Spiral Heat Exchangers Preheat High Solids Black Liquor Without Plugging

Superior heat transfer and condensing abilities find increased application in black liquor, turpentine, and tall oil recovery systems

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The manufacture of nearly all pulp and paper products relies on several heat transfer applications, ranging from the most simple to the most complex from heating, cooling, and condensing duties to heat recovery and energy conservation. An essential component of any heat transfer system is a reliable, easy-to-maintain heat exchanger.

The spiral heat exchanger (SHE) is particularly well suited to the heat transfer needs of a modern pulp and paper mill. The unit has typically been used in blow heat recovery systems and for heating and cooling of a number of caustic and acidic wash water, mill water, and whitewater. However, the spiral unit also has specific application in black liquor recovery boilers and the turpentine and tall oil recovery systems.

The highly fouling and scaling fluids found in pulp and paper mills often cause severe plugging and fouling in other types of heat transfer equipment. Such problems can lead to interruptions in a mill's operation, resulting in less efficiency and considerable cost. Spiral units can easily handle these fiber-laden solutions and high-viscosity liquors found in pulping and papermaking operations.

The spiral unit can sometimes be the best solution to heat transfer. However, because the initial unit cost of a spiral heat exchanger tends to be slightly higher than the shell-and-tube exchanger, many mills shy away from it. Mill experience has proven that cost reductions are possible using the spiral unit in pulp and paper production.

SPIRAL EXCHANGER VS OTHER UNITS. Initially used in blow heat recovery systems, the spiral unit proved to be more efficient and reliable than traditional shell-and-tube units. As efficiency needs increased, use of the spiral unit was expanded into areas of the mill where compact size, efficiency, and low maintenance were required.

The spiral exchanger, with a single flow channel and pure countercurrent flow, produces flow path with high shear rates and high turbulence. At fluid velocities that would normally be in laminar flow in other types of heat-transfer equipment, the SHE is in fully developed turbulent flow. The continuously curving flow channel produces an intense scrubbing effect that prevents fouling deposits from forming. The resulting overall heat transfer coefficient is 10% to 50% higher than in comparable shell-and-tube heat exchangers.

The single flow channel of the spiral heat exchanger eliminates leakage and bypassing streams common in shell-and-tube equipment (such as shell-to-baffle or tube-to-baffle leakage). The unit's single flow passage also eliminates flow plugging caused by mal-distribution and entrance/exit problems, which allows for easy handling of viscous materials. Since there are no sharp turns or corners in the flow channel, eddying and stagnant areas are reduced or eliminated. This has the added benefit of reducing potential problems commonly caused by erosion. The spiral's thicker gauge material minimizes possible erosion and corrosion effects.

The compact size of the spiral heat exchanger is an important factor when space in a mill is at a premium. A unit containing 2,400 ft2 of surface area can be enclosed in an area 5 ft X 7 ft. No additional space is required if covers must be opened. Installation of a shell-and-tube unit, on the other hand, must allow for removal of the tube bundle for cleaning and re-tubing. This process often requires 20 ft of space.

SPIRAL UNIT DESIGN The spiral heat exchanger can be designed in three basic configurations-Type 1, Type 2, and Type 3. Each unit has unique design criteria, which allow the basic spiral exchanger enough flexibility to be tailored for use in a number of heat transfer applications.

Type 1. The Type 1 exchanger is designed for spiral flow on each side. The fluids usually flow counter currently from each other, thus promoting increased turbulence, which results in higher heat transfer coefficients. This enables the Type 1 spiral exchanger to be used in areas that have fluids with high solids levels or fluids that foul or plug quickly.
Generally used for liquid-to-liquid services, the Type 1 unit can be used to heat and cool gases. It also can make a very effective condenser. When set up for condensing duties, the unit uses steam to heat water for various applications and the various digester, turpentine, and tall-oil condensing duties.

The Type 1 can provide a complete separation of the condensate/non-condensable so an external vapor/liquid separator is seldom required. The combination of the spiral flow on each side and through countercurrent flow allows the condensate and non-condensables to be cooled close to the cold side inlet temperature. This can help eliminate or reduce the need for after coolers. In addition, low vapor fraction boiling can also be accomplished in a Type 1 spiral unit.

