

# COMPRESSOR

**TECH<sup>2</sup>**

DEDICATED TO GLOBAL GAS COMPRESSION PRODUCTS AND APPLICATIONS

# Spiral-tube heat exchangers for compressor service

Old technology, new demand. By **Jim Lines**, Graham Corporation

**A** decades old technology is experiencing renewed demand. The energy transition, expanded use of fiber optic cabling and growing use of supercritical fluids have brought this type of heat exchanger to the forefront. Spiral-tube heat exchangers have unique construction features suited for high operating pressure associated with compression applications for hydrogen, helium, natural gas and carbon dioxide service, as examples.

## Industry mainstay

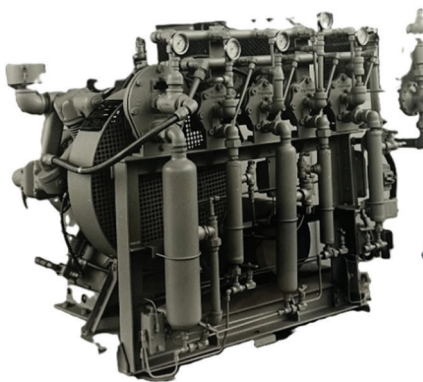
An industry mainstay throughout 1960-1990's, generational turnover within the heat transfer and compression equipment industries led to familiarity with spiral-tube technology waning. Shell and tube type heat exchangers are more well known due to their general use for industrial applications. Spiral-tube heat exchangers are a better choice in particular applications where operating pressure is high, say above 100 bar (1450 psi), when a temperature cross is desirable, specifically, when hot-side gas must be cooled below the cold-side fluid outlet temperature, or if pulsation is anticipated, as may be the case for positive displacement compressors.

Spiral-tube heat exchangers are used as compressor interstage and final stage

coolers. Critically instrumental for improved compressor efficiency and reliability, spiral-tube heat exchangers remove heat of compression and lower interstage temperature along with volumetric flowrate thereby keeping operating temperature within a desired range to ensure proper compressor operation and operating life.

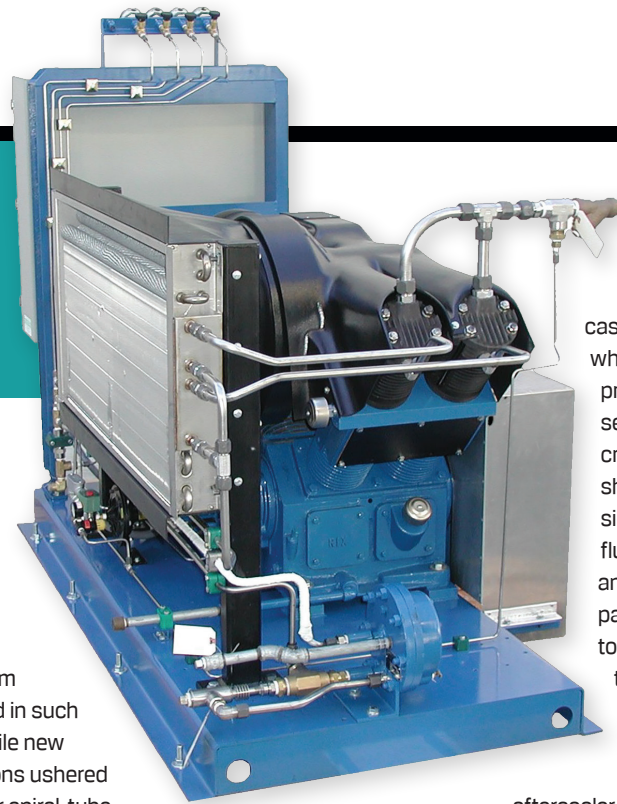
## Early applications

Initial spiral-tube applications for compressor interstage cooling in early 1950's was compression of carbon dioxide for use by the carbonated beverage industry or general purpose air compressor service. As the carbonated beverage and general industries expanded, the demand for compact, high efficiency compressor inter and after stage coolers grew. By the 1960's spiral tube interstage and final stage compressor coolers were in use



**FIGURE 1** Five stage air compressor from 1971 (spiral-tube heat exchangers in a row at top portion of skid) and 2017 (spiral-tube heat exchangers on top of skid in blue).

