storage pressure. The compressors are multi-stage, where heat exchangers remove heat of compression (Figure 2). Spiral-tube heat exchangers are used for compressor inter- and after-coolers to remove heat caused by compression. At such high operating pressures and for system integration, spiral tube exchangers are chosen. A typical heat removal requirement for a hydrogen compressor inter-stage cooler is 100 lb/h of hydrogen at supercritical pressure of 2,000 psig cooled from 300°F to 100°F. For the final compression stage the heat removal requirement typically is the same 100 lb/h of supercritical hydrogen at 10,000 psig cooled from 250°F to 100°F. Actual mass flowrate will vary from installation to installation as will the inter-stage and final-stage cooling requirement based upon compressor design.

Another use of spiral-tube heat exchangers in hydrogen fueling stations is for precooling the hydrogen before it is dispensed to a vehicle. SAE J2601 refers to T40 or T30, for example, meaning the dispensing system is to deliver hydrogen to the vehicle at –40°C or –30°C, respectively. The temperature is essential for meeting fueling time requirements.

Hydrogen has a unique thermodynamic property that is unlike most other gases, except for helium. Most gases, when passing through a control valve, expand adiabatically to a lower pressure and experience a reduction in temperature. Due to a negative Joule-Thomson coefficient for hydrogen and the operating conditions of the fueling system, when hydrogen flows through a flow control valve and undergoes a pressure loss, the temperature actually rises. If the resultant rise in temperature isn't removed, it affects the vehicle filling time.

A hydrogen precooler is used to remove the heat caused by pressure drop across a flow-control valve in the supply line to the fuel dispenser admitting hydrogen into a vehicle. Here too, pressure is high and in the range of 10,000 psi for automobiles or 5,000 psi for mass-transportation vehicles. The removal requirement is typically 120°F hydrogen cooled to –40°F (–40°C) for a J2601 T40 fueling system.

Developing heat exchanger designs at pressures of 5,000 psi or greater with hydrogen in supercritical state is not ordinary fare.

use of supercritical CO_2 to produce quality food products that do not require freezing, refrigeraduring filling operations or as a result of changes in ambient temperature leading to release of CH_2Cl_2 as the storage tank breathes. In order to meet the high reclamation rate of 98% recovery of CH_2