*Not all heat exchangers are created equal.
Helical coil units offer advantages that too often get overlooked,
but they may be ideal for your application.*

Helically Coiled Heat Exchangers Offer Advantages

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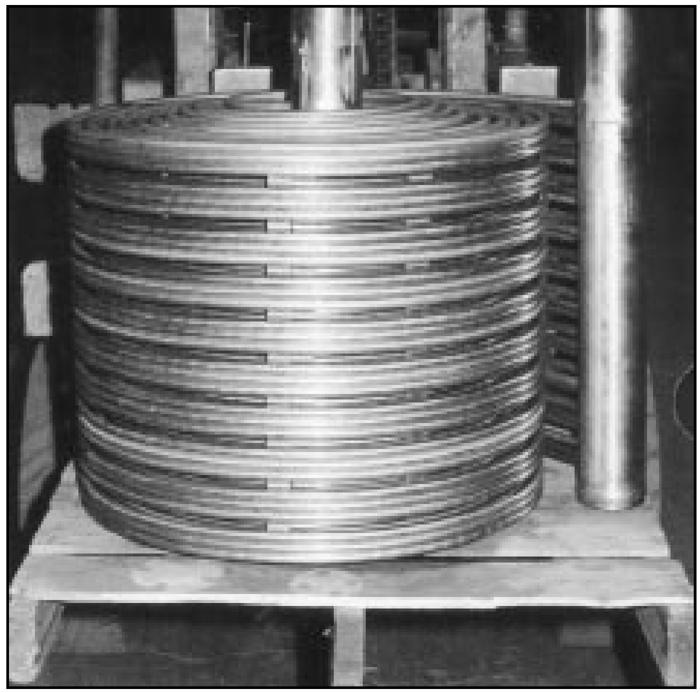
Process heat transfer with conventional shell and tube heat exchangers is familiar to many engineers in many industries. Their use and performance is well-documented. Helically coiled heat exchangers, although they have been around for many years, are not as well known.

Helically coiled exchangers offer certain advantages. Compact size provides a distinct benefit. Higher film coefficients—the rate at which heat is transferred through a wall from one fluid to another—and more effective use of available pressure drop result in efficient and less-expensive designs. True counter-current flow fully utilizes available LMTD (logarithmic mean temperature difference). Helical geometry permits handling of high temperatures and extreme temperature differentials without high induced stresses or costly expansion joints. High-pressure capability and the ability to fully clean the service-fluid flow area add to the exchanger's advantages.

Although various configurations are available, the basic and most common design consists of a series of stacked helically coiled tubes. The tube ends are connected to manifolds, which act as fluid entry and exit locations. The tube bundle is constructed of a number of tubes stacked atop each other, and the entire bundle is placed inside a casing, or shell (Fig. 1.)



Bundle for a water vaporizer in a supercritical water-extraction process. (Fig. 1)

FLOW PATH

Once positioned in the casing, the assembly forms a helical flow path for both the casing and tubeside fluid. Standard units have manifold and casing gaskets, although complete welded designs are available for high casing-pressure service or hazardous applications.

To effectively optimize thermal and hydraulic requirements, the number of tubes (coils) along with their spacing and length may be varied. This allows a design to meet the thermal and hydrodynamic requirements of both the casing and tubeside fluids, so users can select a unit that matches their application's thermal demand and hydraulic limitations.

Other available configurations are:

- Multiple pass design, which increases tubeside velocity, thereby increasing the heat transfer rate. With this configuration, there is an increase in tubeside pressure drop.
- Vaporizer design for liquid vaporization and droplet disengagement (Fig. 2).
- Condenser design, which comes in three typical configurations. Each depends on the process and vessel's discharge connection (Figs. 3a, 3b, 3c).
- Weld-seal designs for completely welded units often are specified when cross-contamination must be prevented, or fluids are hazardous or incompatible with gasket materials (Fig. 4).

