Chemical Process Utilities
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Lecture – 6
Heat Transfer Utilities-I

Welcome to the new concept of heat transfer utilities. As we know, heat transfer media are the integral part of chemical process utilities without which we cannot anticipate, or we cannot observe any kind of a process, and we have already know that the water, different types of heat transfer fluids etc. are an integral part of any chemical process. Now alone heat transfer media cannot fulfill the desired requirement for this we need certain other heat transfer equipment or heat transfer utilities.

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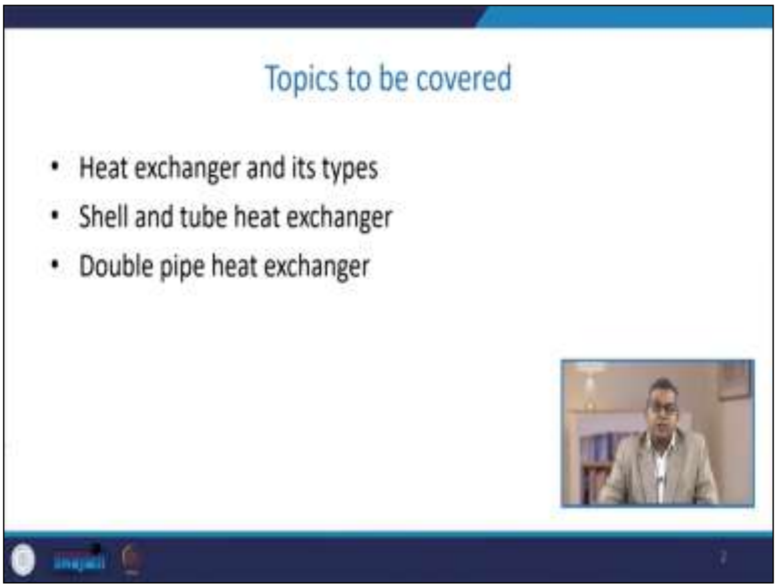

In this particular lecture, we will cover different types of heat exchangers; we will have a brief outlook on the shell and tube heat exchangers we will give a brief outline of double pipe heat exchangers. Heat transfer fluid or heat exchangers are an integral part of any chemical process or chemical operation. The basic concept of a heat exchanger is to transfer the heat energy generated, whether it is from an exothermic reaction or some sort of external source.

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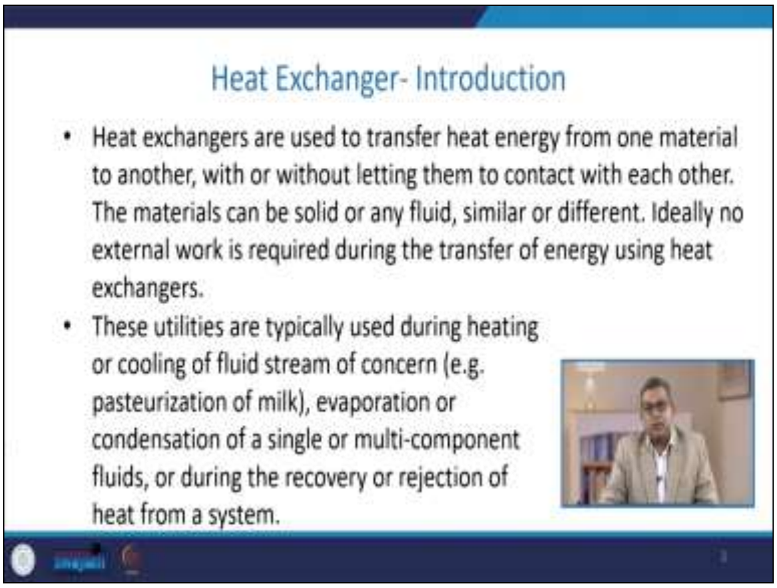

So, the basic concept of heat exchangers is that they are used to transfer the heat energy from one source to another without letting them contact each other. So, this is again a very crucial aspect. Sometimes, you need to let the intimate contact between the heat transfer media and the process material be in question, or sometimes you do not. These materials can be solid or any fluid similar or different ideally. No external work is required to transfer energy using a heat exchanger.

So, that is one ideal aspect. So, while designing any type of heat exchanger or heat transfer media, this concept needs to be addressed. Now when we talk about the heat exchanger utilities. So, they have typically used to heat or cool any fluid stream. Now let us take one example of the pasteurization of milk here. We need to go for an indirect heat exchanger.

Evaporation is again one of the integral parts of chemical processes condensation of a single or multi-component fluid or sometimes during the recovery or rejection of heat from a system. Let us take one example; during the production process of ammonia, it is a highly exothermic reaction and a very temperature-sensitive reaction. During the entire process, you need to maintain the appropriate temperature; otherwise, your entire reaction mass will collapse.

So, in that case, you need to continuously remove whatever excess heat is being generated in due course of time, and for this, you need to since this is a highly exothermic reaction. So, for this, you need to have a proper heat exchange fluid or heat transfer media or heat exchanger device through which you can continuously extract the heat. So that the direction mass can be maintained at the appropriate temperature, whatever desired temperature. So, these are some of the important aspects of heat exchange equipment.

