A heat exchanger is a device which is used to transfer heat from one material to another. These materials may be liquid or gaseous, depending on the situation in which the heat exchanger is being used or heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact.
There are many models and types of heat exchangers, but they essentially work based on the 1\textsuperscript{st} laws of thermodynamics. i.e., “Energy can neither be created nor destroyed. It can only change forms. In any process, the total energy of the universe remains the same”.

When an object is heated, the heat energy contained within that object will diffuse outward to the surrounding environment, until the heat energy in the object and in the environment have reached equilibrium.
In short a **heat exchanger** is a component that allows the transfer of heat from one fluid (liquid or gas) to another fluid. Heat exchangers are used in a process plant:

1. To heat a cooler fluid by means of a hotter fluid. E.g. HE 15.07.

2. To reduce the temperature of a hot fluid by means of a cooler fluid.

3. To boil a liquid by means of a hotter fluid. E.g. HE 15.02 (Deetanizer reboiler).

4. To condense a gaseous fluid by means of a cooler fluid. E.g. HE 15.05 (Debutanizer reflux condenser).

5. To boil a liquid while condensing a hotter gaseous fluid.
Types of Heat Exchangers

1. **Recuperative type:** in which fluids exchange heat on either side of a dividing wall.

2. **Regenerative type:** A *regenerative* heat exchanger is one in which the same fluid is both the cooling fluid and the cooled fluid. That is, the hot fluid leaving a system gives up its heat to "regenerate" or heat up the fluid returning to the system.

3. **Evaporative type:** such as cooling tower in which a liquid is cooled evaporatively in the same space as coolant.
Heat Exchangers are classified

1. According to their flow:
   - Parallel-flow:
     In this heat exchanger, two fluids enter the exchanger at the same end, and travel in parallel to one another in the *same direction* to the other side. In this case, the two fluids enter the unit from the same end with a large temperature difference. As the fluids transfer heat from the hotter fluid to the cooler one, their temperatures start to approach one another.
Counter-flow:

In this heat exchanger, two fluids enter the unit from opposite directions and travel against one another.
Cross-flow:

In this heat exchanger, the fluids travel perpendicular to one another through the exchanger, i.e., one fluid flows through tubes and the second fluid passes around the tubes at 90° angle.
Two of the most popular types of heat exchangers are the **shell and tube** and the **plate** heat exchanger.

**Shell and Tube:**

As the name suggests, a shell and tube heat exchanger contains a bundle of tubes inside a large pressure vessel which is referred to as the shell. The tubes on each end are attached to tube sheets. Two different fluids run through the shell and the tube heat exchanger, one through the tubes and the other outside the bundle of tubes within the shell. As the fluids flow, transfer of heat takes place from the fluid that is at a higher temperature to that at a lower temperature.

Cont.
Shell and Tube heat exchangers are typically used for high pressure applications (with pressures greater than 30 bar i.e. 30.59 Kg/Cm² and temperatures greater than 260°C.) This is because the shell and tube heat exchangers are robust due to their shape.
Plate type:

A plate type heat exchanger consists of plates instead of tubes to separate the hot and cold fluids. Baffles direct the flow of fluid between plates. Because each of the plates has a very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Therefore a plate type heat exchanger, as compared to a similarly sized tube and shell heat exchanger, is capable of transferring much more heat.
3. According to the Pass:

The number of passes indicate the number of times that the fluid pass through the tubes.

- **Single pass:**
  
  Fluid enters from one side & goes out from the other side of the exchanger.
- **Double pass:**
  Fluid enters in the first box i.e. in inlet plenum & goes out from the second box i.e. outlet plenum which is in the same side of the exchanger.
Multi pass:
Fluid enters from one side of the shell and goes out from the other side of the shell after passing through various passes.
4. According to the phases:

**Single Phase:**
The fluids can either be liquid or gas. The heat exchangers with either only liquid or gas in both the tubes and the shell are called the one phase or single phase heat exchanger.

