

Heat Transfer effect of shell-side flow in a shell-and-tube type heat exchanger

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Abstract:

There are arrays of heat exchangers that suit any industrial or domestic need. When determining your needs for a new design, consider the production cost relative to installation, weight, and dimensions. Heat exchangers have many functional uses in objects such as power transmission systems and refrigeration units. The design of heat exchangers itself is a complicated problem. It is more than just a heat transfer analysis. Production and installation costs, weight and dimensions play a significant role in the selection of the final project from the point of view of the total cost of ownership. While cost is an important consideration, in many cases size and footprint are often the dominant factors when choosing a design. Heat exchangers are primarily in the chemical industry, and are essential for energy saving. They provide cryogenic process equipment to liquefy natural gas, light hydrocarbons at extreme low temperatures before doing distillation columns separation. Heat exchangers are devices that transfer heat between various fluids, like H Liquids, gases or vapors (depending on the type used), with different temperatures. Oftentimes, based on architecture, this process can be gas-gas, liquid-gas or liquid-liquid and take place via sorption technology. Other features include building materials and components to help classify types of exchangers available - so they can be used in an organized manner in respected industries. A diverse selection of these heat exchange devices are used in a variety of industries and are designed and manufactured for use in the heating and cooling processes. Designing a heat exchanger can be a time consuming and challenging task. However, to do it well, it is important to understand three modes of transfers: convection, radiation and conduction. First, let us start by learning about how these work so as to design an effective heat exchanger.

1. Introduction

Double-tube heat exchangers allow for temperature changes of up to 50 degrees and help maintain safe operating temperatures in sensitive processes (oil cooling). Nusselt's 3 equations were tested in double-finned tube heat exchangers inside ships with dirty fins. The study revealed that the final model used the open channels which were not plugged. Various proposed Nusselt numerical equations were used in thermal design, and the results of these equations were presented in tables and figures. Consequently, it is considered that the use of encrusted double finned tube heat exchangers as oil coolers in ships is the most suitable choice.

Double Tube Heat Exchangers are made up of concentric tubes with one fluid flowing through the tube side and another through the ring side. They are available in different materials, to withstand high pressure and temperatures. A typical double pipe heat exchanger is illustrated in Fig. Double tube heat exchangers can be arranged in series and parallel configurations to suit the pressure drop. Meanwhile, double tube heat exchangers are used around the globe for delicate processes such as heating and cooling, and their small surface area is an excellent candidate for handling high pressure liquids'. The downside to using these machines is that they are bulky and expensive. Designing a heat exchanger can be a time consuming and challenging task. However, to do it well, it is important to understand three modes of transfers: convection, radiation and conduction. First, let us start by learning about how these work so as to design an effective heat exchanger.



Figure 1 Double pipe heat exchangers

A double tube heat exchanger is designed to interact with both liquid and gases. These can operate in severe fouling conditions, making them easy to clean and maintain without changing the performance of the device. A heat exchanger is a mechanism that when in 2 flows touch each other to transfer thermal energy. In order to have a basic understanding of these devices, read our article [Understanding Heat Exchangers](#) before continuing. We explore the principles behind these mechanical designs, going into detail about how these designs work and their ramifications.

The twin tube heat exchanger, in its simplest form, is a tube held concentrically within a larger tube (hence the name "twin tube"). The inner tube acts as a conductive barrier, with one fluid flowing through this inner tube and another flowing around it through the outer tube, forming an annular shape. The outer or "shell side" flow passes over the inner or "tube side" flow causing heat exchange through the inner tube walls. They are also often referred to as fork, jacketed tube, jacketed U-tube, and tube-in-tube heat exchangers. Inside they can contain a tube or a bundle of tubes (similar to shell and tube exchangers), but the bundle must be composed of <30 tubes and the outer tube must have a diameter <200 mm, otherwise the exchanger is considered a different design (see For more information see our article on shell and tube heat exchangers). The bladder (s) may also have longitudinal ribs, which further increase the heat transfer between the two working fluids.