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In certain cases, the goal is to disaggregate concentrate distillation performance; these govern the process fluid. Now heat transmission between fluids occurs in some heat exchangers; sometimes, the fluids are in direct, intimate contact through a dividing wall. So, when we talk about these two aspects, the heat exchangers can be classified in two ways: direct contact heat exchangers or indirect contact heat exchangers.

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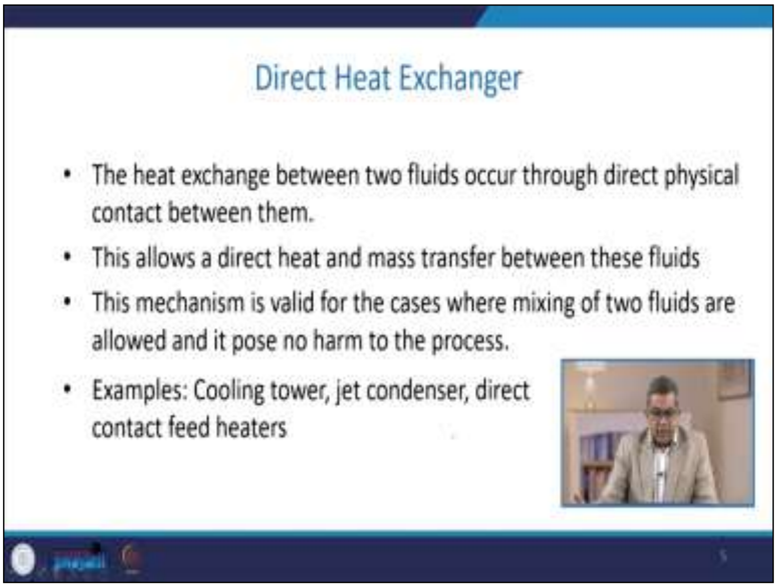

Now let us have a brief outlook on the direct heat exchanger or direct type of heat exchanger. Now the heat exchange between two fluids occurs through direct physical contact between them. Now, this allows a direct heat and mass transfer between these two fluids because they are in direct contact; then again, the mass transfer will occur. Now, this mechanism is valid for the cases where mixing two fluids is allowed and poses no harm to the process.

So, sometimes you need to have any kind of material in which you may introduce the direct pressurized stream; it serves the purpose of heat transfer and agitation. One example is the cooling tower jet condenser direct contact feed heaters. Now let us have a look at the indirect heat exchangers.

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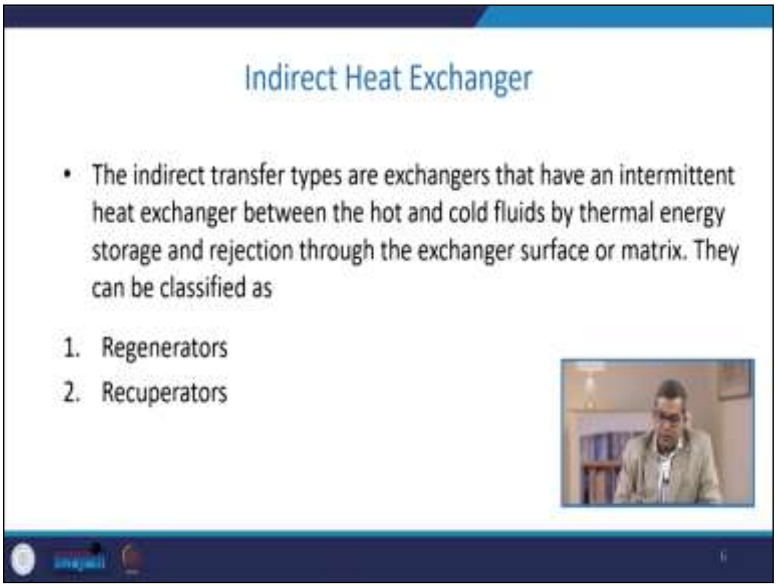

The indirect heat transfer type is the heat exchangers with intermittent heat exchange between the hot and cold fluids by thermal energy, which may be by storage rejection through the exchanger surface or matrix. Now they can be further classified as regenerators or recuperators. The hot and cold fluid are passed through a solid regenerative matrix alternately. The solid matrix has a high heat-absorbing capacity through which the colder fluid transfers the heat as a sink.