Type 2. The Type 2 unit is configured to have one fluid in spiral flow with the other fluid in cross flow. The spiral flow channel is closed on each end, while the cross flow channel is open on each end. The basic spiral body is fitted with extended shells (extensions) on each end to provide vapor distribution/collection spaces. This design produces a unit that has a very large cross sectional area for flow on the cross flow side, along with a short flow path.

Thus, the Type 2 can be applied to areas with large volumes of vapor, gases, or liquids at very low operating pressures and with very low-pressure drops. Operating pressures on the level of 5- to l0 MM Hg, and pressure drops of ½ MM Hg and less, are very easily achieved in a Type 2.

The Type 2 unit is generally used in condensing duties. It is well suited for use as a digester relief gas condenser or turpentine condenser. These applications typically produce large volumes of vapor with large non-condensable loadings at atmospheric pressure or under slight vacuum. When the Type 2 is set up for liquid on the cross flow side, it results in a very effective and compact thermo siphon reboiler. The Type 2 can also be used in a liquid-to-liquid service when the flow rate on one side is much greater than the other.

Studies conducted by Heat Transfer Research Inc. show that for low pressure and vacuum boiling, the Type 2 spiral heat exchanger is often the best choice. In addition, its ability to handle large flow variations at minimal pressure drops makes the Type 2 well suited for heating and cooling large quantities of gases on the cross flow side.

Type 3. The Type 3 unit combines the advantages of the Type 2 unit with the ability to control the amount of sub cooling on the vapor cross flow side with spiral flow on the cold side. With the Type 3, the vapor enters the unit at the top and enters the body of the unit in cross flow. A cover fitted on the bottom end prevents the vapor/condensate from exiting the unit in cross flow as in a Type 2. The unit is set up to have the last turn or two at the periphery on the vapor side closed off on the top end, preventing the vapor from entering this section and forming a spiral flow channel.

Since the vapor (after the majority of the condensation process is complete and the vapor volume is greatly reduced) cannot leave the unit at the bottom end, the only way it can leave the unit is to enter the closed off section of the vapor channel and leave in spiral flow. This short section of spiral flow allows the sub cooling of the condensate to be carefully controlled to produce the desired condensate outlet temperature. By adjusting the length of this spiral flow section on the vapor side along with the condensate level, condensate sub cooling can be specified.

The Type 3 combines the advantages of both the Type 1 and Type 2 spiral heat exchangers in that it can be used in applications with large amounts of vapor at low operating pressures and pressure drops, with the added ability to control the amount of condensate sub cooling. In addition, where a Type 2 must have the spiral flow channel closed on each end, the Type 3 can be designed with the spiral flow channel open on the bottom for easy cleaning and inspection access. This produces a very efficient, compact unit for many condensing applications.

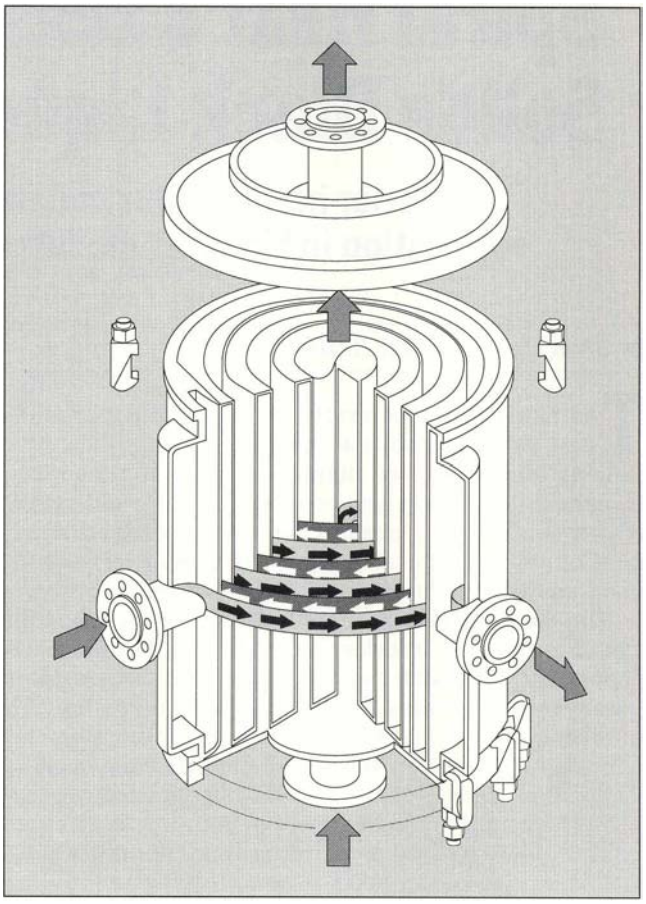
The Type 3 SHE is a most effective condenser for relief vapor and turpentine condensing applications. In addition, it is also extremely useful for heating water, green liquor, whitewater, and other cooling liquors and mill waters with steam or other condensing vapors.

