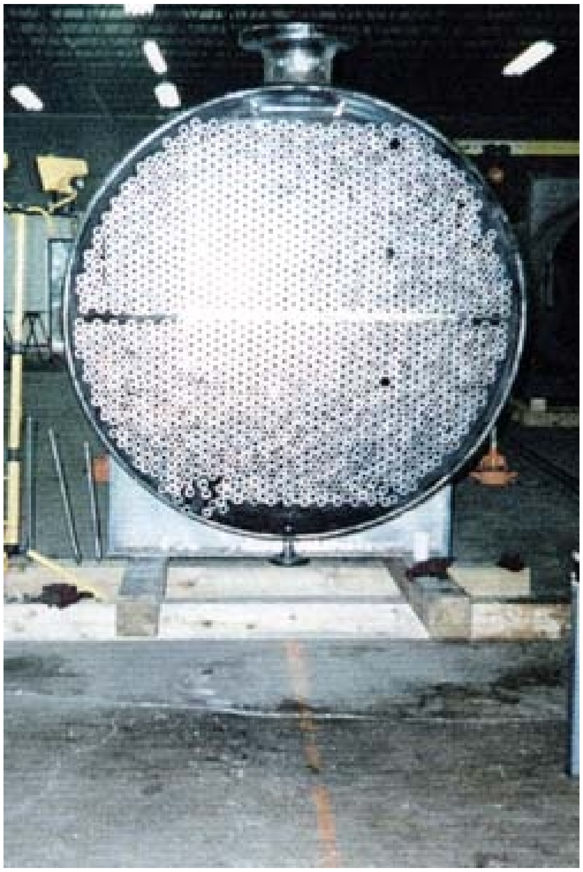
CMS
*engineered **heat transfer** solutions*
www.cmsheattransfer.com

CMS Heat Transfer Division, Inc.
Email: info@CMSHeatTransfer.com
Tel: 631.968.0084 Fax: 631.968.0184
273 Knickerbocker Avenue, Bohemia, NY 11716

Design and Selection

Pass Arrangements for Flow Through Tubes

The simplest flow pattern through the tubes is for the fluid to enter at one end and exit at the other, this is a single pass bundle. This configuration is required when a temperature cross is experienced in the process. However, conditions generally do not make a single pass on the tube side a preferred choice.



Increasing flow velocity and turbulence prevent formation of stagnant films of fluid on the tube surfaces. Thus, higher velocities improve the heat transfer rate. This means increasing the number of tube side passes - that is, directing the flow back and forth through the tubes in the bundle with partitions built into the heads of the exchanger.

There are some limitations on how the different types of heat exchangers can be partitioned to provide various numbers of passes.

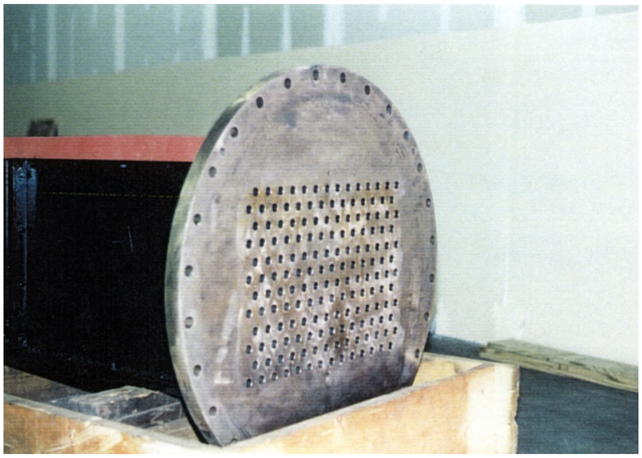
With the "U"-tube exchanger, a single pass is not possible because the fluid must traverse the bundle at least twice. Any practical even number of the passes can be obtained by building partition plates in the front head.

With the floating head pull-through bundle type, any practical even number of passes is possible. For single pass operation, however, a packed joint must be installed on the floating head.

