

Upstream LNG Technology
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Lecture – 26
Heat exchangers in natural gas systems

Welcome. Today, we shall be learning about heat exchangers and their basics because these heat exchangers find wide use in the natural gas industries. So, this lecture pertains to heat exchangers in natural gas systems.

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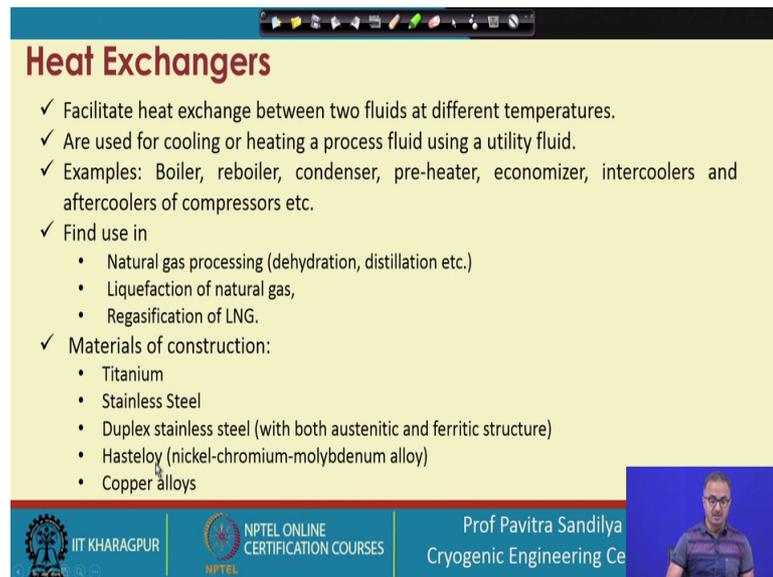
What we shall learn

- ✓ Heat exchanger fundamentals
- ✓ Types of Heat Exchangers
 - Tube in tube
 - Shell and tube
 - Compact

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In this lecture, we shall be learning some fundamentals about heat exchangers and a few types of a heat exchangers, which are commonly used in the natural gas systems. First let us see what heat exchangers mean.

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Heat Exchangers

- ✓ Facilitate heat exchange between two fluids at different temperatures.
- ✓ Are used for cooling or heating a process fluid using a utility fluid.
- ✓ Examples: Boiler, reboiler, condenser, pre-heater, economizer, intercoolers and aftercoolers of compressors etc.
- ✓ Find use in
 - Natural gas processing (dehydration, distillation etc.)
 - Liquefaction of natural gas,
 - Regasification of LNG.
- ✓ Materials of construction:
 - Titanium
 - Stainless Steel
 - Duplex stainless steel (with both austenitic and ferritic structure)
 - Hasteloy (nickel-chromium-molybdenum alloy)
 - Copper alloys

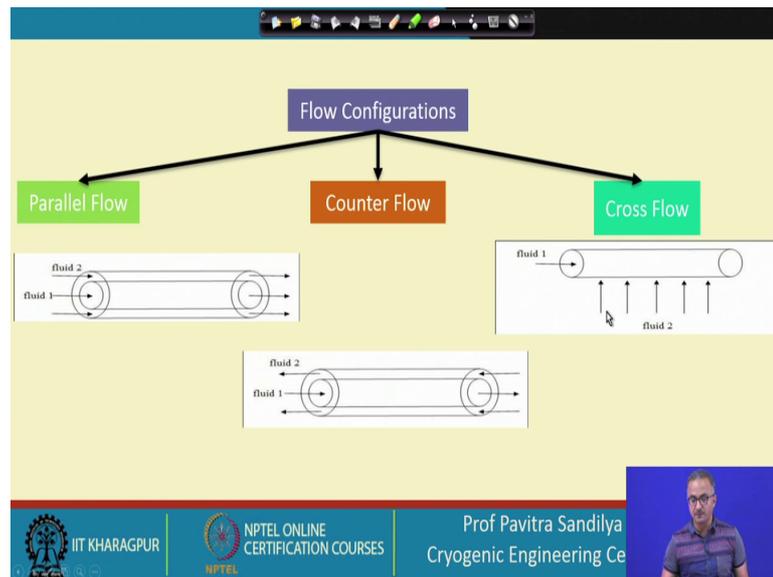
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They denote some facility in which 2 fluids at different temperatures exchange heat energy; and due to this heat energy exchange, what happens that we are able to heat up or cool down some fluid. Now this fluid may be gas or liquid or both, there are several applications of these heat exchangers in the natural gas industries like boiler, reboiler, condenser, preheater, economizer, intercooler and aftercoolers of compressors and many more.

So, we find that these are used in the natural gas processing. So, like for dehydration, distillation, etcetera, liquefaction of natural gas, regasification of LNG and as we take up the various steps in the natural gas processing, you will find that these heat exchangers are coming in different forms in the various systems. Now there are several materials with which these heat exchangers are constructed some of them are like titanium, stainless steel, then duplex stainless steel, then Hasteloy and copper alloys, these are some of the common materials of construction for the heat exchangers.

And there are some of these alloys like Hasteloy, duplex, stainless steel, these are the some alloys and other than that; we have also copper alloys depending on the temperature range, we are working these materials of construction are chosen.

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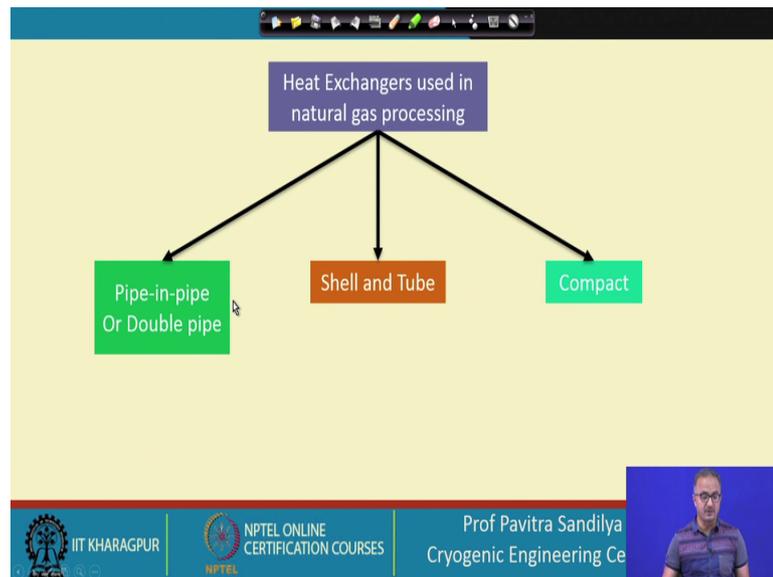


Now, there are several configurations of the flow. So, basically these configurations have been divided into 3 categories; one is parallel flow, another is counter academic flow and another is cross flow.