**Two Phase:**
Heat exchangers involve transfer of heat between two fluids of two different phases, that is a liquid and a gas known as two phase or double phase heat exchanger.
5. According to the Tube arrangements:

**Straight Tubes:**

As the name suggests, these heat exchangers have straight tubes. The ends open into two separate tube sheets. In case of one pass straight tube heat exchangers, one end has the inlet plenum while the other end has the outlet plenum. In case of a two pass straight tube heat exchanger, both the inlets are on the same side. Eg. HE 15.07
U-Tubes:
A heat-exchanger system consisting of a bundle of U tubes (hairpin tubes) surrounded by a shell (outer vessel); one fluid flows through the tubes, and the other fluid flows through the shell, around the tubes. Eg. Expander lube oil cooler.
In our plant we are using Shell & Tube type heat exchangers i.e. most of our heat exchangers that we are using in our process plant is Shell & Tube type.
The body of the Shell & Tube type heat exchanger is made up by the following metals:

2. Bronze.
3. Steel.
4. Aluminum.
5. Copper.
6. Stainless steel. etc.

The tubes inside the Shell is made up by the following:

1. Copper alloy
2. Stainless steel
Advantages

The advantage of the shell and tube design cannot be ignored. Each unit comes with:

1. *Connections* that come in standardized sizes for easy assembly and feature additional thread and surface protection for clean installation.

2. U-bend tubes expanded into a *tube sheet* which allow for tube expansions and contractions due to thermal fluctuations.
3. *Gaskets* that are made of high quality compressed fiber which lends to re-usability.

4. A standard cast-iron or steel *head* for heavy duty services (also available as a spare part).
5. Saddle attaches which make for quick and easy *mounting*.

6. Punched *baffles* with minimal clearances between tubes guaranteeing correct fluid flow and minimized bypass.

7. A welded *shell* protected with high quality paint for corrosion resistance.
8. Copper steel tubes which allow for strong, durable performance over a wide range of applications. Unique *tube bundle* layout minimizes deposit buildup at the edges and optimize media flow for high velocity flow turbulence.
Disadvantages

1. **Fouling** - One of the most serious problems that we will face with heat exchangers is *fouling*. Whenever we use a natural source of water as our cooling medium, a lot of biological debris will enter the heat exchanger and build layers, which will be decreasing the heat transfer coefficient.

2. **Scale** - Another possible problem is scale, which is chemical deposit layers such as calcium carbonate or magnesium carbonate.
3. **Corrosion** – It is a never-ending problem that is solved to some degree by the type of material used to make the heat exchanger. Heat exchangers are typically made from steel, titanium, copper, bronze, stainless steel, aluminum or cast iron. Those made with stainless steel are usually the most corrosion resistant. To avoid corrosion, pitting, stress-corrosion cracking (SCC), and other failures, some heat exchangers are designed with fins to provide greater thermal conductivity.
In our plant we are using all total 17 nos. Shell & Tube type heat exchangers. All these are again categories as:

- **WATER BASE:** (Here water passes through the tube side)

1. **I/C discharge cooler (HE 15.07):** It is a parallel flow, double phase heat exchanger placed after the I/C to lowered down the compression temperature developed during the compression from 87°C to 37.7°C. (NG on Shell side & Water on Tube side, Total tube=689 nos., Approx heat exchange=37.68°C., Shell-split pass & Tube-2 pass.)
2. **B/C discharge cooler (HE 15.08):** It is a parallel flow, double phase heat exchanger placed after the E/C to lowered down the temperature after 2\textsuperscript{nd}.stage compression from 65\(^{0}\)C to 37.7\(^{0}\)C. (NG on Shell side & Water on Tube side, Total tube=625 nos., Approx heat exchange=25.83\(^{0}\)C., Shell-1 pass & Tube-2 pass.)

3. **LPG product cooler (HE 15.12):** It is a parallel flow, double phase heat exchanger placed to increase the LPG product temperature from 44\(^{0}\)C to 32.8\(^{0}\)C. (LP vapor on Shell side & water on Tube side, Total tube=16 nos., Approx heat exchange=10.8\(^{0}\)C., Shell-1 pass & Tube-4 pass.)
4. **Gasoline product cooler (HE 15.06):** It is a parallel flow, double phase heat exchanger placed to lowered down the N.G product temperature from $134^\circ C$ to $32^\circ C$. (Hydrocarbon liquid on Shell side & Water on Tube side, Total tube = 24 nos., Approx heat exchange=$100^\circ C.$, Shell- 1 pass & Tube- 2 pass.)