Rix Industries 4VX industrial compressor with Heliflow Heat Exchanger interstage cooler.



exchanger. The coil is placed inside a casing or housing where a baseplate provides for a sealed enclosure creating the shellside 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. In intercooler or aftercooler service, gas or supercritical fluid is tubeside and coolant service fluid, typically water, is on the shellside.

A number of advantages are present with such a configuration:

for hydrogen and helium compression. Still used in such applications today, while new markets and applications ushered in renewed demand for spiral-tube compression stage coolers. Hydrogen fueling stations, virtual pipeline and supercritical carbon dioxide are more recent markets where demand for this type of heat exchanger has grown.

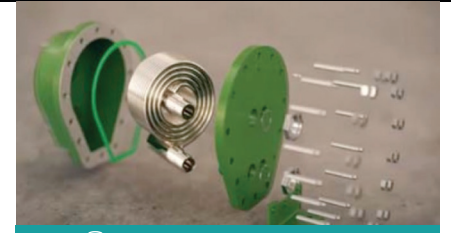
It is important to familiarize once again the compressor industry with spiral-tube heat exchangers so that its unique construction features and performance advantages may more broadly be considered for today's compressor intercooler and aftercooler requirements.

## Spiral-tube heat exchanger

A spiral-tube heat exchanger consists of a number of tubes stacked and helically coiled. The coiled tubes at each end are welded, soldered or brazed into manifolds or piping that permits fluid to enter and exit the coil. In heat exchanger terminology this is referred to as the tubeside of the heat

■ **Package integration ease:** the straight length of tubing, which can be 30 ft long or longer, is coiled resulting in a smaller foot print than might 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<sup>2</sup> of heat exchange area addressing a 3000 psig operating pressure occupies a volume of 5ft x 4 ft x 4 ft. Whereas a shell and tube heat exchanger with high pressure on the tubeside occupies a volume of 15 ft x 3 ft x 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 is comprised of cylindrical parts, specifically, the tubes and manifolds, which can withstand high operating pressures. 5,000 psi (345 bar) is rather



**FIGURE 2** Spiral Heat Exchanger exploded view.

routine and for hydrogen service, pressures of 10,000 psi (690 bar) are economically possible. This attribute is an ideal fit for supercritical service where operating pressure is high or for hydrogen fueling systems. Spiral-tube heat exchangers are in hydrogen service where maximum allowable working pressure is 15,000 psi (1034 bar) have proven out in real-world service.

■ **Suited for pulsating flow:** compressors in high pressure applications are positive displacement equipment and as such flow can pulsate. Spiral-tube exchangers can be provided with chaffing discs to

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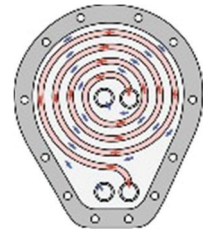
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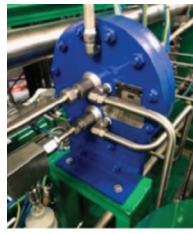
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**FIGURE 3**  
Curvilinear flow path for both tubeside and shellside fluid.



**FIGURE 4**  
Spiral-tube diaphragm compressor hydrogen aftercooler. COURTESY OF HONEYWELL SUNDYNE

eliminate erosion from metal to metal contact.

■ **Maximized LMTD:** fluid flow orientation between hotside and coldside fluids is fully countercurrent thus eliminating LMTD correction factors associated with multipass shell and tube heat exchangers. Such an attribute is ideal when heat transfer requires a temperature cross, more specifically, when the hotside is cooled below the coldside fluid outlet temperature.