Now, what is parallel flow? It means that if we consider 2 fluids. Fluid 1 and fluid 2 and let us assume that these are flowing in a set of concentric pipes; inner pipe is concentrically placed within an outer pipe. So, that inside the inner pipe 1 fluid is flowing and in the annular region between the 2 pipes the another fluid is flowing. So, if these 2 fluids are flowing in the same direction, we call it a parallel flow configuration.

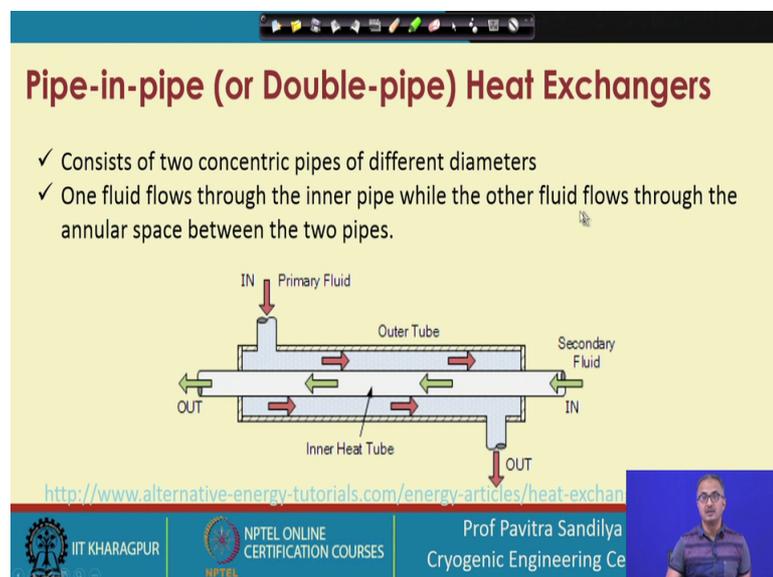
On the other hand, if these 2 fluids are flowing in counter current or opposite direction, then we have the counter current flow, whereas, in the cross flow; what we have that one fluid is flowing through the pipe and another fluid is criss-crossing in perpendicular direction. So, this is what we called the cross flow.

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Now, we have several types of heat exchangers and all these heat exchangers are broadly classified into these 3 categories. One is pipe-in-pipe or double pipe, then shell and tube and compact heat exchanger.

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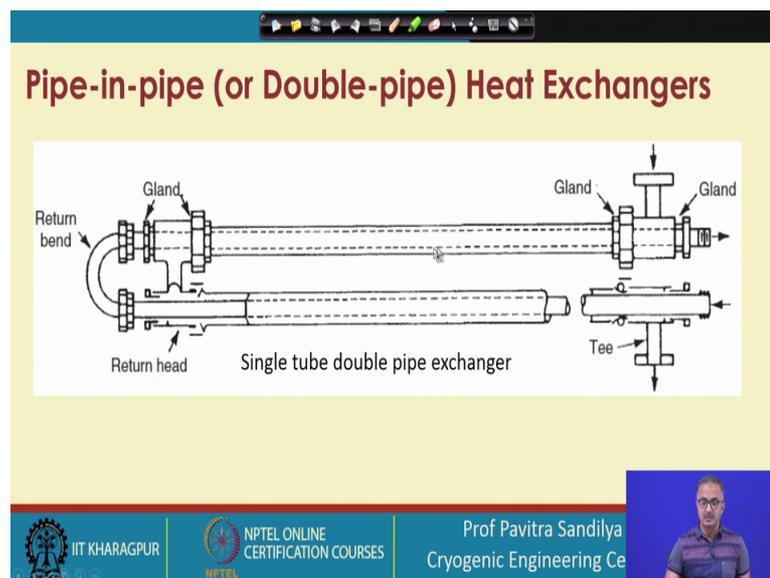
Now, let us see one by one again each of them. Now what is pipe-in-pipe or double pipe; what it consists of 2 concentric pipes of different diameters, this is the easiest configuration one can think of where the 2 fluids are not coming in direct contact with

each other, but are flowing through different pipes. So, one pipe is placed concentrically within the outer pipe concentrically means they have the same axis.

So, this concentric pipes are placed and 1 fluid flows through the inner pipe, while the second fluid flows through the annular space between the 2 pipes and as we can see that this is 1 use of primary fluid primary fluid may be the process fluid and the secondary fluid is the utility fluid that means, if the primary fluid has to be heated, then we need the secondary fluid which has a higher temperature than the primary fluid and if I need to cool down the primary fluid, then we shall choose the secondary fluid with a temperature that is less than that of the primary fluid.

So, here they are taking 2 different control volumes for their passage. So, that is how these pipe-in-pipe or double pipe heat exchangers are constructed.

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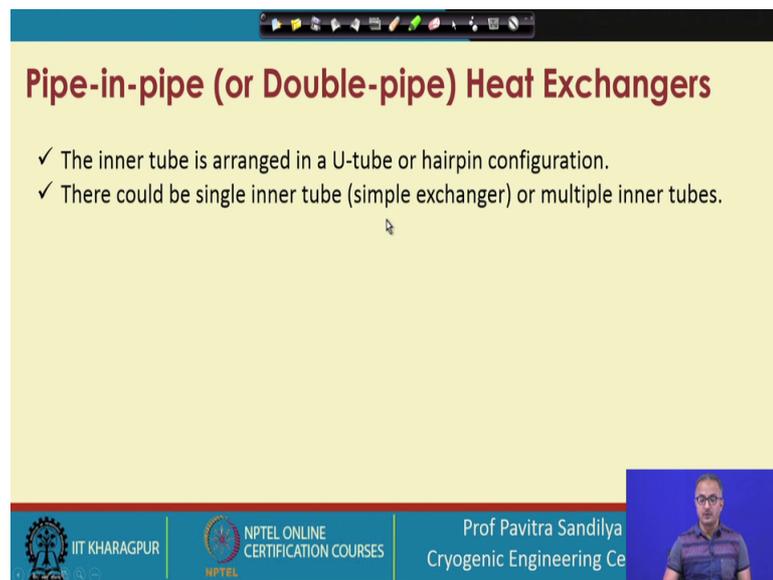
Now, this is a typical industrial construction of this pipe-in-pipe. Now what we find here that this inner pipe that is given by the dashed line is taking a u turn and it is looking like the hairpin used by us. So, this is called a hairpin construction.

