SHELL AND TUBE HEAT EXCHANGER DESIGN "PART A"

STEAM SHELL AND TUBE HEAT EXCHANGERS

The shell and tube heat exchanger (STHE) is the workhorse in the steam world, and it is used in many process steam applications. The design is very flexible to meet the strenuous requirements found in steam and condensate systems. Because of its flexibility, the STHE can be used to heat different process products, CIP systems, water, process fluids, etc. Simply stated, an STHE has two distinct parts: one is a circular vessel or shell, and the other is the tubes in the shell. Typically, steam is delivered to the shell side and transfers the energy from the steam to the process fluids in the tubes without direct contact or mixing the steam with the fluid.

The STHE brings a number of advantages to the steam world, such as the ability to handle different products, high steam pressures, and the high steam temperatures associated with the high steam pressures. Of course, there are always disadvantages too. Here, the primary disadvantage is that the initial cost of the STHE will be higher than the other heat transfer devices that can be used for the process applications. The other disadvantage of the STHE is its size; it is larger than other heat transfer designs, so it requires a greater allotment of installation space, and the allotted area must have enough space to permit removal of the tube bundle.

Certain items need to be taken into account when designing an STHE unit to ensure proper operation and to provide an efficient method to transfer the steam energy to the process fluid. Some applications require even more design consideration, such as when there can be no contamination of the product if a leak were to occur in the STHE unit into the steam side or vice versa.

DESIGNING AN STHE

Several organizations can be of assistance in designing the STHEs. Tubular Exchanger Manufacturer Association (TEMA) and American Petroleum Institute (API) Standard 660 are the most common standards used in the design of STHE units. All plants should select the design standards to follow and institute a program to ensure the standards are followed.

There are different TEMA letters for different services, such as the following:

- TEMA C: Standards for unfired units for moderate conditions
- TEMA B: Standards for unfired units for chemical process
- TEMA R: Standards for unfired units for severe conditions

STHEs do not have to be manufactured according to TEMA design or any other standards, but it is highly suggested for...
To ensure accurate test results, the plant should establish standard operating procedures (SOPs) the proper protocols for testing procedures, and all personnel should be trained on the test methods.

**THERMAL EXPANSION AND CONTRACTION**

Steam will be at a higher temperature (in the shell) during operation than the process fluid in the tubes; therefore, the STHE design must be able to accommodate the thermal expansion. When the process is in a shutdown mode, contraction will take place in the STHE. The unit’s design must be able to accommodate the thermal expansion and contraction. The easiest method of accommodating the thermal expansion and contraction is the U-tube design.

The Steam Tech Paper will review the different designs and explain how they can compensate for expansion and contraction.

**PROCESS FLUID**

There are different methods to distribute the process fluid into the tubes to ensure the highest energy transfer possible in the unit. The subject of process fluid distribution will be discussed in more detail in Part B of this Steam Tech series.

**U-TUBE DESIGN**

The simplest and most cost-effective unit is the U-tube design STHE. In a U-tube STHE, the tubes are bent in a “U” or hairpin shape, the tube firmly fastens to the tube sheet, and the rest of the tubes are allowed to freely move in a back and forth plane to compensate for the expansion and contraction. The advantage of this design is the lower cost in manufacturing the STHE unit. However, the applications of this design are limited to clean fluids that require no tube cleaning.

It is ideal for heating water, CIP, light fuel oils, and other low viscosity products that do not cause any tube fouling that would require tube cleaning. Tube cleaning can only
FLOATING HEAD DESIGN WITH STRAIGHT TUBES

The SHTE design incorporates a floating head that has an internal gasket to prevent leakage between the tube side and shell side.

One advantage of the floating head design SHTE unit is that its tubes can be used with products that do have a fouling factor that require mechanical cleaning.

The other major advantage is that the tube bundle can be replaced if it fails. Another advantage to a floating head design is the elimination of the need for a bellows expansion device to compensate for the expansion and contraction. If the bellows expansion joint fails, it can release high-pressure steam into the work area, thus presenting a safety risk. The floating head is allowed to move to compensate for the thermal expansion and contraction. The disadvantages are the limited number of passes that can be accomplished with this design (two maximum on the tubes) and the limits on the pressure and temperature ratings.

FLOATING HEAD SPLIT BACKING RING

The floating head split backing ring unit is bolted to the split backing ring. The tube bundle is allowed to move freely against the seal and compensate for the thermal expansion. These units are often used in the petroleum industry for moderate operating pressures and temperatures.

STRAIGHT FIX TUBE SHEET DESIGN

The fixed tube sheet SHTE unit incorporates the use of straight tubes firmly attached to tube sheets at both ends of the tubes. The tube sheet is welded to the shell, so it cannot be removed. A shell bellows-type expansion joint will compensate for the thermal expansion and contraction.

The main advantages of the straight tube SHTE design are that its cost is lower than the other straight tube designs, that its tubes can be mechanically cleaned, and that it has a lower shear factor for the process fluid.

The disadvantage of the design is that the tube bundle cannot be removed for repair. If the tube fails, the entire unit must be removed and replaced.

be accomplished by a chemical process, not mechanical cleaning.
There are other types of floating head STHEs: the outside lantern ring, split backing ring, and outside packed stuffing box type. All designs have their advantages and disadvantages, and each application needs to be analyzed so the correct STHE unit is selected for the process.

**SHTE INTERNAL COMPONENTS**

**Tube Baffles**

Typically, the steam flow is in the shell side of the unit, and there are methods in the shell that distribute steam to ensure even energy transfer throughout the unit.

Internally, the steam flow from the inlet nozzle to the outlet nozzle could be a laminar flow and reduce the efficiency of the STH, as shown in Figure 7. Internal tube supports can have some effect on the shell-side steam flow (distributing the flow pattern), but the main reason for the supports is to support the tubes in a bundle.

Therefore, the STH design incorporates internal baffles engineered to transform the laminar steam flow to a wiping steam flow path, as shown in Figure 8.

This wiping steam flow path around the tubes increases the steam flow velocity in the tube bundle, which results in a higher transfer coefficient.

**Cross-Contamination**

If the steam could get into the process fluid and cause a problem, or if the process product could get into the steam/condensate system and cause a problem, then a double tube sheet construction is used to eliminate this problem. The construction is a tube sheet with a second tube sheet installed inside the main tube sheet with a small distance between the tube sheets. Typically, a weep hole is installed between the tube sheets to allow indication of a tube failure.

The advantage of the double tube sheet construction is that no cross-contamination can occur. The disadvantages are that it drives up the cost of the STH unit and that the thermal conductivity can be reduced by the gap between the steam and the process fluid that is caused by the tube within a tube.

**Figure 5. Checking All Steam Components**

**Figure 6. Floating Head Outside Packed Stuffing Box**

**Figure 7. Laminar Flow: No Baffles**

**Figure 8. STH Internal Baffles**
The impingement plate diverts the steam flow around the tube area and allows the steam to decrease its velocity.

**CONCLUSION**

Always have all the required information for any application in a well-defined request for quotation. There are many choices in selecting an STHE, and each choice will have plusses and minuses. So long as the plant evaluates all parameters in the selection process, there will be a positive result.