As with any heat exchanger, the flow rate, allowable pressure, physical properties of the fluid, and construction material control final design.

No matter the design, helical heat exchangers offer several distinct advantages to the user.

High film coefficients are achieved on both the coil and casing side. The helical flow path imparts higher shear rates and turbulence at a given pressure drop, which can result in film coefficients

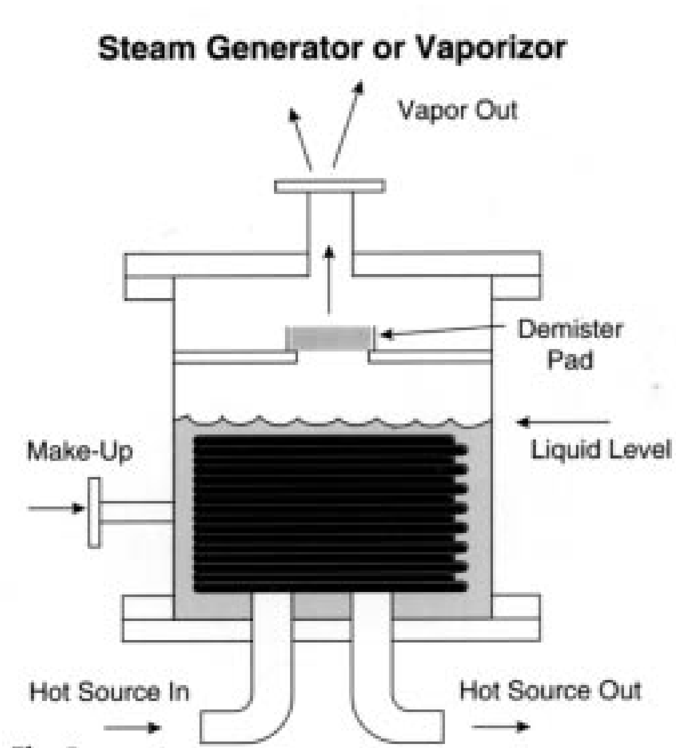


Fig. 2

Vaporizer design of a helical heat exchanger for liquid evaporization and droplet disengagement. (Fig. 2)

up to 40% higher than those achieved with many comparable shell and tube units. Departure from laminar floss and fully developed turbulent flow occur at lower Reynolds numbers.

The 100% counter-current flow allows full use of the available LMTD and makes temperature cross—when the hotside outlet temperature is cooled below the coolside outlet temperature—possible without multiple units in series. The flow geometry of a helical unit is such that a temperature cross is managed within a single unit. This is possible because 100% counter-current flow permits closer temperature approaches and improved heat recovery.

Cleaning the casing-side flow area is easily managed. The casing can be unbolted and the entire bundle assembly removed for cleaning, inspection or replacement. Fully welded designs (weld-seal) though, do not have this feature.

The coil arrangement's compactness also provides advantages, because the exchanger requires minimal floor space.

The heat exchanger's spring-like coil eliminates thermal expansion and thermal shock problems that often occur during startup or during cryogenic or high-temperature service.

High operating pressures are easily handled on the coilside, and without the need for the tubesheet of a shell and tube unit, required thicknesses are minimal, even at high operating pressures. Pressures exceeding 10,000 psi are possible.

The high shear stresses and induced turbulence of helically coiled exchangers reduce the tendency for fouling. This results in longer operating cycles between scheduled cleaning intervals. Additionally, the lower fouling tendency permits the use of less conservative safety margins at the initial design Stage. Conventional designs allow casing-side access for cleaning and inspection.

Economical unit selection is possible due to approved film coefficients, full use of available LMTD and minimal required thicknesses.

LIMITATIONS

There are very few limitations for the use of helically coiled heat exchangers. Generally, a pressure limit of 10,000 psig covers the majority of applications. Temperature limits are determined by construction materials, as are the corrosion rates.

Surface areas of 1 to 650 sq. ft. are available, and using units in series or parallel may extend this range substantially.