So, these are returned from here this tube is coming inner tube is coming and taken a U-turn, U-tube and then it is going out, whereas, the other outer tube is not taken the U-turn there likes the other. Now fluid is flowing in the inner tube take a U-turn and the outer

tube is just this fluid is flowing from the outer tube, it is flowing like this and it is coming through this particular duct and flowing in this way and is going out.

So, what we find in this particular section this, these 2 fluids are going counter current to each other, whereas, in this section also, we are finding that the 2 fluids are going counter current to each other. So, in this is a counter current manner, this is the flow is occurring in a double pipe heat exchanger.

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Pipe-in-pipe (or Double-pipe) Heat Exchangers

- ✓ The inner tube is arranged in a U-tube or hairpin configuration.
- ✓ There could be single inner tube (simple exchanger) or multiple inner tubes.

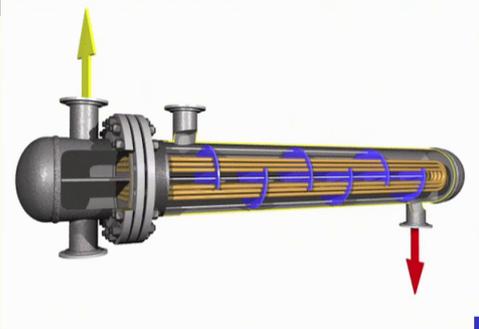
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Now, the inner tube is as I said that inner tube is arranged in U-tube or hairpin configuration, and there could be single inner tube; what we call simple heat exchanger and are can be multiple inner tubes.

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Pipe-in-pipe (or Double-pipe) Heat Exchangers

- ✓ The inner tubes are placed in the outer tube.
- ✓ There could be several inner tubes.



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So, when we are multiple inner tubes, we can see here in this thing that there are several inner tubes are placed and all of them are taking this, U-turn, then there are several of this hairpin exchangers and this is the outer tube. So, what is happening? So, from this side that from outer tube 1 fluid, which is given by the yellow arrow is flowing, whereas, this is going through the U that is inner tubes, whereas, the outer tube this red color one is coming and it is going through the outer tube and coming out of this particular exit. So, there are 2 exists for the 2 fluids.

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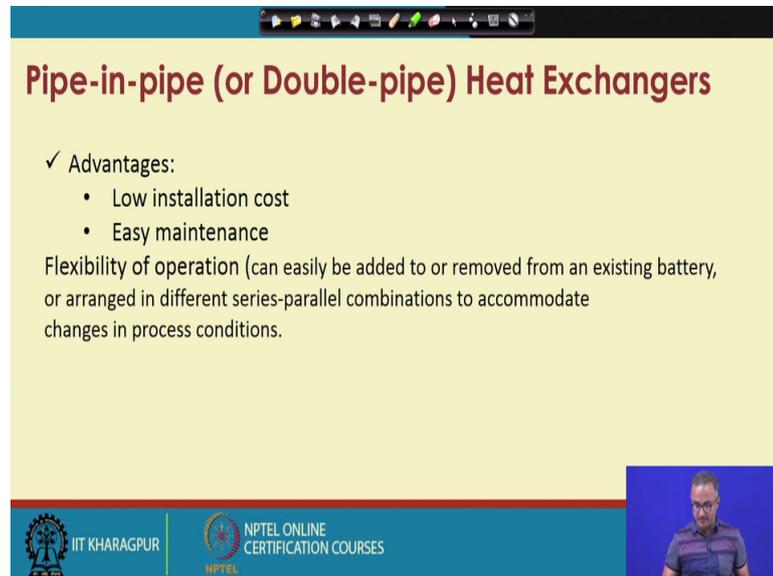
Pipe-in-pipe (or Double-pipe) Heat Exchangers

- ✓ Applications:
 - Low flow rates
 - High temperature
 - High pressure

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Now, these kinds of heat exchangers find applications for a low flow rates for a high temperature and for high pressure applications.

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Pipe-in-pipe (or Double-pipe) Heat Exchangers

✓ Advantages:

- Low installation cost
- Easy maintenance

Flexibility of operation (can easily be added to or removed from an existing battery, or arranged in different series-parallel combinations to accommodate changes in process conditions.)

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Now, their advantages are that they are simple construction. So, they have low installation cost and they are easier to maintain; that means, cleaning, etcetera is easier and there we having flexibility of operation in the sense that they can be easily added or removed from an existing battery of tubes or arranged in series and parallel combinations to accommodate changes in the process conditions.

So, these are the flexibility, they offer in that we can whenever we want, we can use several of these modules or we can take out some of these modules as per the requirement.

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Pipe-in-pipe (or Double-pipe) Heat Exchangers

Type	ID	OD
Simple	¾ - 6 inch	2 - 8 inch
Multi-tube		3 - 16 inch

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Now, these are the typical dimensions of such kind of tubes, we find out the inner diameter comes from 3-4 things to about 6 inch, and these are the outer diameters for the simple tube, it is goes from 2 to 8 inch are some multiple tubes, it can go to 3 to 16 inches.

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Pipe-in-pipe (or Double-pipe) Heat Exchangers

✓ For heat transfer area > 1000 ft², finned tubes are used

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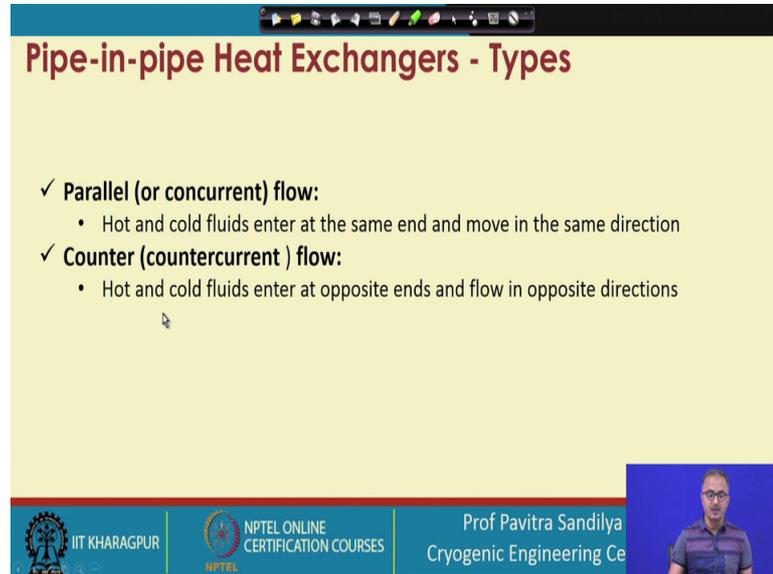
And the heat transfer area is generally less than 1000 feet square, if we need more than this heat transfer area, then finned tubes are used fin means we put some kind of projections of the wall of the tubes to increase the area for heat transfers. So, these are

called fins. So, these fins are used, if we need higher than 1000 feet square of heat transfer area.