2. Working of Double Pipe Heat Exchangers

The hottest flow flows through the bladder, while the cooler flow passes through the outer shell (note this is not always the case). The heat of a stream is transmitted through the inner tube wall, which is built of a conductive material such as steel or aluminium, in a twin tube heat exchanger. When the fluids in a twin tube heat exchanger move in opposite directions, it is known as counter flow (as shown above). Dual-tube heat exchangers obtain true counterflow across concentric tubes, and designers take use of this to boost the system's heat transfer coefficient. They can also be utilized in parallel flow, where both fluids are moving in the same direction, but the counter current is usually present.

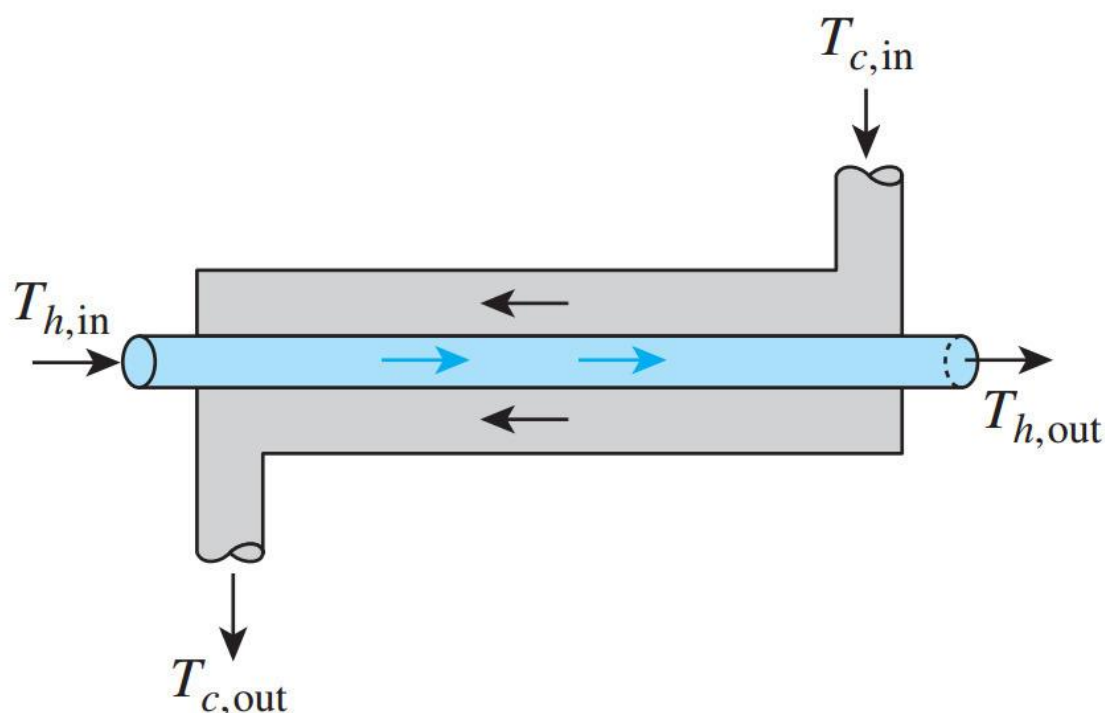


Figure 2 Simplified diagram of operational heat exchangers

Because they are free to expand and have a strong and simple structure, double tube heat exchangers can tolerate high pressures and temperatures. As the cold flow outlet temperature ($T_{c, out}$) rises above the hot flow outlet temperature ($T_{h, out}$), they may suffer counter-current temperature crossings. This may or may not be advantageous in some situations, however it should be noted that some alternative designs, such as the plate heat exchanger, are unable to achieve the temperature crossover.