A special modification of the Type 3 configuration, Type 3H, is horizontally mounted and allows the spiral flow channel to handle solids or fiber-laden fluids, and those that foul or plug readily, as in a Type 1 spiral. The vapor side is set up to produce a two-pass flow arrangement for use with steam. The Type 3H is ideally suited for heavier fluids, such as high-solids black liquors and other similar materials.

Improvements, in the form of larger units and higher working pressures, now allow the spiral heat exchanger to be used in areas not applicable 20 years ago. The ability to fabricate units from continuous coil has reduced the amount of internal welds. Computer-controlled forming and welding techniques have also contributed to increased quality.

Recent advances in material of fabrication are also constantly monitored. The requirements for more chloride-resistant materials of construction have brought new alloys, such as AL-6XN and 2205, which provide higher resistance to corrosive attack than the standard 300-series austenitic stainless steels, at a slightly higher cost.

***FIGURE* 1: A Type 1 spiral heat exchanger, used in black liquor recovery operation, has media in full countercurrent flow and may be mounted horizontally and vertically. With horizontal mounting arrangement, the turbulent action of the fluid maintains any solids in suspension.**



USE IN BLACK LIQUOR RECOVERY. Weak black liquor typically contains 15% to 20% solids. Using a series of multiple-effect evaporators, the liquor is concentrated to approximately 65% to 68%. A Type 1 spiral heat exchanger can easily be used for the solid-laden caustic liquor, using evaporator condensate to preheat the liquor feed to the next stage. The high solids level typically fouls or plugs traditional shell-and-tube units. Very high flow rates (using recycle loops) are needed to maintain velocities high enough to prevent fouling. This results in very large units and high pumping costs. The spiral heat exchanger does not require these recycle loops and can also reduce pumping costs.

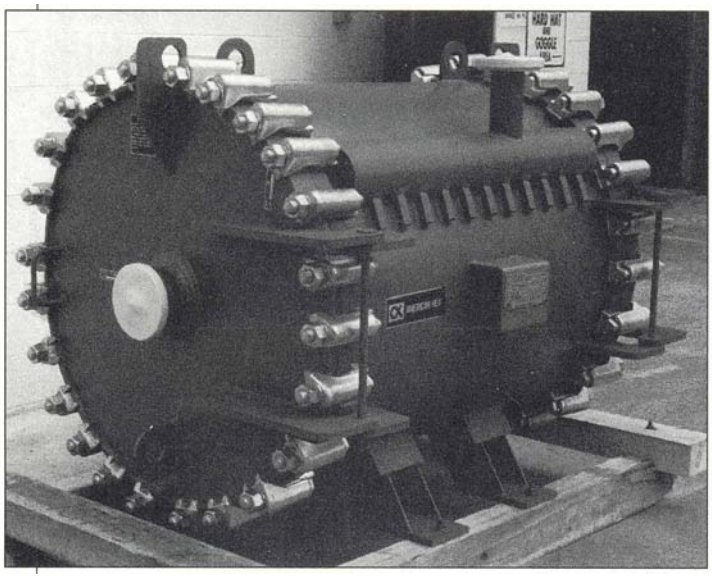
The water evaporated off the black liquor can be condensed in a Type 2 or Type 3 SHE. The vapor typically is under vacuum and requires minimal pressure drop to allow successful operation. The Type 2 or Type 3 can be used in this application due to their ability to handle large volumes of low-pressure vapor with minimal pressure drop. By using a Type 3 unit, sub cooling can be adjusted to maximize energy recovery from the overhead vapor.