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Pipe-in-pipe Heat Exchangers - Types

- ✓ **Parallel (or concurrent) flow:**
 - Hot and cold fluids enter at the same end and move in the same direction
- ✓ **Counter (countercurrent) flow:**
 - Hot and cold fluids enter at opposite ends and flow in opposite directions

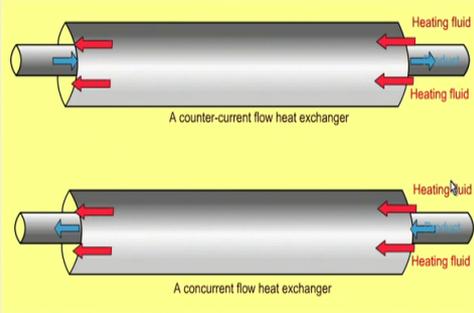


The slide features a yellow background with a blue header and footer. The header contains the title 'Pipe-in-pipe Heat Exchangers - Types'. The main content area lists two types of flow configurations with their characteristics. A small inset image of Prof. Pavitra Sandilya is visible in the bottom right corner of the slide area.

Now, we have 2 types of flow configurations as we discussed that, one is parallel flow or counter current flow in which the hot and cold fluids enter at the same end and move in the same direction, another one is the counter or counter current flow that is the hot and cold fluids enter at opposite ends and flow in the opposite directions.

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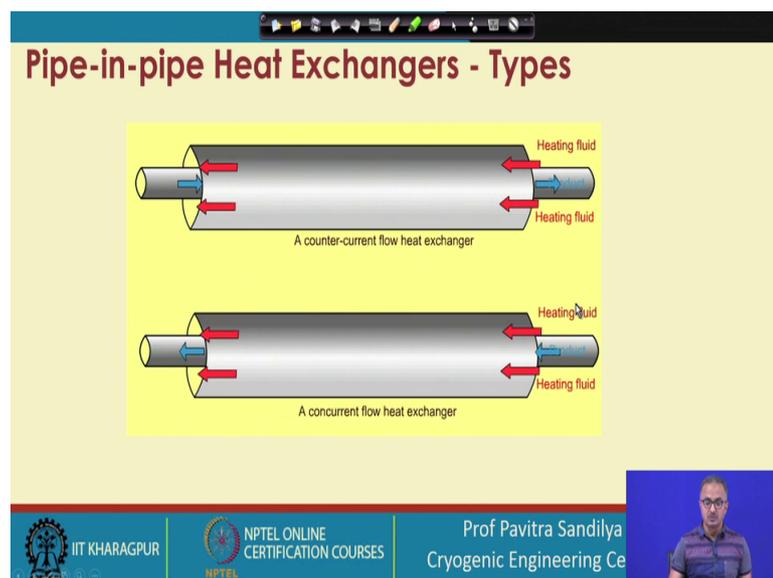
Pipe-in-pipe Heat Exchangers - Types



The diagrams illustrate two types of pipe-in-pipe heat exchangers. The top diagram shows a counter-current flow heat exchanger where the heating fluid (red arrows) and the fluid being heated (blue arrows) enter at opposite ends and flow in opposite directions. The bottom diagram shows a concurrent flow heat exchanger where both the heating fluid (red arrows) and the fluid being heated (blue arrows) enter at the same end and flow in the same direction.

A counter-current flow heat exchanger

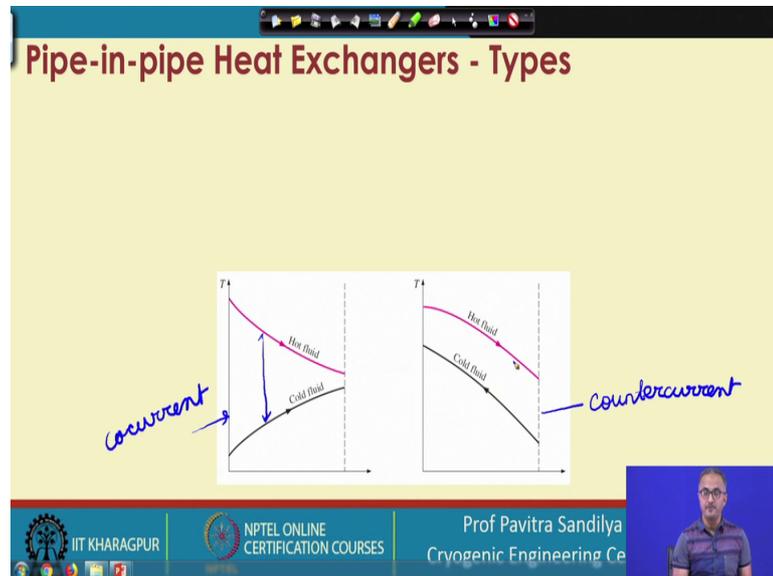
A concurrent flow heat exchanger



The slide features a yellow background with a blue header and footer. The header contains the title 'Pipe-in-pipe Heat Exchangers - Types'. Below the title are two diagrams illustrating different flow configurations. A small inset image of Prof. Pavitra Sandilya is visible in the bottom right corner of the slide area.

So, here as we said that for tube and tube this is the kind of configuration, we have for the counter current and this is for the concurrent flow of the 2 fluids.

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And the difference comes that in the, that the difference in the temperature at several location.

So, this y axis represents the distance from one end and we find that where the hot in case of this hot fluid and cold fluid we are finding that they are approaching their temperatures, in case their in the co current flow and this is one each for the counter current flow in which we are finding that. So, this is for the counter current flow and this is for the co current.