The dual tube heat exchanger is a tiny modular design that can be used in settings where typical tube bundle heat exchangers are either too large or too expensive. To readily enhance the rate of exchange, double tube exchangers can be connected in series or parallel.

3. Advantages and Disadvantages of Double pipe Heat Exchangers

Due to its basic structure, the double tube heat exchanger is one of the easiest kinds to build, install, and maintain. They have distinct advantages over some of the more complicated heat exchanger designs, but they also have considerable disadvantages. The following are the key advantages of employing a dual-pipe heat exchanger:

- ❖ High pressure and high temperature can be effectively managed.
- ❖ Because of its popularity, their parts have been standardized, making it easy to find and fix parts.
- ❖ They are one of the most adaptable models, allowing for easy part addition and removal.
- ❖ They have a small footprint and require little to no upkeep, but they distribute heat well.

However, it is critical to recognize the drawbacks of such a design, which include the following: They are limited to smaller thermal loads than other larger types.

- ❖ Despite the fact that they can be utilized in parallel flow, they are almost always used in counter flow, which limits some uses.
- ❖ Leaks are possible, particularly when many devices are linked.

- ❖ Pipes are readily blocked and difficult to clean without disassembling the complete heat exchanger. A dual-tube design is often a less effective way of heat transfer if budget and space allow for a shell and tube heat exchanger.

4. Types of Double Pipe Heat Exchangers

Double tube heat exchangers can be classified according to the flow direction. Both parallel and countercurrent can be used in these switches and the position of the inputs and outputs is important. The choice of parallel and counter-current affects the heat transfer and pressure drop in the system, among other things, in some applications it is necessary to choose between the two.

4.1 Counter Flow Double Pipe Heat Exchangers

The best design for a dual-tube heat exchanger is counter-current. In this model, the heat exchanger has the optimum heat transfer coefficient and can cool or heat the outputs as desired. Figure 2 shows the location of the inputs and outputs. As this guy shows, the streams flow in opposite directions to each other and in the end we have the maximum temperature difference between the liquids' in the two heads. Look at the reflux diagram and assume that liquid 1 is hot and liquid 2 is cold. The outlet cold side temperature (T_{2out}) can reach temperatures close to T_{1in} and, as is known, this temperature is higher than T_{1out} . With this type, the temperature of the lump liquid can reach a higher temperature at the hot side outlet, while it is impossible with the parallel outlet. Counterflow heat exchanger is one of the types of double tube heat exchangers. In a counterflow heat exchanger, one working fluid has a flow direction opposite to the flow direction of the other working fluid. With this design, the heat exchanger has the highest heat transfer rate and we can easily heat or cool the outputs as needed.