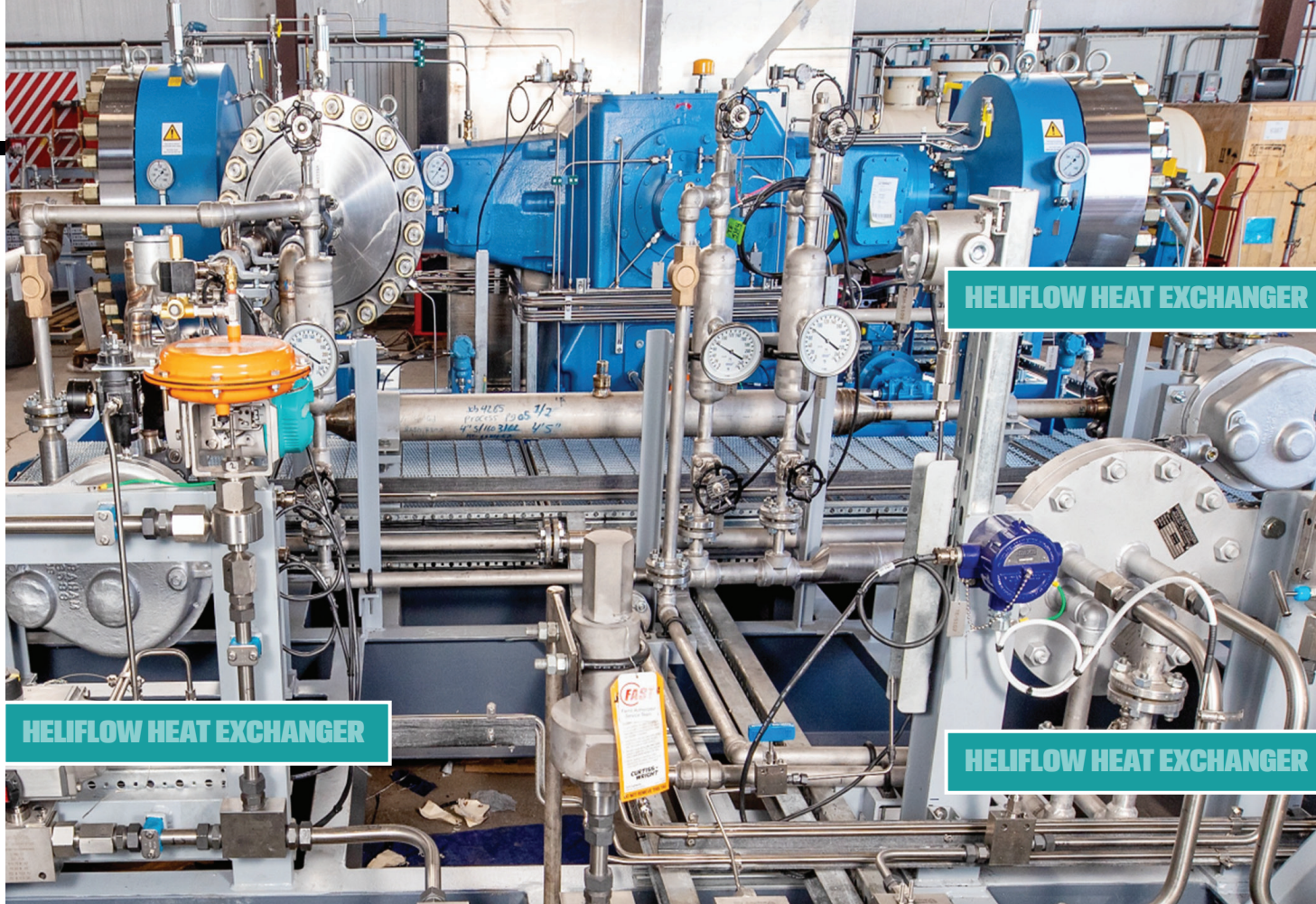
■ **Flow path:** The curvilinear flow path of a spiral-tube (Figure 3) improves heat exchanger efficiency compared to a straight tube of a shell and tube heat exchanger.

■ **Removable bundle:** in most common geometries the casing or shellside is accessible for cleaning or removal of fouling deposits. Also the coil can be removed and easily replaced.

