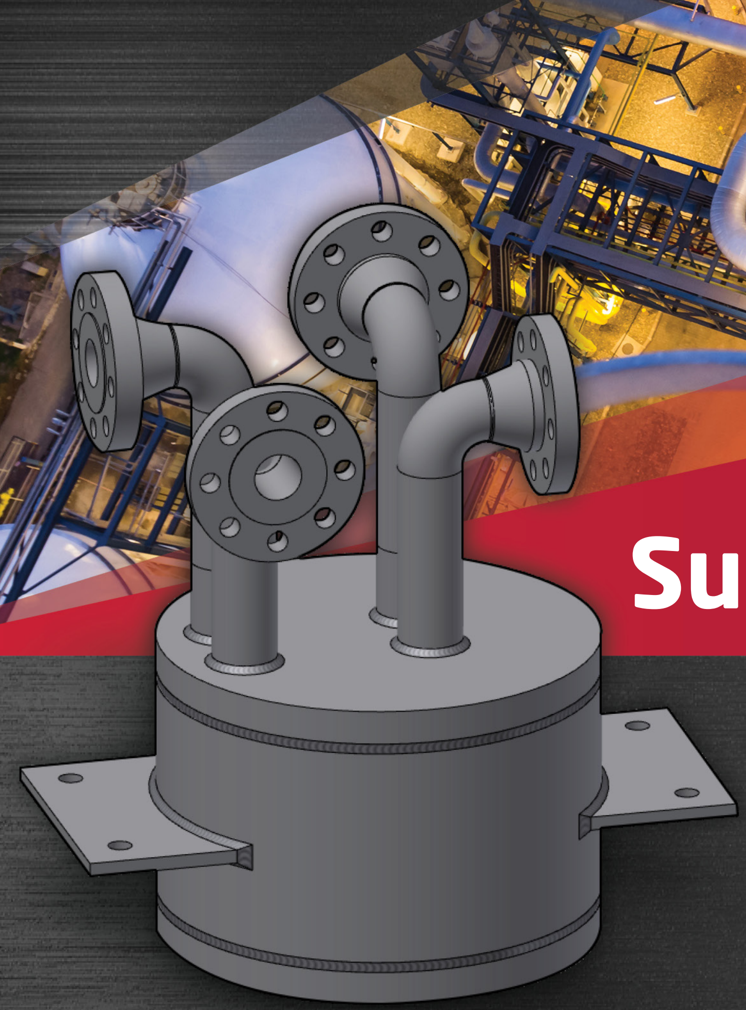
GRAHAM
ENGINEERING ANSWERS



Heliflow Heat Exchanger Applications

Supercritical Fluids

What are Supercritical Fluids?

Supercritical fluids exist when any substance is at a temperature and pressure above its critical point as seen in Figure 1. In this supercritical state, the fluid will have a combination of vapor- and liquid-like properties. Small variations in the pressure or temperature can have an immense impact on the properties of the supercritical fluid, allowing it to be fine-tuned based on the application. Most substances require very high temperatures and pressures to transform into their supercritical state, making the Heliflow Heat Exchanger the ideal option to handle these extreme conditions.

Graham Heliflow Overview

The Heliflow Heat Exchanger is a compact, helically coiled shell and tube heat exchanger. The spiral, countercurrent flow path enhances thermal efficiency, reduces fouling, and delivers exceptional heating and cooling in a fraction of the surface area of standard shell and tube exchangers. Large temperature gradients and close approach temperatures are possible due to the 100% countercurrent flow configuration.

Advantages/Disadvantages of Supercritical Fluids

When a fluid is operated above its critical temperature and pressure, it becomes a supercritical fluid with liquid-like density and vapor-like viscosity. Due to the unstable nature of a supercritical fluid, slight variations in pressure or temperature can drastically change the properties. With a small increase in pressure you can see a large increase in density; this variability allows the fluid to be fine-tuned to a certain application or process. The lack of surface tension effects allows a

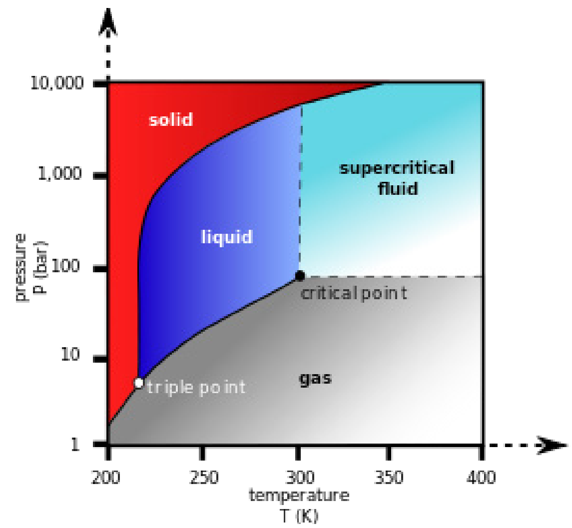


Figure 1. Carbon dioxide pressure-temperature phase diagram. Above a pressure of 300 bar and 300 K, carbon dioxide becomes supercritical. Jacobs, Mark. Phase Diagram of Carbon Dioxide. N.d. Supercritical Fluids. Web. July 2014.

supercritical fluid to come in contact with a solid and leave no distortion or shrinkage, making it useful in extraction applications. The transition of carbon dioxide from a separate gas and liquid phase to a supercritical fluid can be seen in Figure 2.