So, in this co current counter current, we find that how the temperatures are varying for the 2 fluids. So, in the concurrent, we find that this difference between the temperatures which is the driving force of heat transfer it keeps coming down whereas, in case of counter current flow, we are able to maintain more or less the same driving force for the heat transfer and the driving force decides that how easy or how difficult, it would be to maintain certain heat transfer rate and if the it becomes too less, then what happens the area for a for a given heat transfer rate the area of the heat exchanger has to be increased.

So, this is a very important parameter to see to it that we are able to maintain the good amount of driving force or that in this case, the temperature difference between the 2

fluids. So, that is how we find that the co current and counter current flow dictate the driving force, next, we go to the and the other types are that shell and tube type in this case we find that.

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Shell and Tube Heat Exchangers

- ✓ Contains a bundle of tubes packed coaxially in a cylindrical shell
- ✓ One fluid flows inside the tubes while the other fluid flows through the shell

The diagram illustrates a shell and tube heat exchanger. It consists of a cylindrical shell containing a bundle of tubes. The tubes are connected to a front-end header and a rear-end header. Fluid flows from the shell inlet through the shell, across the tubes, and out through the shell outlet. The tubes are supported by baffles. The tube side has a tube inlet and a tube outlet. The shell side has a shell inlet and a shell outlet. The diagram shows the flow paths for both fluids.

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We have a bundle of tubes packed coaxially in a cylindrical shell and one fluid flows inside the tubes while the other fluid flows out throughout the shell. Now this is the typical configuration of a shell and tube heat exchanger, we find that there are the bundle of this inner tubes and this is the outer shell, which is given by the white and this pink is showing the tube side. So, here we find that some fluid is coming on the tube side. So, this is coming through the header is this is the header region and through the header this tube is getting into several streams to the various tubes and then all of these fluids from the various tubes are getting collected in the rear end header and they are going out.

Whereas, on the shell side, we find the shell side those liquid is come some fluid is coming and then we have we have putting some baffles here baffles are nothing, but some kind of a resistance the to the flow of the fluids about which we shall learn a bit later and then this fluid is taking this kind of a flow path and before it goes out of this.

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Shell and Tube Heat Exchangers

- ✓ Contains a bundle of tubes packed coaxially in a cylindrical shell
- ✓ One fluid flows inside the tubes while the other fluid flows through the shell
- ✓ We may have
 - Fixed head (tubes are permanently fixed inside the shell), or
 - Floating head (tube bundle may be removed for ease of cleaning and replacement)

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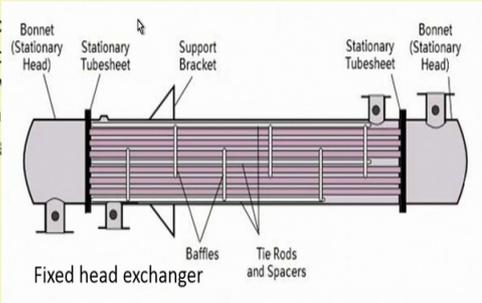


Now, we may have a fixed head, what we called tubes are permanently fixed inside the shell or we may have floating head the tube bundles maybe removed for ease of cleaning and replacement.

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Shell and Tube Heat Exchangers

- ✓ Contains a b
- ✓ One fluid fli
- ✓ We may ha
- Fixed h
- Floatin



Fixed head exchanger

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So, this is here, we find that we have the fixed head configuration here, this is the stationary head on the both the sides and here, we have the baffles and tie rods are tie rods, etcetera for the fixed head exchanger.

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Shell and Tube Heat Exchangers

- ✓ Contains a bundle of tubes
- ✓ One fluid flows through the tubes
- ✓ We may have
 - Fixed head
 - Floating head

Labels in diagram: Pass Partition, Stationary Tubesheet, Shell, Tie Rods and Spacers, Floating Tubesheet, Shell Cover, Stationary-Head Channel, Support Saddles, Baffles, Floating-head exchanger, Floating-Head Cover.

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And here we have the floating head kind of thing that here we find that these are floating head and these tubes are arranged a floating head. So, whenever we want to do some kind of maintenance or replacement, we can simply take out this head from the shell and even after cleaning or replacement, again, we can put it back into the shell.

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Shell and Tube Heat Exchangers

- ✓ The design is guided by TEMA (Tubular Exchanger Manufacturers Association) standards.
 - Class R is used for petroleum and related processing applications.
- ✓ The choice of configuration depends on
 - Fluids handled
 - Pressure drop
 - Heat transfer efficiency
 - Corrosion potential
 - Ease of cleaning

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So, these are the 2 configurations that is the floating head and the fixed head. Now these designs of these kind of shell and tube heat exchangers are guided by TEMA that is tubular exchanger manufactures association. So, these are some kind of standards fixed

by this TEMA according to which the shell and tube heat exchangers are manufactured and generally for the petroleum and related processing applications the classes R type of the shell and tube heat exchangers are used.

Now, the choice of the configuration would depend on the type of fluid, we are handling the pressure drop the pressure drop that is because whenever there is a fluid flowing through the pipelines they will be pressure drop. So, whatever the along the pressure drop is that will be that will decide the type of the heat exchanger and the pressure drop it translates into the cost of the compression. So, that is very important for us, then we have the heat transfer efficiency, they dictates that how big will be the heat exchanger because that will decide the heat transfer area needed and then we have the ease of cleaning and some corrosion potential of the heat exchanger by the fluid.

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Shell and Tube Heat Exchangers

- ✓ Shell OD up to 120 inch
- ✓ Tube OD varies between $\frac{1}{4}$ and 2 inch
 - Tube thickness: Given by Birmingham Wire Gage (BWG)
- ✓ Tube arrangements:
 - Square

The diagram shows a square tube arrangement with four tubes in a 2x2 grid. Each tube is represented by a circle with a cross inside. The tubes are arranged in a square pattern, with an arrow pointing to the center of the arrangement.

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Now, these are typical dimensions of the shell and the tube we find that shell OD can go up to one twenty inch whereas, the tube OD varies between one fourth inch to 2 inch and in this case, the tube thickness is given by the Birmingham wire gage and earlier we learnt about a schedule number, but in this case of heat exchanger we talk in terms of BWG or Birmingham Wire Gage or the thickness.

Now, there are several arrangements of the tubes how the all the tubes will be put in the in a bundle. So, first we have the square configuration in which we see that this if join

the centers of this 4 tubes, we find that this is looking like a square. So, this is called a square arrangement and then we have rotated square.