Materials of construction for coiled tube heat exchangers are comparable to those common for shell and tube exchangers. Stainless steel, duplex, copper, copper-nickel, titanium, Hastelloy®, Inconel®, 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 shellside of a spiral-tube heat exchanger.

**Extremely high pressure**

Hydrogen compression systems, especially for electric vehicle fuel cell applications, compress hydrogen to extremely high pressures. For automobile fueling pressure



**HELIFLOW HEAT EXCHANGER**

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**FIGURE 4** Diaphragm compressor package with three (3) spiral-tube compression heat removal heat exchangers. COURTESY OF NEUMAN AND ESSER AMERICAS

at 700 bar (10,000 psi) is common or for truck and mass transit 350 bar (5,000 psi) is typical. Heat exchanger mechanical design for such high pressure is challenging for any type of heat exchanger. Spiral-tube exchangers have supercritical hydrogen flowing tubeside. The tubing and manifolds are cylindrically shaped and able to withstand high operating pressure without extreme thicknesses found for shell and tube type that have flat surfaces, such as a tubesheet.

Figure 4 is a hydrogen diaphragm compressor spiral-tube aftercooler that is

15" wide x 17" tall x 8" thick rejecting 80,000 Btu/hr of compression heat where hydrogen gas after compression is cooled from 400 deg F to 120 deg F. The compactness and efficient heat transfer permitted ease of integration into the compressor package.

Key attributes must be efficient heat exchanger without high pressure drop on the hydrogen side. Owing to the curvilinear flow path, the hydrogen heat transfer coefficient is enhanced due to turbulence, mixing and thin boundary layer resulting from the spiral flow path.

A review of spiral-tube compression heat removal applications during the past five years highlights how this versatile heat exchanger continues to serve the

compressor industry and the prominence of hydrogen compression currently versus 20 years ago. For the author's company hydrogen compression is most prevalent followed by air compression today. Whereas 20 years ago hydrogen compression was not front and center. Hydrogen compression systems usually are very high discharge pressure for the final stage where spiral-tube heat exchangers are well suited.

Hydrogen compression is largely for transportation applications. Air compression is for general industrial applications. Helium compression is for medical technology, inert gas for welding applications, fiber optic production and semiconductor manufacturing. Methane compression is for alternate transportation fueling or virtual pipeline applications. Carbon dioxide compression service carbonated beverage and botanicals industries.

Spiral-tube heat exchangers have over an eight (8) decade history of proven performance service the compressor industry. Primary factors that have driven this long-term success include,

- Compactness and ease of integration into compressor package

- Cost effectiveness for high operating pressures, pressure above 1450 psig (100 Barg)
  - Construction suited for positive displacement machines
  - Improved thermal efficiency compared to double pipe or shell and tube heat exchangers
  - Low maintenance requirements and high durability/reliability
- Spiral-tube heat exchangers have had applications throughout the high pressure compression industry. Not only for the

- Nitrogen compression for enhanced oil recovery
  - Carbon dioxide compression for cannabis application
  - Air compression for geophysical seismic oil exploration
- This type of heat exchanger should be considered for compression intercooling and aftercooling regardless of pressure. It is well suited for package integration and has had a history of broad use throughout the compression machine industry.

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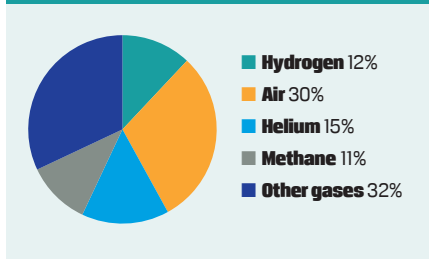
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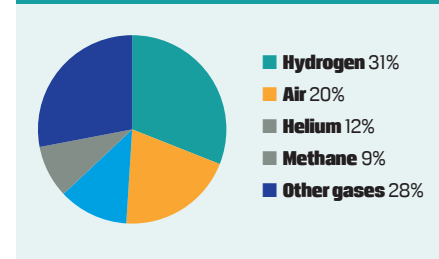
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