APPLICATIONS

The use of helically coiled exchangers continues to increase. Applications include liquid heating/cooling, steam heaters, vaporizers, cryogenic cooling and vent condensing. Listed below are the details for standard services in which helical exchangers warrant consideration.

- Sample Cooling
- Analyzer Pre-cooling
- Seal Coolers
- Condensers
- Cryogenic Vaporizers
- Compressor Inter- and After-Coolers
- General Applications

Sample Cooling. Continuous monitoring of process output is necessary to ensure product quality within allowable tolerance. Grab-sample cooling (Fig. 5) is needed prior to transport to lab technicians for analysis, so an inexpensive compact unit is needed to efficiently cool sample streams to desirable levels.

The helical coil design, with definitive flow path for both sample and cooling water, provides a counter-current flow design of high efficiency and predictable close-temperature approach. Typical sampling locations are boiler steam, distillation column overheads, reboiler bottoms, condensate drums, distillation column cut-points and de-aerators.

Boiler steam sampling is often at high pressures and coiled tube units are not affected by these operating requirements.

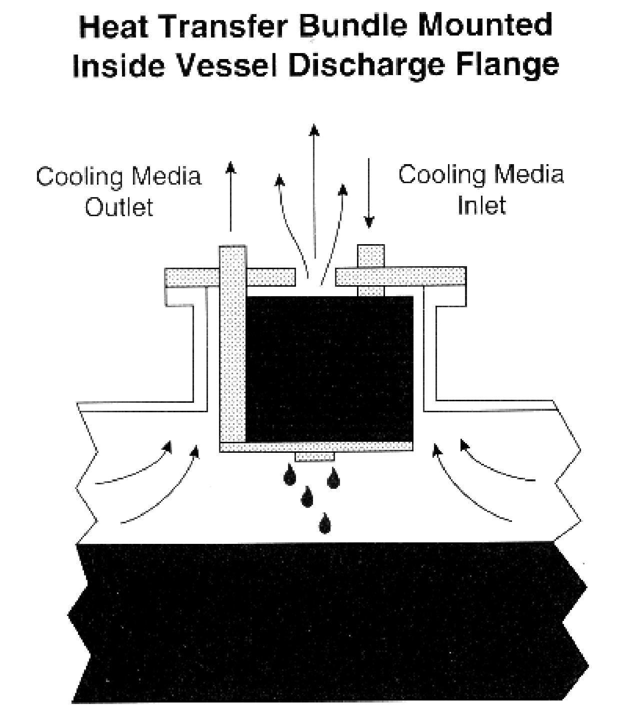


Fig. 3a

Condenser design with helical bundle mount inside vessel's discharge flange is typical of reflux-condensing applications. (Fig. 3a)

Analyzer Pre-cooling. Many components are processed as liquids at, or near, their boiling points. As the liquid passes through a measuring device there is a loss of pressure, which causes the liquid to flash or boil. Measurement devices lose accuracy when handling two-phase flow. Traditional volumetric or velocity measuring instruments introduce accuracy uncertainties when measuring a two-phase fluid. From the process viewpoint, this is a major problem.

Typical liquids, such as ammonia, carbon dioxide, sulfur dioxide, freon and ethylene are processed at their boiling point. Pre-cooling the liquid prior to an analyzer may be necessary to ensure that flashing does not occur and measurement accuracy is not compromised. Many plants install a compact helical heat exchanger in their measurement packages for the purpose of pre-cooling the saturated liquid prior to measuring. By pre-cooling prior to measuring, the resulting pressure drop across the measuring device does not result in flashing and two-phase flow.

Seal Coolers. Centrifugal pumps require cooling of their mechanical seals to ensure reasonable mechanical seal service life. The pump seal liquid absorbs heat generated at the mechanical seal to shaft contact surface, and this heat must be removed.