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Shell and Tube Heat Exchangers

- ✓ Shell OD up to 120 inch
- ✓ Tube OD varies between ¼ and 2 inch
 - Tube thickness: Given by Birmingham
- ✓ Tube arrangements:
 - Square
 - Rotated square

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In which we find there is slight modification in this thing that this is with respect to the front view.

So, this is looking like square that is on the front view it is looking like a bit rotated. So, this is the rotated square thing and next one we have the equilateral triangle.

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Shell and Tube Heat Exchangers

- ✓ Shell OD up to 120 inch
- ✓ Tube OD varies between ¼ and 2 inch
 - Tube thickness: Given by Birmingham Wi
- ✓ Tube arrangements:
 - Square
 - Rotated square
 - Equilateral triangle
- ✓ Tube pitch: Centre-to-centre distance between tubes
- ✓ Clearance: Minimum distance between tubes
- ✓ Pitch = Clearance + Outer diameter

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So, these are this is the one that this three tubes they are centered with center if are joined then they will be coming like a equilateral triangle. So, we have different types of this tube arrangements and this will be decided based on the pressure drop based on the heat transfer rate.

And we defined for these tube pitch that is a center to center distance between the tubes and then we have the clearance as we see if the pitch is here that between center to center as the pitch and the clearance is the minimum distance between the tubes that is this distance between the tubes are clearance and pitch is equal to the clearance plus the outer diameter. Now we can see that this particular distance pitch is equal to this clearance plus this plus this that these are 2 radii.

So, $2R$ means the diameter. So, this is how we are getting pitch equal to clearance plus outer diameter now.

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Baffles in Shell and Tube Heat Exchangers

- ✓ Used to
 - Support the tube bundle against bending and vibration
 - Make the shell-side fluid flow across the tube bundle, thereby enhancing the heat transfer rate.
- ✓ Types:
 - Plate (Single segment, double segment, triple segment)

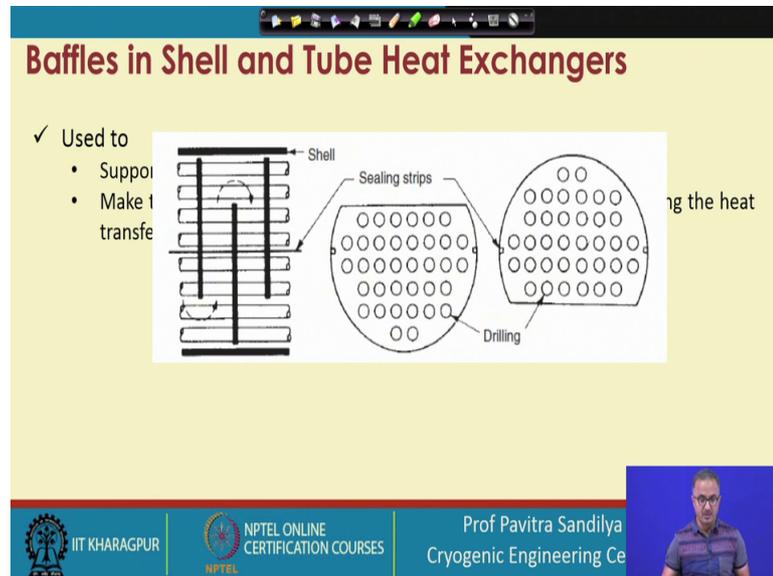
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We saw some baffles in the earlier figures. Now here we see why we need baffles, baffles are used to support the tube bundle against bending or vibration because they come at several lengths so far a very long lengths we need to hold them. So, that they do not bend or they do not vibrate. So, to restrict their vibration and bending we need the baffles.

And make the shell side fluid flow across the tube bundle. So, that we can get higher heat transfer because when the shell side tube, we found that the shell side fluid was taking

bends and by the taking the several bends we are able to enhance the rate of heat transfer. So, that is how also the baffles are helping for better heat exchange.

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So, here we have one type of baffle that this baffle what we see that this is the front view of the baffles. So, these are of segment of a circle, you can think of that here, we have this holes are nothing, but to accommodating the tube and on these 2 sides, we have some strips this strips will be helping to prevent any kind of channeling. So, we shall see those things.

So, these are sealing strips are used this sealing strips are used to prevent channeling and these are the drilled holes through which the tubes are passing and these are the shell and this is how these baffles are placed inside the tube and this shell side fluid is taking this bends and thereby increasing the rate of heat transfer.

Now we have several types of this baffles, one is plate type that is become the single segment, it may be double segment or it may be having triple segment.

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Baffles in Shell and Tube Heat Exchangers

- ✓ Used to
 - Support the tube bundle
 - Make the shell-side transfer rate.
- ✓ Types:
 - Plate (Single segmental)

enhancing the heat

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So, we have these find the this; this is we have only single segment baffle these baffle is on the lower side and this baffle is on this top side and then we have double segment here we find that it is as if we have cut down into 3 pieces full circle and these are the this is the middle one is this one and this one is this one and this one is this one.

So, that is how we make the double segmental baffle and a lastly, we have a triple segmental in this, we find that again, we are making 5 pieces out of this and again, this we see that we have 1; 1, 2, 3, 4 and 5. So, this 5 pieces are this 5 pieces here which have been placed in this tube to make this triple segmental baffle.

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Baffles in Shell and Tube Heat Exchangers

- ✓ Used to
 - Support the tube bundle against bending and vibration
 - Make the shell-side fluid flow across the tube bundle, thereby enhancing the heat transfer rate.
- ✓ Types:
 - Plate (Single segment, double segment, triple segment)
 - Disk and doughnut
 - Orifice
- ✓ Sealing strips: used to minimize channelling of the fluid between outer row of tubes and shell.
- ✓ Baffle cut = $\frac{\text{Height of cutout segment}}{\text{Shell ID}}$

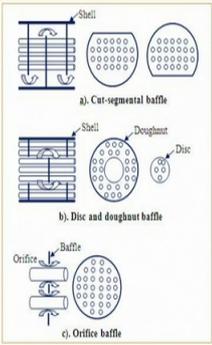
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Then we have the disk and doughnut type and orifice type.