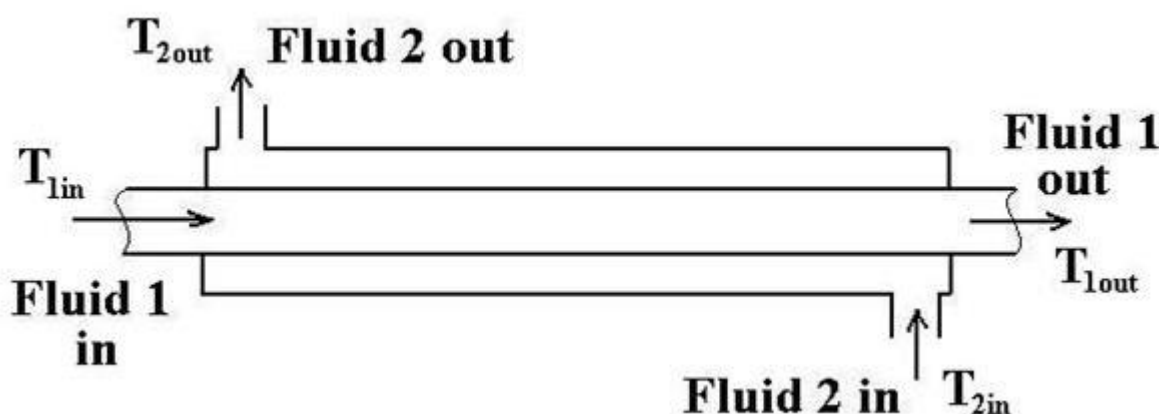


Figure 3 Counterflow – DPHEX

The diagram above shows the locations of the outlet and inlet. As the diagram shows, liquids' flow in opposite directions and liquids' have the maximum temperature difference at the ends of the two heads. Look at the diagram above and imagine that liquid 1 is hot and liquid 2 is cold. The leaving cold end temperature (T_{2out}) can be reached near the inlet temperature T_{1in} . As you know, the inlet side (T_{1in}) has more temperature than the outlet side (T_{1out}). However, in the case of the counter flow heat exchanger, the temperature of the cold side fluid can exceed the temperature at the outlet of the hot side, which is not possible with the flow heat exchanger.

Maximum shell and tube and shell and tube heat exchangers have the counter flow design as it is one of the most efficient designs. The counter-current design allows for maximum temperature variations between working fluids.

4.2 Parallel Flow Double Pipe Heat Exchangers

Parallel flow is the type where the inputs and outputs are in one head. The heat transfer is lower than the countercurrent and the efficiency is low; however, in some applications, we should choose this type. As the name parallel heat exchanger suggests, both fluids flow in the same direction through this heat exchanger. Parallel flow double tube heat exchangers have

the same direction for inlet and outlet fluids. This heat exchanger design has lower efficiency and heat transfer rate than the counter-current design. However, we need this side project for some specific applications.

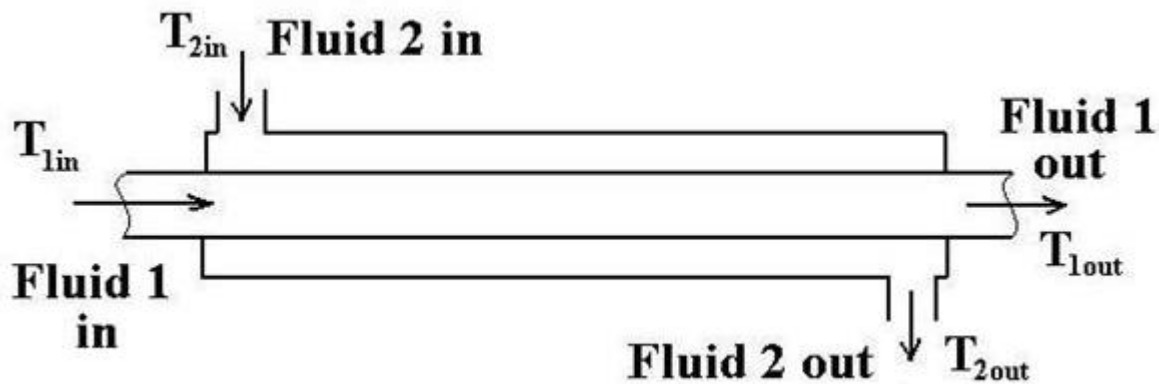


Figure 4 Parallel Flow DPHEX

A typical dual-tube heat exchanger is shown in Fig. 2. It consists of two concentrically arranged tubes or tubes, one fluid flowing in the inner tube and the other in the annular space between the tubes. Special end fittings are used to direct fluids in and out of their respective flow channels and prevent them from escaping into the atmosphere. Additional dual pipe sections can be added in series or parallel to provide the required amount of heat transfer surface.