The fixed tubesheet type can be used for any practical number of passes, odd or even. For multi-pass arrangements, partitions are built into both heads.

Shell Side Fluid Flow

Tube supports
The tubes in heat exchangers are somewhat flexible since they are long and relatively thin-walled. Consequently they must have supports at intervals in the shell to prevent sagging and minimize vibration.



Tube supports impart some directional effect to shell side flow but are primarily used to support the tubes in a bundle.

Baffles
Baffles are used to modify shell side flow conditions so that an optimum coefficient of heat transfer can be achieved.

Without baffles, fluid would enter at one end of the shell, distribute itself across the tube bundle, and flow slowly, generally parallel to the tubes, to the outlet end.

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Heat Exchanger Designs and Selections

Shell and Tube Heat Exchangers are simple devices with no moving parts which function on the principal that heat is exchanged between one fluid or vapor flowing through the tubes and another fluid or vapor flowing in the space around the tubes within the shell.

There are four basic considerations in choosing a mechanical arrangement that provides for efficient heat transfer between the two fluids or vapors, while taking care of such practical matters as preventing leakage from one into the other.

These are:
• Consideration for differential thermal expansion of tube and shell
• Means of directing fluid through the tubes
• Methods of controlling fluid flow through the shell
• Consideration for ease of maintenance and servicing

Various types of heat exchangers have been developed with different approaches to these fundamental design factors. The following will show how the three principal types of heat exchangers meet these design basics.

Differential Thermal Expansion

Since fluid in the shell is at a different temperature than the fluid in the tubes, there are corresponding differences in expansion of shell and tubes. Some provision must be made in design to compensate for this difference in thermal expansion.

"U"-Tube Design
In the "U" -tube exchanger, the shape of the tubes takes care of differential expansion. As the name implies, the tubes have a "hairpin" shape, with both ends of the tube fastened to one tubesheet. This "U" bend design allows each tube to expand and contract independently.

Floating Head Designs
This type meets the expansion problem by having one stationary tubesheet, and one free to move - "float" - back and forth as the tubes expand and contract under the influence of temperature changes.

Fixed Tubesheet Design
The fixed tubesheet heat exchanger employs straight tubes secured at both ends into tubesheets, which are welded to the shell. When a thermal expansion problem exists, an expansion joint is incorporated in the shell. This permits the shell to expand and contract.

When the possibility of intermixing of the shell side and tube side fluids cannot be tolerated, double tubesheet construction will offer positive assurance against one fluid leaking into the other at a tube to tubesheet joint. A second tubesheet is installed with a small space between tubesheets - usually open to the atmosphere.

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Impingement Plates (based on application)

When the impact factor exceeds the TEMA (Tubular Exchanger Manufacturers Association) limits and when corrosive, erosive, or two-phase fluids enter the bundle, impingement protection is recommended. Most frequently used for impact protection is the impingement plate (impact plate).

Maintenance and Servicing Considerations

Tubesheet arrangements are designed so as to include as many tubes as possible within the shell for maximum heat transfer surface. Sometimes a layout must be selected which also permits access to the tubes for cleaning as required by process conditions.

Principal Components

The main components of a heat exchanger are the front head, shell section and rear head. Each component is available in a number of varying standard designs.

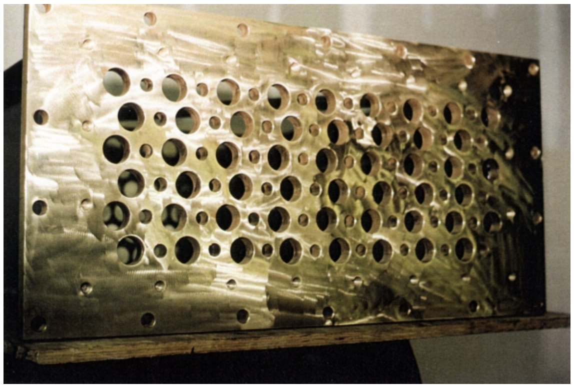
Front and Rear Head Designs
Head designs can vary from plain standard castings to fabricated assemblies with many special features. In many cases, the requirements of an installation may dictate the choice of the more elaborate design.