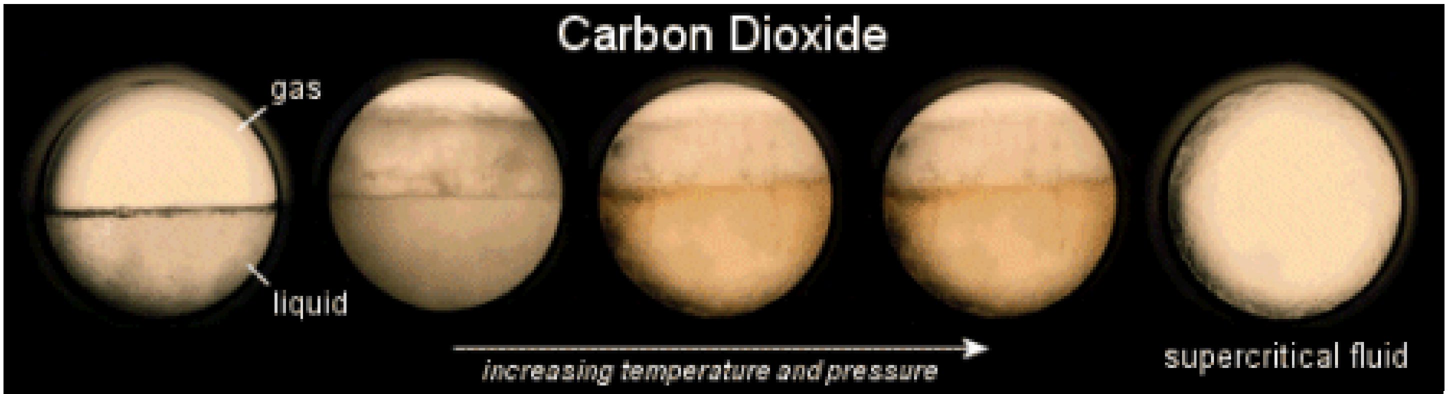


Figure 2. Carbon dioxide transitioning to its supercritical stage. N.d. NASA Harvesting Mars. Web. July 2014

Applications with Supercritical Fluids

The most common use of a supercritical fluid is being used as a medium for extraction. The rate of extraction can be rapid due to the low viscosities and high diffusivities associated with supercritical fluids. Extracted material can easily be recovered by lowering the pressure, allowing the supercritical fluid to return to a gas phase while leaving little to no residue.

Compressed natural gas fueling stations operate at supercritical conditions to utilize the benefits of their unique properties. When natural gas is stored in a supercritical state, the pressure can be increased to make the fluid more dense, which in turn increases the efficiency of the natural gas being pumped while maintaining the viscous properties of a gas for easier delivery.

A majority of modern oil wells utilize hydraulic fracturing, commonly called fracking. These wells have large amounts of water injected into them under high pressure to help free natural gas and oil from shale deposits. Some of the world's largest sources of shale gas can be found in locations with little to no water available, making this technique impractical. This is leading some companies to use supercritical carbon dioxide in place of water to charge the wells and enhance oil recovery. Water-free fracking allows natural gas to flow more freely and most of the carbon dioxide comes back out of the well to be used again, increasing efficiency.

Heliflow Advantages with Supercritical Fluids

Supercritical fluids require a high pressure and temperature environment; these types of applications are well suited to the Heliflow design. The unique spiral tube design of the Heliflow allows it to move freely under thermal cycling as the tube bundle is allowed to expand and contract as necessary. This movement helps alleviate the stress and thermal shock problems that can be seen with a standard shell and tube design. To handle high pressure on the tube side as well as the shell side, the Heliflow is available as a WeldSeal (Figure 3).

This option replaces the standard bolted design (Figure 4) and welds the baseplate to the casing, allowing the shell side to handle pressures up to 5,000 psig. The tube side can see up to 15,000 psig. Many different material options are available for both the tube and shell side of the Heliflow. Standard materials include copper, 304 SS, 316 SS, while some more uncommon materials are Inconel, Titanium, and Duplex 2205. Graham as a rule builds to ASME standards and can provide U-Stamping. [Other certifications available include Canadian CSA B51, European PED, and Malaysian DOSH.]

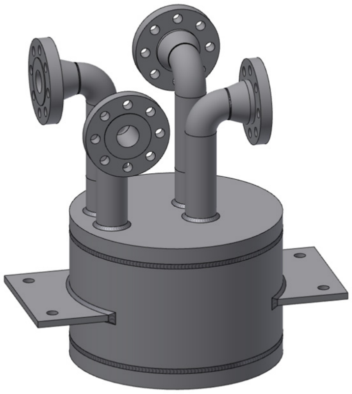


Figure 3. WeldSeal Heliflow (Baseplate welded to casing; shown with flanged connections).

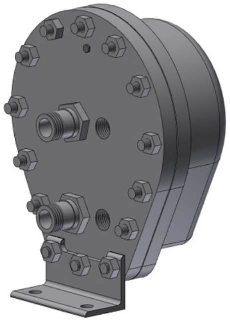


Figure 4. Standard Heliflow (Bolted casing joint; shown with NPT connections).

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