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Baffles in Shell and Tube Heat Exchangers

- ✓ Used to
 - Support the tube bundle against bending and vibration
 - Make the shell-side fluid flow across the tube bundle, thereby enhancing the heat transfer rate.
- ✓ Types:
 - Plate (Single segment, double segment, triple segment)
 - Disk and doughnut
 - Orifice



a) Cut-segmental baffle

b) Disc and doughnut baffle

c) Orifice baffle

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And if we look at this figure, we see that this is the disk and doughnut type of the tube arrangement and this is the orifice type in the orifice type, we find that there is some orifice small hole within this things.

So, this is the orifice type orifice means small hole. So, after learning about this as I told you the sealing strips are used to minimize channelling of the fluid between the outer row

of the tubes and the shell and we define baffle cut as the height of the cutout segment to the shell inner diameter.

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Passes of Shell and Tube Heat Exchangers

- ✓ Pass denotes number of times
 - Tube-side fluid travels the whole length of the shell
 - Shell-side fluid travels the whole length of the tube
- ✓ Multiples passes
 - Increase the contact time between tube-side and shell-side fluids thereby enhancing heat transfer
 - May be used for either or both tube-side and shell-side fluids.
 - Are achieved by
 - Having U-turns on tube-side
 - Partitioning the shell with longitudinal baffles.
- ✓ Tube-side passes: up to 16; Shell-side passes: Up to 6

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So, we use several passes and what are passes a pass denotes number of times tube side fluid travels the whole length of the shell or the shell side fluid travels the whole length of the tube.

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Passes of Shell and Tube Heat Exchangers

- ✓ Pass denotes number of times
 - Tube
 - Shell

Shell-side fluid In shell
Tube-side fluid Out tube
Out In

(a) One-shell pass and two-tube passes

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So, here we see that in this case the shell side is traveling this way once, it is traveling. So, it is only one pass. So, it is only once, it is flowing all over the length of the tube. So,

it is one pass whereas, in case of this tube side fluid; what we find first, it traverses the whole length of the shell fluid and then again, it travels through another length. So, it is having 2 passes. So, in this case, we find we have 1 shell pass and 1 and 2 tube passes.

Now, multi passes increase the contact time between the tube side and the shell side fluids, thereby enhancing the rate of heat transfer and there may be used for either or both the to the tube side and the shell side fluids and how do we achieve them that in case of tube side multiple passes, we give some u turns to the tubes, whereas, in case of the shell side fluid what we do we partition with some longitudinal baffles.

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Passes of Shell and Tube Heat Exchangers

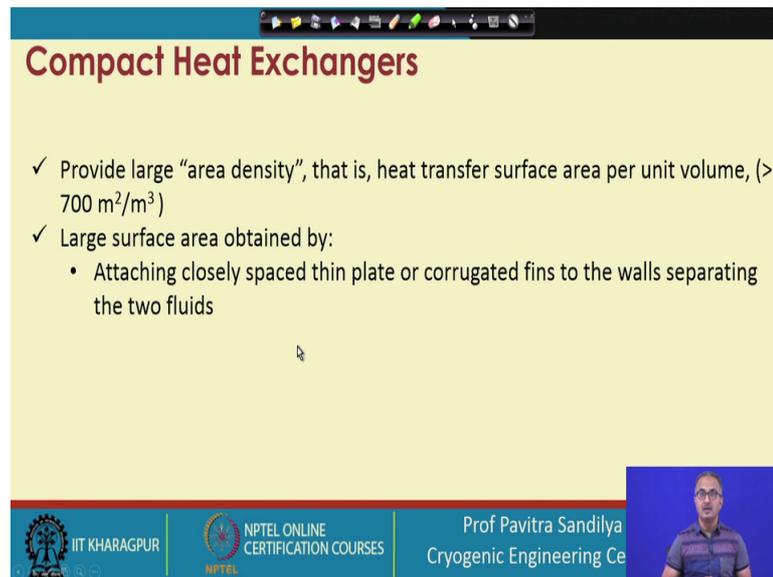
- ✓ Pass denotes number of times
 - Tube-side fluid travels t
 - Shell-side fluid travels t
- ✓ Multiples passes
 - Increase the contact enhancing heat transfe
 - May be used for either
 - Are achieved by
 - Having U-turns on tu
 - Partitioning the shel

(b) Two-shell passes and four-tube passes

And as we see here that we have middle made the multiple passes for the tubes side by putting these u turns at the ends, whereas, for the shell side we put this kind of a longitudinal barrier. So, that this fluid will come in a shell side, it will flow like this and again, it will flow like this; so, that is how we are getting 2 passes for the shell side and 4 passes; 1, 2, 3 and 4; 4 passes for the tube side fluid.

And generally tube side passes can number up to 16 and we may have up to 6 number of shell side passes please mind it that even though passes are good for enhancing the heat transfer, but they also increase the pressure drop. So, we have to carefully chose the number of passes for a given application. Now lastly, we shall be talking about compact heat exchanger, in this case, we have compact means they are the area density that is the heat transfer area per unit volume of the exchanger is large.

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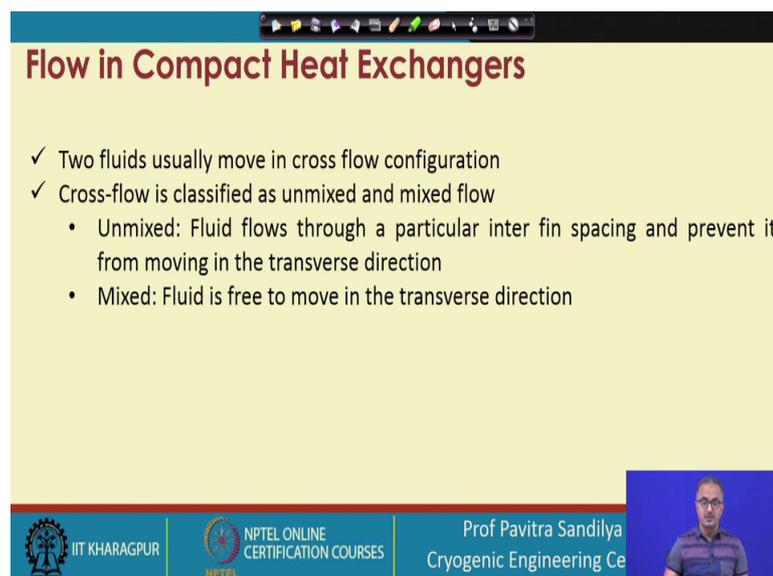
Compact Heat Exchangers

- ✓ Provide large “area density”, that is, heat transfer surface area per unit volume, ($> 700 \text{ m}^2/\text{m}^3$)
- ✓ Large surface area obtained by:
 - Attaching closely spaced thin plate or corrugated fins to the walls separating the two fluids

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So, in this case, large means if we have any exchangers with more than 700 square meter per cubic meter of the specific surface area, then we call it a compact heat exchanger and in this case, we obtain large surface area by attaching closely spaced thin plate or corrugated fins to the walls separating the fluids. So, we have we can have various types of arrangements to provide heat transfer area between the 2 fluids. So, there is no hard and fast rule in to design this.