Shell Section Designs
Heat exchanger shells are manufactured in most standard sizes, materials, and thickness. Small sizes are usually fabricated of standard size pipe. Larger sizes are fabricated of plate.

Selection of a particular size shell depends, of course, on the requirements of a given installation.

Heat Exchanger Tubes

Tubing used for heat exchanger service may be either welded or seamless. The welded tube is rolled into cylindrical shape from strip material and welded automatically under precisely controlled manufacturing conditions.



A seamless tube may be extruded or hot pierced and drawn. Both are high quality products. Copper alloys are available only as seamless products, whereas most commercial metals are offered in both welded and seamless.

Tube size is specified by outside diameter and wall thickness. Almost all heat exchanger tubes range between a 3/8 inch and a 2 inch outside diameter. Most popular are the 5/8-inch and 3/4 inch sizes. These sizes give best all-around performance and are most economical in many applications.

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Materials of Construction

The materials of construction used in heat exchangers depend on the fluids or vapor being handled, process conditions, such as pressures, temperatures, etc., and a balance of initial cost against expected life and maintenance requirements.

Any component or the entire unit can be made of materials such as carbon steel, stainless steel, copper alloys, nickel, nickel alloys or other special alloys.

Selection of materials involves careful evaluation of factors other than the basic cost of possible metals compatible with the application.

Economic Considerations in Heat Exchanger Selection

At the flow diagram stage there are usually many variables, such as temperatures, pressures, flow rates and the like, which can be changed within limits. Later on, these factors become set as fixed quantities. It is well to recognize during the design of the system that they do have an influence on the size and cost of heat exchange equipment.

•Temperatures of heating and cooling media
A higher heating media temperature results in a smaller heat exchanger for a given heating load. Limitations of materials must be kept in mind here.

•Pressure drops permitted by the system affect heat exchanger size
The highest allowable pressure drop will result in substantial savings in heat exchanger size.

•Length restriction sometimes affect heat exchanger costs
However, there are so many exceptions and limiting conditions that we cannot simply say ‘‘the longer the cheaper.”

•Materials of construction
Corrosive tendencies and purity requirements of fluids being handled. Often, the choice here is based on reliable data and experience.

Heat Exchanger Rating Versus Expected Loads

A well designed shell and tube heat exchanger will handle its rated load under the conditions for which it was specified.

Emergencies occur in some processes, and it may be advantageous to have some extra margin of heat exchanger capacity to take care of them. The cost of such a safety factor can be modest compared to the protection it will afford to valuable material in process or to other expensive equipment in the system.

Fouling affects capacity, and this factor sometimes accounts for a certain amount of confusion when ratings are compared.

There is no economy in assuming an optimistically low fouling factor even if it seems to make a smaller heat exchanger feasible. Later on, difficulties with reduced capacity; low process yields frequent shutdown for cleaning and extra maintenance can dissipate this saving very quickly.

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Fundamental Heat Transfer

Complicated calculations are required in heat exchanger design and application. Some of them involve elaborate theoretical work, some entail multitudes of separate computations.

Most of the thermal and mechanical calculations are beyond the scope of this site.

However, a few of the basic formulas and mathematical concepts are quite useful, They provide a good working grasp of the heat exchanger application problem. Also, their understanding has proved most helpful to people whose specialties lie in other fields, but who have occasions to participate in the selection and procurement of heat exchanger equipment.

For those reasons, the fundamental mathematical expressions are outlined here. Terms are defined in an informal way, and their significance is discussed briefly. If your work requires a more complete discussion of this topic, we recommend that you refer to textbooks on heat transfer - or contact CMS directly.

Load is the Measure of Heat Transferred

Most heat exchanger studies begin with a given flow rate and temperature change. A certain amount of heat must be taken out of a flow of material or put into it per unit of time. This is the load.