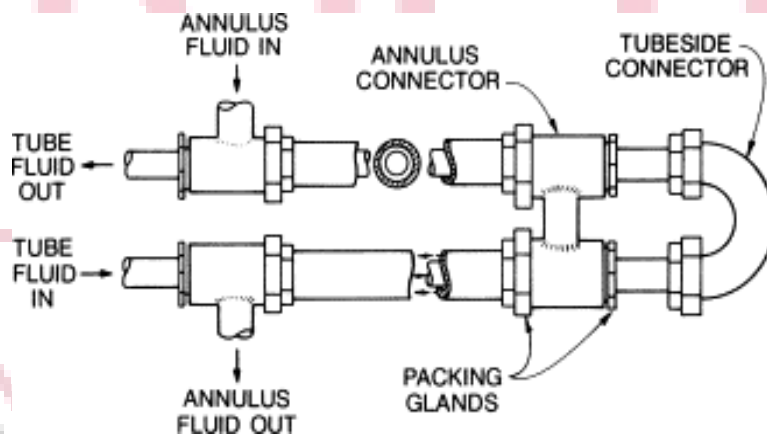


Figure 5 Typical Double Pipe Heat Exchangers

The double-tube exchanger is very flexible: single-phase evaporation, condensation or convection can be carried out in both channels and the exchanger can be designed for very high pressures or temperatures if necessary. A wide range of flow rates can be managed by correctly selecting the diameters and flow arrangements. The exchanger can be quickly assembled from standard components and just as quickly expanded or reconfigured to meet evolving process requirements.

The inner tube may have longitudinal fins on the inner or outer surface, or both, when additional heat transfer in contact with a fluid having a low heat transfer capacity is required. However, the double tube exchanger is relatively heavy, bulky and expensive per unit of heat exchange surface and is generally limited to exchangers with a surface area of less than about 20 m². There are also multitude heat exchangers available where the inner tube is replaced by a U-shaped tube bundle, as shown in Figure 6. The tubes can be smooth or have longitudinal ribs. Simple dual tube heat exchangers with external tubes from 2 "to 8" and internal tubes from 3/4 "to 6" are commercially available. Multitude heat exchangers usually have external tubes that are 3 to 16 inches in size and different sized tubes. However, multi-tube units with outer tube sizes up to 36 inches are commercially available.

Shell and tube heat exchangers are commonly used in applications with relatively low flow rates and high temperatures or pressures, for which they are particularly suitable. Other benefits include low installation costs, ease of maintenance and flexibility. Hairpins can be easily added or removed from an existing battery or arranged in various series-parallel combinations to accommodate changing process conditions. However, simple finless twin tube heat exchangers tend to get bulky when heat transfer areas greater than about 1000 square feet are required. They are also relatively expensive per unit of heat transfer area. Significantly larger heat transfer surfaces are useful in multi-tube systems with finned tubes.