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Flow in Compact Heat Exchangers

- ✓ Two fluids usually move in cross flow configuration
- ✓ Cross-flow is classified as unmixed and mixed flow
 - Unmixed: Fluid flows through a particular inter fin spacing and prevent it from moving in the transverse direction
 - Mixed: Fluid is free to move in the transverse direction

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So, let's see, what happens that 2 fluids usually move in cross flow configuration and cross flow configuration may again be in be unmixed flow or mixed flow and what will happens in unmixed flow, that fluids flow through a particular inner fin spacing and prevent it from moving in the transverse direction and in mixed flow, there is a transverse direction movement also.

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Flow in Compact Heat Exchangers

- ✓ Two f
- ✓ Cross
- U
- N

(a) Both fluids unmixed: Shows multiple parallel tube plates. Fluids flow through the tubes and across the plates in a cross-flow arrangement. Labels include 'Cross-flow (unmixed)' and 'Tube flow (unmixed)'.

(b) One fluid mixed, one fluid unmixed: Shows a bundle of tubes within a shell. Fluids flow through the tubes and across the shell in a cross-flow arrangement. Labels include 'Cross-flow (mixed)' and 'Tube flow (unmixed)'.

spacing and prevent it

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So, we can see from this figures that what we mean by unmixed that the cross flow is happening the tubes are coming like this. So, the if fluid is coming out of this tube side and 90 degree to it, we have the another fluid going. So, this is that is why it is cross flow and in this case, what will happening this; this movement of this particular fluid is restricted within this tube plates. So, it is not able to move in a in a transverse direction. So, we are calling it a unmixed flow, whereas, in this case, we are not putting any kind of partition there is again a cross flow.

But there is a, the transverse movement is allowed. So, this is a unmixed; it is a mixed flow for this fluid and unmixed for the tube fluid. So, this is both fluids are unmixed in this case, tube fluid is unmixed whereas, the other fluid is mixed.

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Types of Compact Heat Exchangers

- ✓ Plate and Frame Heat Exchangers
- ✓ Plate-Fin Heat Exchangers
- ✓ Brazed Plate Heat Exchangers
- ✓ Welded Plate Heat Exchanger
- ✓ Brazed Plate-Fin Heat Exchangers
- ✓ Diffusion-Bonded Plate-Fin Heat Exchangers
- ✓ Spiral Heat Exchangers
- ✓ Printed Circuit Heat Exchangers
- ✓ Plate and Shell Heat Exchangers
- ✓ Polymer Heat Exchangers

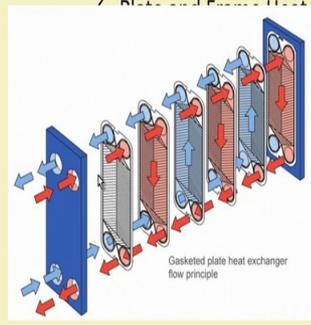


Now, we have several designs of this, first, let me let me just show you that how its looks like that is one is the which is very common plate and frame heat exchanger and here it is that we have this two fluids are going.

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Types of Compact Heat Exchangers

✓ Plate and Frame Heat Exchangers



Gasketed plate heat exchanger flow principle

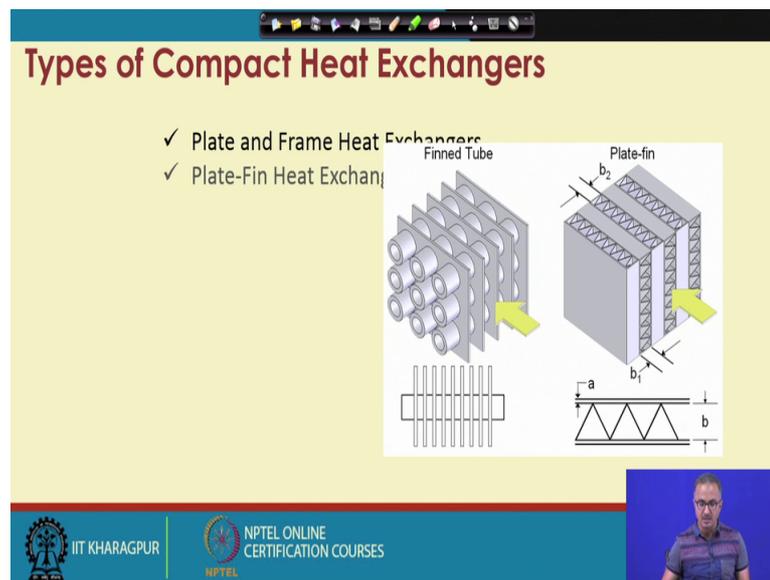


Let us look at the red line first that we find that the red fluid is going like this and it is going through coming down like this and it is collected, it is flow taking this channel and the other fluid is taking the other channel and they are going from the 2 sides means this heat exchangers happening between these 2 plates means this plates, we have shown for

our convenience, we have just separate the flow, but in actual actuality what happens this plates are there join with each other with some gas kit.

So, this is how we find these 2 fluids are exchanging the energy between the this through this plates. So, this is the my arrangement for the plate and frame heat exchanger, then we have plate fin heat exchanger in which what we are doing we are using some kind of fins over here.

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So, this is the plate fin we are using. So, here again the tubes are going and these tubes are some fins over there these are fins of the tube and these fins are providing some more surface area for the heat transfer or this kind of we can also have this kind of corrugations as fins.

So, it is a corrugated plates. So, these corrugations are also able to provide more surface area for the heat transfer. So, this is one of one fluid is going like this and another fluid is going through the tubes. So, this is way, we are able to get high surface area per unit volume and there are several other types of these compact heat exchangers and these are many designs are there and all these designs are being also innovated new designs are being innovated. So, there can be many types of this kind of compact heat exchangers. So, we have learnt the basic heat exchangers used in the natural gas sys industries. So, these are some of the references which we can refer to for more detail about the heat exchangers.

Thank you.