Using common terms, we measure heat in BTU or British Thermal Units, and we express heat transfer rate on an hourly basis. Then, load - termed q in the following equations - is expressed in BTU/hr.

In heat exchanger design two flows of materials are involved - one in the tubes and one on the shell side surrounding the tubes - we assume that all the heat given up by one material goes into the other material. It does not matter which flow of material we use to measure load if that assumption is made.

If either fluid vaporizes or is condensed from a vapor in the heat exchanging operation, then temperature differences alone do not account for the load. A large amount of heat - usually the greatest part of it - will be latent heat used or given up during this change of state.

A Combination of Three Factors Governs Load Capacity

How large a heat exchanger must be to handle a given load depends on the following:
•Over-all heat transfer coefficient
•Temperature difference between the two fluids or vapor

The surface of a heat exchanger is its total heat transfer area. Load capacity will be proportioned to this area, but the other two factors can vary so widely that it is most helpful to consider the combination of all factors together.

q = U MTD A

Where:

q = load, BTU/hr.

U = design over-all heat transfer coefficient, BTU/hr./sq. ft./ºF

MTD = mean temperature difference between hot and cold fluids, degrees F

A = effective outside area of tubes, square feet

This relationship can be expressed also in words, and the equation is then stated: The rate that heat is transferred in a shell and tube heat exchanger is the product of three factors: (1) over-all heat transfer coefficient, (2) corrected mean temperature difference between the hot and cold fluids, (3) effective outside area of tubes and other heating surfaces.

To represent a practical application situation, the equation should be transposed so that A stands alone:

A = q / U MTD

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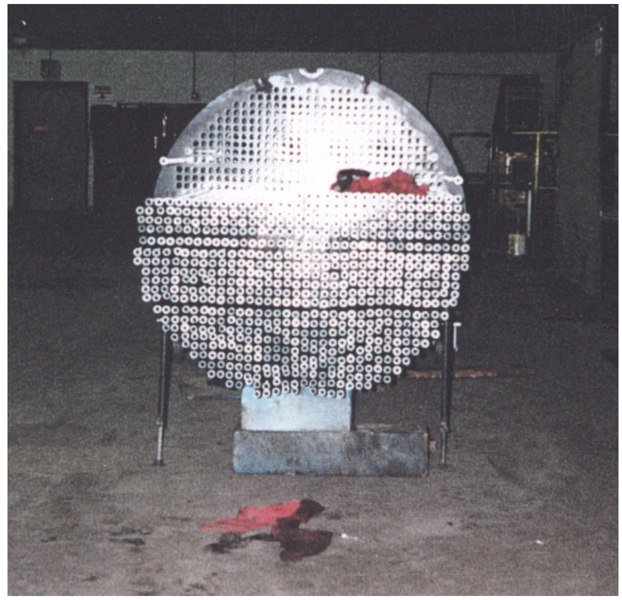
Heat Transfer Coefficient (U) Depends on Many Variables

The over-all heat transfer coefficient is a measure of performance. It evaluates the ability of the tube in a given mechanical arrangement to transmit heat from one fluid to another.

A clearer concept of heat transfer can be gained by considering the reciprocal of heat transfer coefficient, which we may term heat flow resistance. The advantage of this mathematical inversion lies in the fact that over-all resistance is the simple sum of five individual resistances. These are the resistance to the flow of heat through the tube side fluid, tube side scale, tube metal, shell side scale and shell side fluid.

Usually the smallest individual resistance to heat transfer is that of the metal tube wall itself.