Compact helical heat exchangers have long been specified for this service, because they can efficiently reject heat absorbed the seal liquid and economically handle the often high operating pressures of a centrifugal pump. Also, the helical coil may be mounted so it operates as a thermosyphon and thereby complies with the stringent requirements of American Petroleum Institute (API) 682.

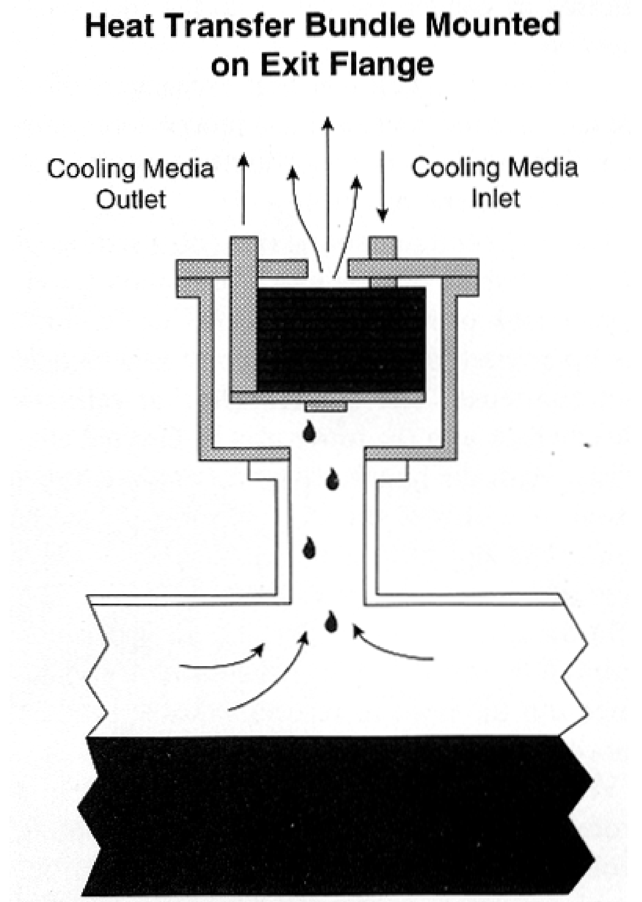


Fig. 3b

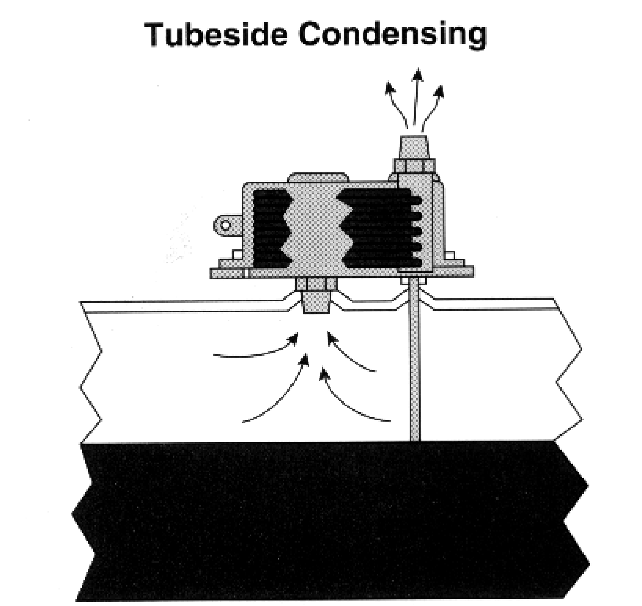
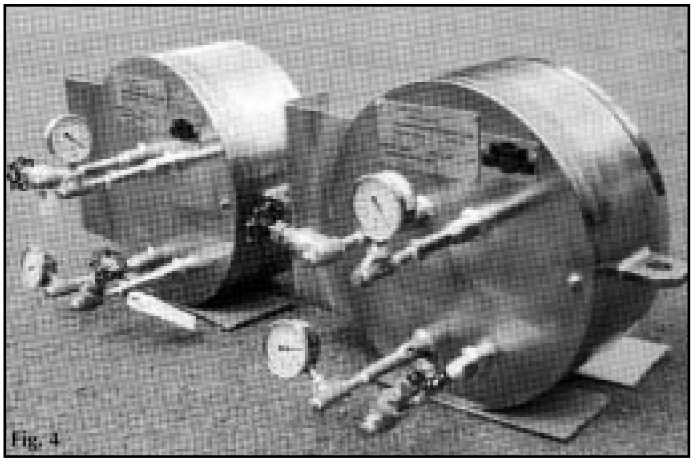


