



# Specification Tips to Maximize Heat Transfer

SHELL AND TUBE EXCHANGERS

# Choosing the right shell and tube heat exchanger for your application

Heat exchangers are widely used in various industries including chemical, oil & gas, power generation, food & beverage, HVAC & refrigeration, pulp & paper to name a few, and are expecting strong growth over the coming years driven in part by a rising focus on environmental impact and improving efficiency standards.

Although used for varied applications, a heat exchanger's primary role is to transfer heat from one fluid or gas to another in order to control the temperature of a system and manage waste heat. Growing environmental concerns and regulations are motivating energy-intensive industries to look at ways to improve heat exchanger performance and maximize energy efficiency use.

Choosing the right heat exchanger to fit the needs of specific applications and systems is critical in achieving optimal efficiency.

Operating conditions, ease of access for inspection and maintenance, and compatibility with process fluids are just some of the variables to be considered when assessing heat exchanger options. Other factors include:

- Maximum design pressure and temperature
- Heating or cooling applications
- Maintenance requirements
- Material compatibility with process fluids
- Gasket compatibility with process fluids
- Cleanliness of the streams
- Temperature approach

A properly selected, installed, and maintained heat exchanger can help enhance the reliability and efficiency of a fluid system by optimizing energy consumption and reducing associated operating costs.

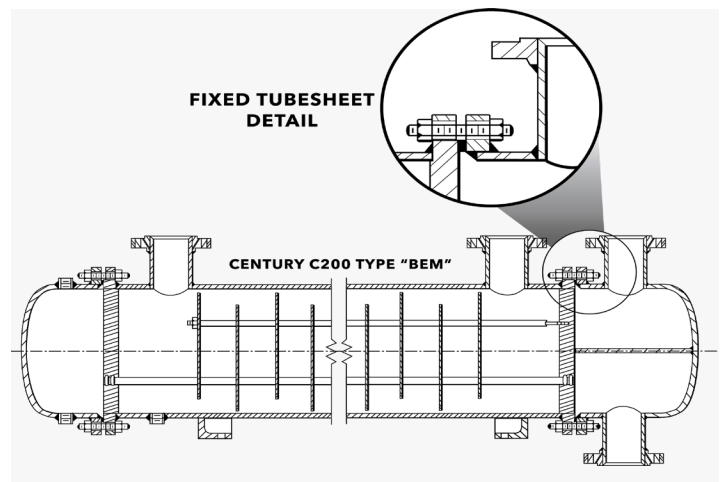
In this whitepaper we look at the specification tips to maximize heat transfer in shell and tube style heat exchangers in order to boost heat exchanger performance and increase efficiency.

## Shell and tube exchangers

The shell and tube exchanger's flexible design, high pressure and temperature capabilities, and its ability to handle high levels of particulate material make it the most common heat exchanger used. Mechanically simple in design and a proven technology, the shell and tube offers a low-cost method of heat exchange for many process operations. Following is a brief description of each of the most common shell and tube configurations:

### Straight tube, fixed tubesheet exchangers

The fixed tubesheet exchanger is the most common, and typically has the lowest capital cost per square foot of heat-transfer surface area. Fixed tubesheet exchangers consist of a series of straight tubes sealed between flat, perforated metal tubesheets (Figure 1).



**Figure 1.** Fixed tubesheet exchanger

*In a fixed tubesheet exchanger, straight runs of tubing are attached to two perforated tubesheets. The design has no shellside gasket or packed joints. This minimizes the potential for leakage, and makes this exchanger ideal for high-pressure operations, or those handling potentially lethal fluids.*

Because there are no packed or gasketed joints on the shellside, potential leak points are eliminated, making the design suitable for higher pressure or potentially lethal service. However, because the tube bundle cannot be removed, the shellside of the exchanger (outside the tubes) can only be cleaned by chemical means. The inside surfaces of the individual tubes can be cleaned mechanically, after the channel covers have

been removed. The fixed tubesheet exchanger is limited to applications where the shellside fluid is non-fouling; fouling fluids must be routed through the tubes.