5. **Debut reflux condenser (HE 15.05):** It is a parallel flow, double phase heat exchanger used to condense the vapor of C3 & C4 mixture coming out from the top of the debutanizer column at $54^\circ C$. Here temp. drop down to $44^\circ C$. (Propane/Butane on Shell side & Water on Tube side, Total tube=204 nos., Approx heat exchange=$10^\circ C.$, Shell-1pass & Tube-1pass.)
6. **Regeneration gas trim cooler (HE 15.09):** It is a parallel flow, double phase heat exchanger used to lowered down the temperature of regeneration gas coming out from the dehydrator at 49°C to 37.8°C. (HC vapor, water & steam on Shell side & water on Tube side, Total tube= 84 nos., Approx heat exchange=12.77°C., Shell-1 pass & tube-6 pass.)

7. **Expander lube oil cooler (HE 15.401):** It is a parallel flow, double phase heat exchanger used to lowered down the lube oil temperature of expander. (Lube oil on Shell side & water on Tube side, Total tube= 31 nos., Approx heat exchange=15°C., Shell-1pass & Tube-1pass.)
GAS BASE: (Here comparatively low temperature gas flows through the tube side)

1. Warm Gas/Gas Exchanger (HE 15.01A&B): It is a parallel flow, single phase heat exchanger used to increase the residue gas temperature from -76.7°C before meeting the sale gas stream to 32.2°C. (NG on Shell side & NG on tube side also, Total tube=(836 + 836) =1672 nos., Approx heat exchange=12.36°C., Shell-1pass & Tube-1pass.)

2. Cold Gas/Gas Exchanger (HE 15.10): It is a parallel flow, single phase heat exchanger used to treated the residue gas temperature before entering the warm gas-gas exchanger & meeting the sale gas stream. (NG on Shell side & NG on tube side also, Total tube=(676+676) =1352 nos., Approx heat exchange=16.30°C., Shell-1pass & Tube-1pass.)
3. **De-thanizer reflux condenser (HE 15.04):** It is a parallel flow, double phase heat exchanger used to condense the de-ethanizer overhead vapor of -15.60°C to -31.80°C. (LPG vapor on Shell side & NG on Tube side, Total tube=187 nos., Approx heat exchange=16.42°C., Shell-1pass & Tube-1pass.)

4. **Gas-Liquid exchanger (HE 15.02):** It is a parallel flow, double phase heat exchanger used to exchange the temperature of 30 % line flow at 37.80°C with cold separator liquid at -30°C before entering the de-ethanizer feed preheater (HE-15.11). (LPG on Shell side & NG on Tube side, Total tube=234 nos., Approx heat exchange=10.60°C., Shell-1pass & Tube-1pass.)
5. **De-thanizer re-boiler exchanger (HE 15.03):** It is a parallel flow, single phase type heat exchanger used to increased the liquid temperature from 55.6°C to 62.2°C of the de-ethanizer tower. (NG on Shell side & LPG on Tube side, Total tube=314 nos., Approx heat exchange=10.63°C., Shell-1pass & Tube-1pass.)

6. **De-ethanizer feed pre-heater (HE 15.11):** It is a parallel flow, double phase heat exchanger used to exchange heat with 30 % line flow at -25.6°C with the expander separator liquid at -84°C before meeting the 70 % flow. (LPG on Shell side & NG on Tube side, Total tube=190 nos., Approx heat exchange=60.02°C., Shell-1pass & Tube-1pass.)
AIR BASE: (Here hot substance exchange heat with air.)

1. I/C lube oil cooler: It is a forced draught type heat exchanger used to expel the hot temperature of the lube oil of I/C to atmosphere. (In forced draught the fan is placed in the bottom).

2. Cooling towers (SERIES 15 & 18): It is a induced draught type heat exchanger used to expel the latent heat from the hot water which is being used to exchange heat in a exchanger. (In induced draught the fan is placed in the top).
3. Regeneration gas cooler (HE 15.09A1&A2): It is a forced draught type heat exchanger used to expel the hot temperature of the regeneration gas after dehydration from 260°C to 49°C.
**OIL BASE**: (Here hot oil is used to exchange heat with a cool one)

**Debut re-boiler [Kettle type] (HE 15.13)**: It is a parallel flow, double phase heat exchanger used to increase the bottom temperature of the debutanizer column from 121°C to 135°C. (Hydrocarbon liquid on Shell side & Hot oil on Tube side, Total tube=104 nos., Approx heat exchange=15.5°C, Shell-1pass & Tube-1pass.)

![Diagram of Debut re-boiler](image)
THANK YOU