Fig. 3c

Condenser design mounted external to vessel is commonly used with vent-condensing applications.(Fig. 3b)

Condenser design with condensing on the tubeside is typical of corrosive services or when costly process contacted materials are necessary. (Fig. 3c)



Two welded units that are nitrogen-purged and blanketed for use in a computer-chip wash application. (Fig. 4)

Similarly, helical coil units are used as seal coolers for liquid vacuum pumps by removing the heat absorbed by the liquid ring – a result of heat generated by the pump itself – and the heat released by condensing vapors during their compression.

Condensers. Helical coil heat exchangers often are used as condensers within a process loop, such as reflux condensers or as discharge vent condensers at the end of a process.

The coil configuration allows for insertion of the tube bundle directly into a distillation tower, storage tank or reactor. This allows vapors flowing up a vessel to contact the cooled tube bundle and condense. The condensate that refluxes directly back into the tower may be directed elsewhere. With the bundle inserted directly into the vessel, not only is there a benefit from direct reflux, but also there is the elimination of overhead piping and support structures.

In the case of vent condensers, the application is driven by new Clean Air Act Amendment mandates and the need to recover valuable product not consumed in a process loop.

Vent condensers can control emissions from a process, reactor or storage tank by recovering product and reducing atmospheric emission. Coolants such as liquid nitrogen, chilled methanol, ethylene glycol or brine solutions often are used to provide a cooling media that is sufficiently cool to maximize reclamation of vapors. The coolant allows for greater recovery, of the product with minimal loss to the environment.

The coil geometry, with its constant change in flow direction, forces warm vapor to contact the cold tube wall. This results in vapor condensation and product recovery. The improved condensation efficiency coupled with 100% counter-current flow allows maximum recovery with minimum surface area.

Compressor Inter- and After-Coolers. Multi-stage gas-compression packages require intercoolers between compression stages as well as an after-cooler following final compression. These are rigorous duties for any heat exchanger. The compactness of a helical coil unit minimizes package size and layout. The ability to economically handle several thousand psi operating pressure at final compression is perhaps a helical coil's best attribute.