In line with the Tubular Exchanger Manufacturers Association (TEMA) heat exchanger standards and nomenclature, shell and tube heat exchanger types have a three-letter designation which refers to the specific type of stationary head at the front end, the shell type, and the rear-end head type, respectively.

Common TEMA designations for the straight tube, fixed tubesheet exchangers are BEM, AEM, NEN. Common applications include:

- Vapor condensers
- Liquid-liquid exchangers
- Reboilers
- Gas coolers

### Removable bundle, externally sealed, floating head exchanger

Floating head exchangers are so named because they have one tubesheet that is fixed relative to the shell, and another that is attached to the tubes, but not to the shell, so it is allowed to “float” within the shell. Unlike fixed tubesheet designs, whose dimensions are fixed at a given dimension relative to the shell wall, floating head exchangers are able to compensate for differential expansion and contraction between the shell and the tubes.

Since the entire tube bundle can be removed, maintenance is easy and inexpensive. The shellside surface can be cleaned by either steam or mechanical means. In addition to accommodating differential expansion between the shell and tubes, the floating tubesheet keeps shellside and tubeside process fluids from intermixing.

Although the externally sealed, floating head design is less costly than the full, internal floating head exchanger, it has some design limitations due to it being a serviceable joint exposed to the atmosphere: both shellside and tubeside fluids must be non-volatile or non-toxic, and the tubeside arrangements are limited to

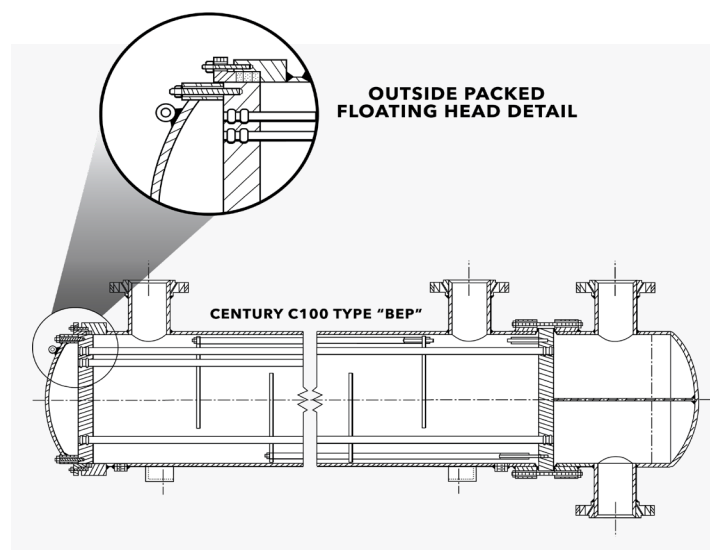
one or two passes. In addition, the packing used in this exchanger limits design pressure and temperature to 300 psig and 300°F.

Common TEMA designations are AEW and BEW. Applications include exchangers handling:

- Inter-and after-coolers
- Oil coolers
- Jacket water coolers

### Removable bundle, outside packed, floating head exchanger

This design is especially suited for applications where corrosive liquids, gases or vapors are circulated through the tubes, and for air, gases or vapors in the shell. Its design also allows for easy inspection, cleaning and tube replacement, and provides large bundle entrance areas without the need for domes or vapor belts (Figure 2).



**Figure 2.** Removable bundle exchanger

*In a removable bundle, outside packed floating head exchanger, straight runs of pipe are attached to one fixed (or stationary) head, and one floating head, which allows the entire assembly to be removed for cleaning and repair. Also, the floating head accommodates differential thermal expansion during operation.*

Unlike the previous design, only shellside fluids are exposed to packing, allowing high pressure, volatile or toxic fluids to be used inside the tubes. The packing in the head does, however, limit design pressure and temperatures.

Common TEMA designations are BEP and AEP.