How the various heat flow resistances affect U, the heat transfer coefficient, can be shown in the equation:



Where:

= resistance to flow of heat through the tube side fluid film

= resistance to flow of heat through scale deposits inside the tube -Fouling resistance

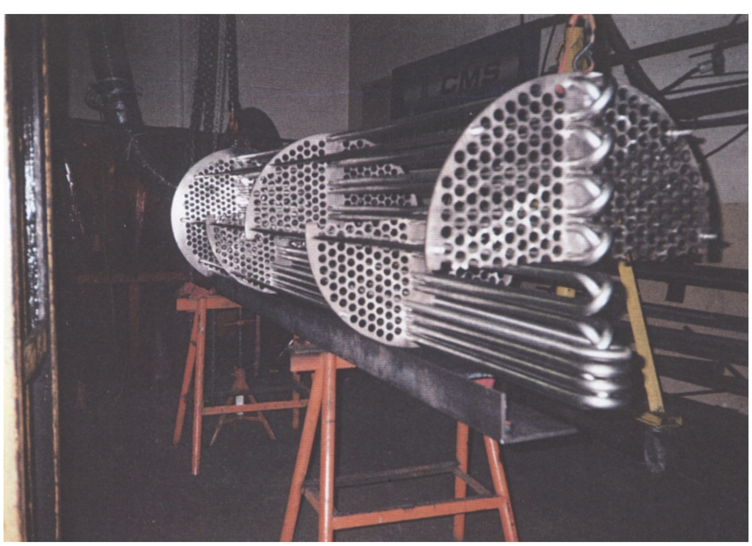
= resistance to flow of heat through metal tube wall

= resistance to flow of heat through scale deposits outside the tube -fouling resistance

= resistance to flow of heat through shell side fluid film

Area is the Total Effective Tube Area

The end result of choosing the most advantageous combination of all factors is the most economical value for A, the effective tube surface area. This area gives an answer to the question: “How big a unit must we provide in order to meet our requirement?”



The effective tube area is that portion within the shell exposed to the shell side fluid.

It is common practice to figure the area in square feet using the outside diameter of the tubing instead of an inside or mean diameter. This is merely for convenience, because the area per foot of a given O.D. tube is the same for all wall thickness.

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At CMS Industries we'll put our years of heat transfer "know-how" to work for you. In addition to sizing a shell & tube heat exchanger for your specific heat transfer needs, our engineers incorporate measures to insure ease of maintenance and longer equipment life - this equates to both smaller initial capital and maintenance costs over the years.

Code conformance and certification

Our products are engineered to meet rigid standards, and quality is always the first priority. Units can be provided in accordance with ASME Sect. VIII, Sect. V and Sect. IX of the Boiler and Pressure Vessel Code, TEMA, API, HEI, and 3A standards. In addition, our designs can incorporate all of your specifications to insure compliance with your plant standards.

Engineering support

It is our engineering department's primary goal to provide the best technical support required to solve your heat transfer problems. With the aid of state-of-the-art integrated software our engineers can rate and size the appropriate equipment for your application.

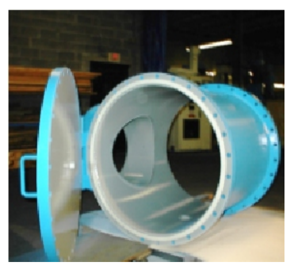
Mechanical design

Our products can be fabricated in a variety of materials including cupro-nickel, carbon and stainless steels and nickel alloys. Correct material selection will insure long life of the exchanger even in the most corrosive services. In addition, our engineers will incorporate the appropriate configuration in the design of your unit to insure ease of maintenance and the ability to withstand the most vigorous thermal and mechanical demands.

Process design

At CMS we have the expertise to solve all of your process heat transfer needs. With the use of state-of-the-art software, we can size and rate a shell and tube heat exchanger to your exact specifications. Single and two-phase-flows, liquid-to-liquid, single and multiple condensable in the presence of or absence of non-condensables, no process is too complex. Our engineers will provide the technical support to insure a proper design. It's like having a process engineer on staff.

Service beyond the expected



Experienced in all phases of heat exchange technologies

Shell and Tube Heat Exchangers

- Oil Coolers
- Fuel Oil Pre-Heaters
- Aftercoolers
- Steam Converters
- Condensers
- Kettles
- Thermo-Syphon Reboilers
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For "Old Reliable"

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