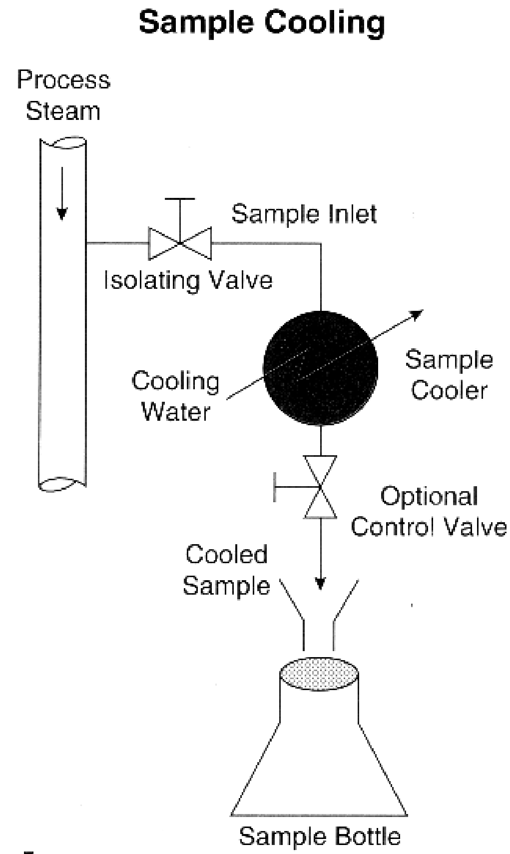


Fig. 5

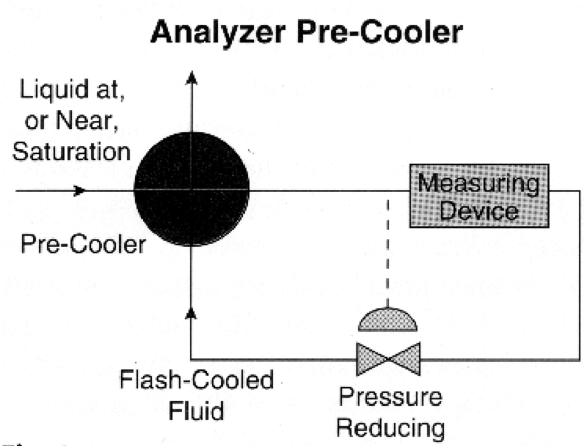


Fig. 6

Sample cooling arrangement with isolating valve is used to bleed a sample stream from main process line.(Fig. 5)

Liquid to be measured passes through a pressure-reducing valve where its pressure is reduced and then flash-cooled to a lower temperature. This acts as the cooling media for the analyzer pre-cooler. (Fig. 6)

General Applications. The applications discussed above are the more common applications for helical coil heat exchangers, but their use in industry is far greater and more diverse. Helical oil units commonly are used as interchangers, preheaters, steam condensers, vacuum system inter- and after-condensers, reboilers, batch heaters and/or coolers and reactor-jacket coolers.

Helical coil heat exchangers offer distinct advantages, such as improved thermal efficiency, compactness, easy maintenance and lower installed cost. When an application requires equipment suitable for high operating pressure and/or extreme temperature gradients, a helical coil unit should be considered. The exchangers also are suitable for less demanding applications, such as heat recovery, condensing, boiling and basic heat exchange.

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Worksheet for Heat Exchanger Design

	Tubeside Fluid	Casing-Side Fluid
Fluid Name		
Flow Rate, #/hr		
Inlet Temperature, °F		
Outlet Temperature, °F		
Specific Gravity		
Specific Heat, Btu/# °F		
Thermal Conductivity, Btu/hr ft °F		
Viscosity at two temperatures, cP		
Temperature_______ °F		
Temperature_______ °F		
Operating Pressure, psig		
Preferred Materials		
Design Pressure, psig		
Design Temperature, °F		
Design and/or construction codes:		
Special considerations or comments:		

Use this worksheet when you set out to design your heat exchanger. It contains the factors you must consider for a system that will meet your application's requirements.

Worksheet for Vent Condenser Design

Condensing on: Tubeside________________ Shellside________________

	Cooling Media		Vent Stream
Fluid Name		Composition	
Flow Rate, #/hr		Flow Rate, #/hr or SCFM	
Inlet Temperature, °F		Inlet Temperature, °F	
Outlet Temperature, °F		Outlet Temperature, °F	
Specific Gravity		Vapor Pressure @ ____ °F, psia	
Specific Heat, Btu/#°F		Vapor Pressure @ ____ °F, psia	
Thermal Conductivity, Btu/hr ft °F		Vapor Pressure @ ____ °F, psia	
Viscosity at two temperatures, cP		Vessel Discharge Connection	
Temperature_______ °F		Size, inches	
Temperature_______ °F		Latent Heat, Btu/#	
Operating Pressure, psig		Vessel Fill Rate, GPM	
Preferred Materials		Preferred Materials	
Design Pressure, psig		Design Pressure, psig	
Design Temperature, °F		Design Temperature, °F	
Design and/or construction codes:			
Special considerations or comments:			

Use this worksheet to design an accurate vent condenser. The details for each of the factors listed will help to ensure that you get the appropriate system.