Typical applications include:

- Oxygen coolers
- Volatile or toxic fluids
- Gas processing

### Removable bundle, internal clamp ring, floating head exchanger

This design is useful for applications where high-fouling fluids require frequent inspection and cleaning. And, because the exchanger allows for differential thermal expansion between the shell and tubes, it readily accommodates large temperature differentials between the shellside and the tubeside fluids.

This design has added versatility since multi-pass arrangements are possible. However, since the shell cover, clamp ring and floating head cover must be removed before the tube bundle can be removed, service and maintenance costs are higher than in "pull through" designs (discussed below).

Common TEMA designations are AES and BES.

Typical applications include:

- Process plant condensers
- Inter-and after-cooler designs
- Gas coolers and heaters
- General purpose industrial heat exchangers

### Removable bundle, pull-through, floating head exchangers

In the pull-through, floating head design, the floating head cover is bolted directly to the floating tubesheet. This allows the bundle to be removed from the shell without removing the shell or floating head covers, which eases inspection and maintenance.

This is ideal for applications that require frequent cleaning. However, it is among the most expensive designs. And, the pull-through design accommodates a smaller number of tubes in a given shell diameter, so it offers less surface area than other removable bundle exchangers.

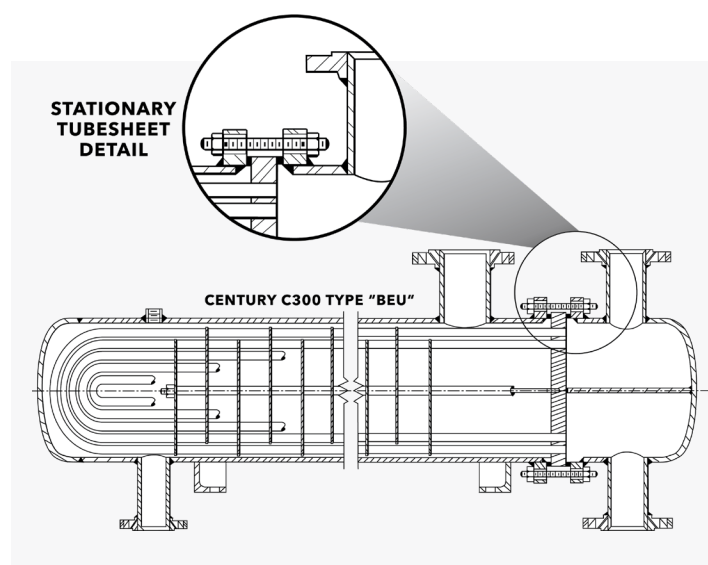
Common TEMA designations are AET and BET, and

typical applications include:

- Exchangers handling chemical fluids
- Hydrocarbon fluid condensers
- Air or gas compressors
- Inter-and after-coolers

### Removable bundle, U-tube exchangers

In the U-tube exchanger, a bundle of nested tubes, each bent in a series of concentricly tighter U-shapes, is attached to a single tubesheet (Figure 3). Each tube is free to move relative to the shell, and relative to one another, so the design is ideal for situations that accommodate large differential temperatures between the shellside and the tubeside fluids during service. Such flexibility makes the U-tube exchanger ideal for applications that are prone to thermal shock or intermittent service.



**Figure 3.** Removable bundle U-tube exchanger

*Removable bundle U-tube exchangers have only one tubesheet, which allows for maximum differential expansion between the shell and the tubes during operation.*

As with other removable bundle exchangers, the U-tube bundle can be withdrawn to provide access to the inside of the shell, and to the outside of the tubes. However, unlike the straight tube exchanger, whose tube internals can be mechanically cleaned, there is no way to physically access the U-bend region inside each tube, so chemical methods are required for tubeside



maintenance. As a rule of thumb, non-fouling fluids should be routed through the tubes, while fouling fluids should be reserved for shellside duty.

This inexpensive exchanger allows for multi-tube pass arrangements. However, because the U-tube cannot be made single pass on the tubeside, true countercurrent flow is not possible.