Since the vapor can contain some fiber and other debris, the spiral heat exchanger offers the added benefit of being easy to clean. In addition, water spray nozzles can be built into the top of the unit to

allow cleaning in place by water flushing, eliminating the need to open the unit for cleaning.

Prior to firing the high-solids (65% to 68%) black liquor in the recovery boiler, it must be brought to proper temperature. Current technology uses direct steam injection into the liquor to heat it to this point. This, unfortunately, wastes steam as the condensate cannot be reused and dilutes the liquor. A Type 3H exchanger can handle the high-solids black liquor and indirect heating of the liquor. This removes the need for direct steam injection, resulting in improved efficiency in the recovery boiler and allowing the condensate to be recovered.

After firing in the recovery boiler, smelt collected at the bottom of the boiler is dissolved in a caustic solution to produce green liquor. The Type 3 SHE can be used for the heating requirements in the green liquor recovery area. After liming of the green liquor and subsequent filtration and separation, the white liquor is returned to the cooking chemicals storage tank for use in the digestion process. Heating or cooling of the white liquor can be easily done with a Type 1 spiral exchanger, and many units have been used for this application.



The compact size of the spiral heat exchanger means no additional space is necessary if covers must be opened for cleaning.

BLOW HEAT, TURPENTINE RECOVERY. The amount of energy recovered in the digestion area of the mill can be critical to the facility's operation. This area includes the blow heat system and the relief vapor and turpentine condensing systems.

The blow heat recovery system is designed to recover some of the large amounts of energy used in the digestion process. The Type 1 spiral heat exchanger is suited for fiber-laden condensate from the blow heat system.

Relief vapor and turpentine recovery systems typically produce large amounts of vapor containing non-condensables. A Type 2 or Type 3 SHE can be used to meet condensing and sub cooling requirements in these areas at minimal pressure drop. This reduces the need for large vacuum extraction units for the non-condensable gases. By optimizing the amount of sub cooling, additional

amounts of turpentine can be recovered from the vapor, increasing turpentine yields.

A Type 1 or Type 3 spiral can also be used in the tall oil recovery systems, which condense the tall oil after distillation. This is typically done under vacuum, and the ability of the spiral heat exchanger to handle vapor under vacuum with minimal pressure drop makes it suitable for such applications.

Recovery of cooking chemicals is also an extremely important part of the digestion process. These cooking liquors can contain fibers and chips of undigested wood stock and other solids. Heat recovery and temperature maintenance of these liquors are very important and require a heat exchanger that can handle fouling and plugging liquors. The Type 1 spiral exchanger can be used in this application due to its ability to operate over long periods of time without cleaning or other maintenance.

USE IN OTHER AREAS. Bleaching requires large quantities of water and produces waste streams that contain bits of the pulp stock. These streams are typically caustic in nature and can be extremely fouling. However, these waste streams can be used to provide large amounts of heat suitable for use in other parts of the mill. The heat exchanger for this area must be capable of handling these waste streams with a minimum of maintenance or downtime.

The spiral heat exchanger is particularly well suited in heat recovery applications using the waste caustic filtrate streams. Typically, these streams contain high percentages of fiber, which clog and plug traditional units. The Type 1 spiral heat exchanger is suitable for this application and can recover usable amounts of heat from otherwise wasted sources. By recovering heat from these waste streams, the environmental impact is drastically minimized and fuel use by the mill is optimized.

The spiral heat exchanger has also been used in heating stock prior to bleaching. Use of a Type 1 spiral heat exchanger can combine this operation with one of the previously described waste streams, resulting in a truly useful waste heat recovery application.

A new application for the spiral heat exchanger is heating the chlorine dioxide bleaching solution by using waste filtrate streams. Despite the requirement for titanium construction, the spiral heat exchanger can be an economical and low-maintenance piece of equipment for this application, again due to its ability to handle the fiber-rich waste filtrate stream.
Heating of re-circulating white water is also an area where a Type 1 unit can be used. The ability of the spiral heat exchanger to heat this fluid without frequent downtime for cleaning and maintenance is highly desirable for continued, efficient production. The Type 1 spiral heat exchanger has also been used to heat the incoming stock prior to entering the paper machine.