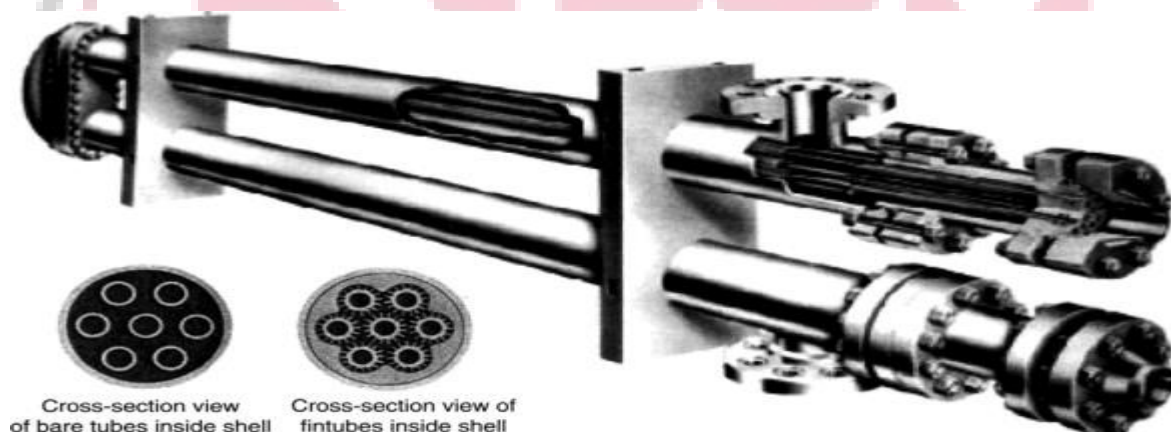


Figure 6 Multi-tube Heat Exchangers

5. Shell and Tube Heat Exchangers:

Of all types of heat exchangers, shell and tube heat exchangers are the most versatile. A shell and tube heat exchanger consists of a series of tubes arranged in a cylindrical shell. The popular design of this type of heat exchanger allows for a wide range of pressures and temperatures. When large volumes of liquids or gases need to be cooled or heated, the use of the shell and tube heat exchanger is an option to consider. Although a shell and tube heat exchanger is smaller than other types, it can be easily disassembled, making it easier to clean and repair.

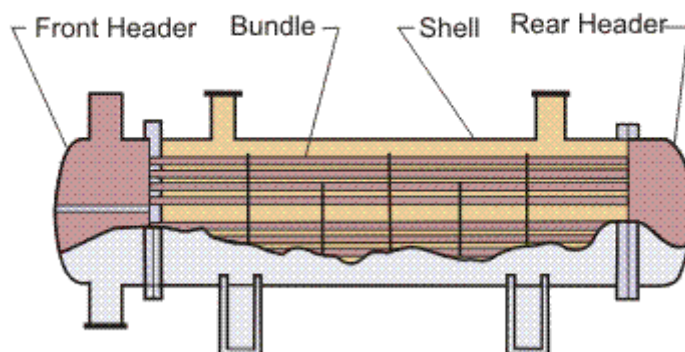


Figure 7 Shell and Tube Heat Exchangers

Shell and tube heat exchangers are one of the most popular types of heat exchangers due to the flexibility the designer must have to accommodate a wide range of pressures and temperatures. There are two main categories of shell and tube heat exchangers: those used in the petrochemical industry and generally covered by TEMA standards, Tubular Exchanger Manufacturers Association (see TEMA standards); those used in the electrical industry, such as power water heaters and power plant condensers.

Regardless of the type of industry in which the use of the heat exchanger is intended, there are some common characteristics (see condensers). A shell and tube heat exchanger consists of a series of tubes mounted in a cylindrical housing. The diagram shows a typical unit found in a petrochemical plant. Two fluids can exchange heat, one fluid flows out of the tubes while the second fluid flows through the tubes. The fluids can be single-phase or two-phase and parallel or cross / counter current flow.

6. Tube in Tube Heat Exchangers:

Similar to other types of heat exchangers, a tube-in-tube heat exchanger consists of two tubes, one for each fluid. However, the tubes are rolled together to form an outer and inner pattern. Applying for a tube-in-tube design can be quite creative. Since the tubes are wound together, most models of this type are compact. Applications for a tube-in-tube heat exchanger focus on high temperature and high pressure. Because it operates at a higher capacity, a tube-in-tube heat exchanger tends to be more efficient.

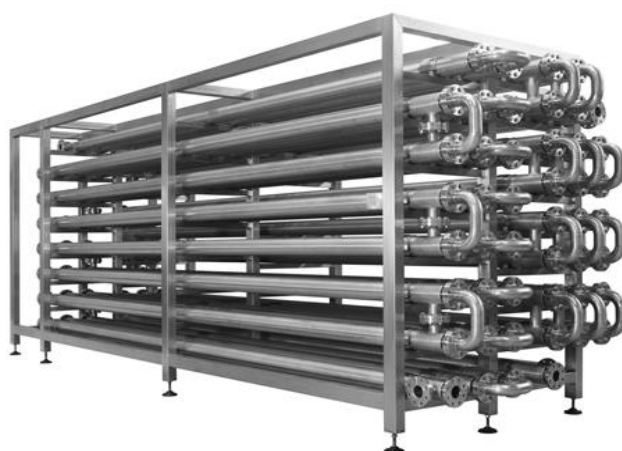


Figure 8 Tube in tube heat exchangers

The equipment consists of a single tube mounted in an outer casing tube so that the fluid produced flows counter-current through the inner tube and the service fluid surrounds it. The unit features a fully welded construction with a bellows tube on the hull to absorb thermal expansion.