Common TEMA designations are BEU and AEU, and typical applications include:

- Oil cooling
- Chemical condensing
- Steam heating

## Special designs

For applications with high vapor flow and high pressure conditions, a specially designed shell and tube exchanger is often the only viable solution. Special designs may also be called for when applications have temperature crossing, meaning the outlet temperature of the warmed fluid exceeds that of the cooled fluid.

Following are several examples:

- TEMA K-type shells, which allow for proper liquid disengagement for reboilers
- TEAM J-type shells, which accommodate high vapor flows by allowing for divided flow in the shellside
- Two-pass TEMA F-type shells, which can be used for applications when a temperature cross exists
- TEMA D-type front head designs, which are often the answer for high-pressure tubeside applications

While these specially designed exchangers may be the solution to a process problem, construction costs tend to be higher than those of "standard" engineered shell-and-tube equipment.

Common TEMA designations include BKU, BJM, BFM and DED. Specially designed exchangers are often called for in:

- Reboilers
- Steam heaters
- Vapor condensers
- Feedwater heaters

## Choosing pre-engineered shell and tube exchangers

Fixed tubesheet and U-tube shell and tube exchangers are the most common types of pre-engineered heat exchangers available today. Such models are often used as components in vapor condensers, liquid-liquid exchangers, reboilers and gas coolers for smaller capacity applications such as pilot plants.

Standard fixed tubesheet units, the most common pre-engineered shell-and-tube heat exchangers, range in size from 2 to 8 inches in diameter. Materials of construction include brass or copper, carbon steel, and stainless steel. Even though this exchanger is one of the least expensive available, it is still generally constructed to standards specified by the manufacturer and not to TEMA specifications. If the user desires, pre-engineered exchangers can be constructed to American Society of Mechanical Engineers (ASME) codes.

U-tube heat exchangers are commonly used in steam heating applications, or heating and cooling applications that handle chemical fluids as opposed to water. While the U-tube is generally the lowest-priced heat exchanger available, service and maintenance costs tend to be higher than other exchangers since the nested, U-bend design makes individual tube replacement difficult.

Custom-designed heat exchangers, though more expensive than the pre-engineered counterparts, are generally made to higher design standards than pre-engineered exchangers. Many manufacturers follow the TEMA standards for design, and fabrication following the TEMA industry classifications:

- TEMA B is the most common TEMA designation, and provides design specifications for exchangers used in chemical process service
- TEMA C guidelines provide specifications for units used in commercial and general process applications
- TEMA R guidelines provide specifications for exchangers used in petroleum refining and related process operations

Each of these classes are applicable to shell and tube heat exchangers with the following limitations:

- Shell diameter does not exceed 100 inches
- Pressure does not exceed 3,000 psi
- The product of shell diameter (in.) times pressure (psi) does not exceed 100,000

Standards set by the American Petroleum Institute (API) are also generally accepted throughout the heat exchanger industry.

While there are obvious advantages to purchasing a custom-designed exchanger that meets either TEMA or API manufacturing guidelines, these specifications add to the cost of the exchanger and may have a longer manufacturing cycle.

There are a multitude of shell and tube heat exchanger options available; these guidelines should provide a basis for comparison to help you choose the correct design for your specific application. No matter what configuration is ultimately implemented, the emphasis on clean, efficient heat recovery ensures that the heat exchanger will remain one of the most critical components in the manufacturing process.

## About Standard Xchange

Standard Xchange has been developing heat transfer solutions for more than 100 years. Our top-notch technical expertise ensures our products run efficiently and perform well. It also means you're assured of technical guidance throughout the process of evaluating, selecting, and installing the right heat exchanger. Our experts can help you define your needs, determine specifications, and answer questions; and they can even provide precise technical drawings and mechanical details, if needed.

With our in-house, state-of-the-art lab, we can test equipment to your precise application before anything is shipped to you. In short, we'll work with you every step of the way to make sure you get the exact solution you need for your heat transfer problems.

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