7. Plate Heat Exchangers:

While all types of heat exchangers discussed so far have a similar structure, the plate heat exchanger is the exception. Metal plates are used to transfer heat between two liquids'. The plate is a metal shell with interstices in each plate that act as corridors for the passage of fluids. A plate heat exchanger has a larger contact surface with liquids', so it has better heat transfer rates than all other types. Although plate heat exchangers may be more expensive, the efficiency achieved through the design is a big plus. This type of heat exchanger is best used in places like power plants due to its durability and low repair rates.

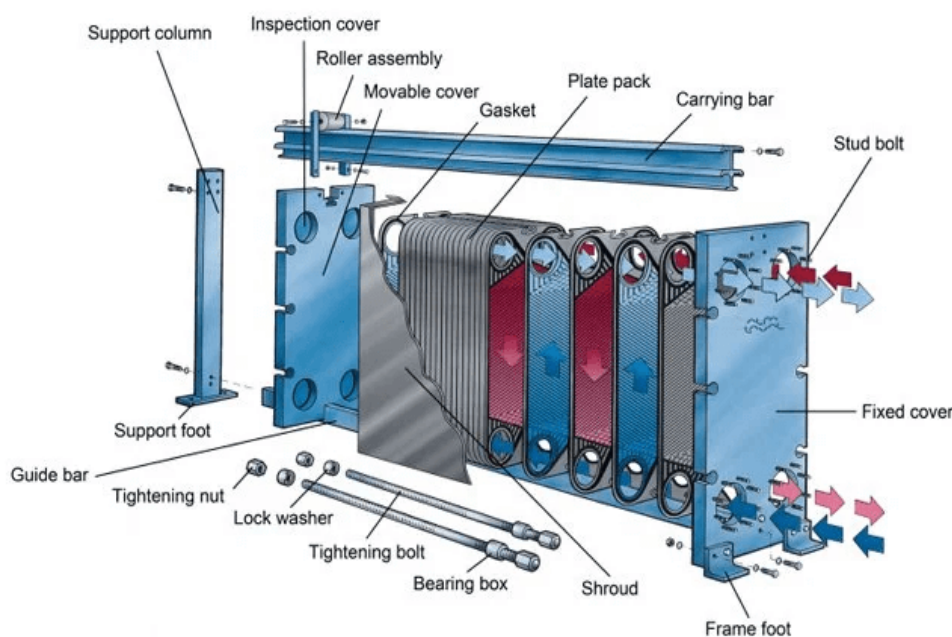


Figure 9 Plate heat exchangers

Plate heat exchangers consist of relatively few parts. Since plate heat exchangers are used to transfer heat, they require inlets and outlets where the circulating fluid - or liquid - can enter and exit the heat exchanger. A fluid can be a liquid or a gas. Since liquids' are often assumed to be just fluids, we use the term fluid to avoid confusion. Seals and plates serve to separate the circulating fluids and prevent mixing; the joints are glued only on one side of each panel. The plates hang from a support rod and are pressed together with fixing bolts. When plates are pressed together, they are called "plate stacking". A guide rail ensures correct alignment of the plates when opening and closing the stack of plates.

The final components of interest are the two covers at opposite ends of the plate stack. One cover is movable whilst the other is fixed. The movable cover and fixed cover are also sometimes referred to as the frame plate and pressure plate. Note that the inlets and outlets are mounted to the fixed cover only.

Conclusion

This report explores heat exchange parameters in tubes of various shapes, including triangular, hexagonal, and octagonal. The standard shape of a double pipe heat exchanger was chosen for this analysis, shows the standard size and measurement of cross-sectional area and dimension. Because of its properties such as machinability, ductility, wear resistance, and hardness, brass is chosen as the specimen for the external pipe of a DPHEX. Copper is used for the inner pipe of heat exchangers because of its properties such as high melting point, thermal

conductivity, and ductility. The list the properties that are taken into account during simulation. Even though oil and gas companies use double pipe heat exchangers more than other industries, ethanol is chosen as the hot fluid that flows through the inner pipe.

Reference

- [1] Sun, Z., Zhang, K., Li, W., Chen, q., &Zheng, N. (2018). Investigations of the turbulent thermal-hydraulic performance in circular heat exchanger tubes with multiple rectangular winglet vortex generators. *Applied Thermal Engineering*, 168(November 2019), 114838.
- [2] Hu, C., Sun, M., Xie, Z., Yang, L., Song, Y., Tang, D., & Zhao, j. (2019). Numerical simulation on the forced convection heat transfer of porous medium for turbine engine heat exchanger applications. *Applied Thermal Engineering*, 180(May), 115845.
- [3] Culha, O., Gunerhan, H., Biyik, E., Ekren, O., &Hepbasli, A. (2020). Heat exchanger applications in wastewater source heat pumps for buildings: A key review. *Energy and Buildings*, 104, 215–232.
- [4] Hussain, A. R. j.,Alahyari, A. A., Eastman, S. A., Thibaud-Erkey, C., johnston, S., &Sobkowicz, M. j. (2021). Review of polymers for heat exchanger applications: Factors concerning thermal conductivity. *Applied Thermal Engineering*, 113, 1118–1127.
- [5] Aresti, L., Christodoulides, P., &Florides, G. (2021). A review of the design aspects of ground heat exchangers. *Renewable and Sustainable Energy Reviews*, 92(April), 757–773.
- [6] Sheikholeslami, M., jafaryar, M., Said, Z., Alsabery, A. I., Babazadeh, H., &Shafee, A. (2021). Modification for helical turbulator to augment heat transfer behavior of nanomaterial via numerical approach. *Applied Thermal Engineering*, 182, 115935.
- [7] Hassan, M., Marin, M.,Alsharif, A., &Ellahi, R. (2022). Convective heat transfer flow of nanofluid in a porous medium over wavy surface. *Physics Letters, Section A: General, Atomic and Solid State Physics*, 382(38), 2749–2753.
- [8] Arasteh, H., Mashayekhi, R., Ghaneifar, M.,Toghraie, D., &Afrand, M. (2023). Heat transfer enhancement in a counter-flow sinusoidal parallel-plate heat exchanger partially filled with porous media using metal foam in the channels' divergent sections. *journal of Thermal Analysis and Calorimetry*, 141(5), 1669–1685.
- [9] HajatzadehPordanjani, A., Aghakhani, S., Afrand, M., Mahmoudi, B., Mahian, O., &Wongwises, S. (2024). An updated review on application of nanofluids in heat exchangers for saving energy. *Energy Conversion and Management*, 198(july),
- [10] Pandya, N. S., Shah, H., Molana, M., &Tiwari, A. K. (2024). Heat transfer enhancement with nanofluids in plate heat exchangers: A comprehensive review. *European journal of Mechanics, B/Fluids*, 81, 173–190. <https://doi.org/10.1016/j.euromechflu.2020.02.004>
- [11] Dinesh Kumar, S., Chandramohan, D., Purushothaman, K., &Sathish, T. (2025). Optimal hydraulic and thermal constrain for plate heat exchanger using multi objective wale optimization. *Materials Today: Proceedings*, 21(xxxx), 876–881.