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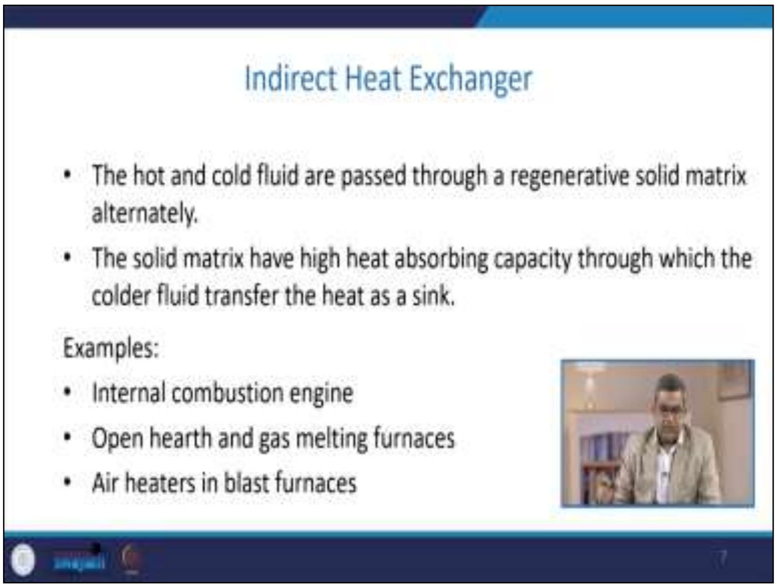

Examples of these indirect heat exchangers are internal combustion engines open earth, and gas melting furnace heat air heaters in the blast furnace.

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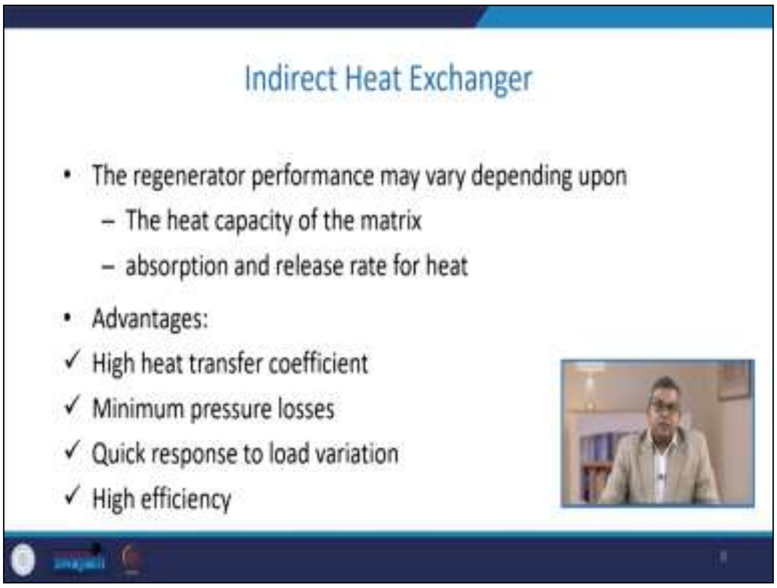

The regenerator performance may vary depending upon the heat capacity of the matrix absorption or release rate for heat. There are various advantages associated with the indirect heat exchangers like high heat transfer coefficient, minimum pressure losses, quick response to load variation, or sometimes high efficiency.

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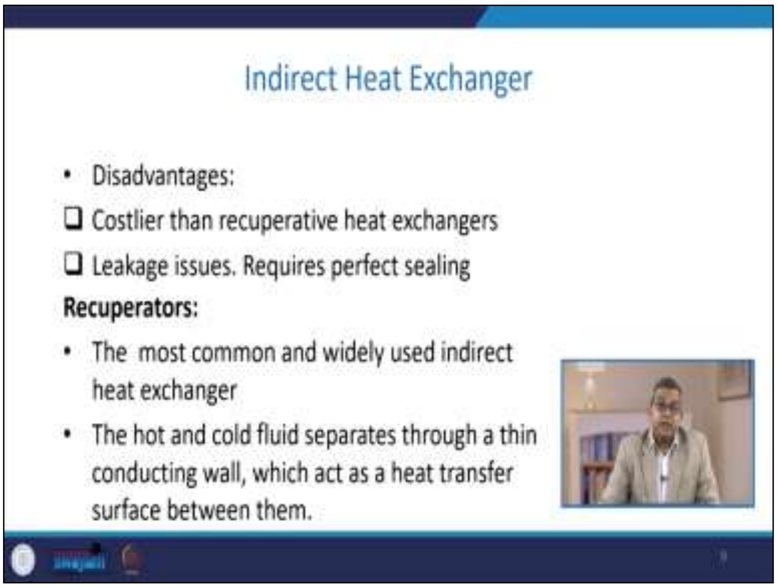

But simultaneously, there are a couple of disadvantages. They are a bit costlier than recuperative heat exchangers sometimes, you may experience the leakage issue they require the perfect ceiling, and this is again some sort of a costlier affair. Now let us have a look at the recuperators, the most common and widely used indirect heat exchangers. The hot and cold fluid separates through a thin conducting wall which has a heat trans, which acts as a heat transfer surface between them.

It may be like this here you may have a heat transfer fluid here on the surface you need to go, and this is the thin conducting wall.

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Let us have a couple of examples like the radiator of vehicle oil coolers, air preheaters, economizers, superheaters, being used in different types of boilers, condensers, pasteurization apparatus, etc. There are several advantages linked with this type of heat exchanger like they are easy construction, are very economical, and provide a high surface area for heat exchange.

But simultaneously, they attract certain disadvantages like they have less heat transfer coefficient, less generating capacity, sometimes you may experience the clogging scaling issues etc. So, these are some of the disadvantages. So, you need to optimize things accordingly.

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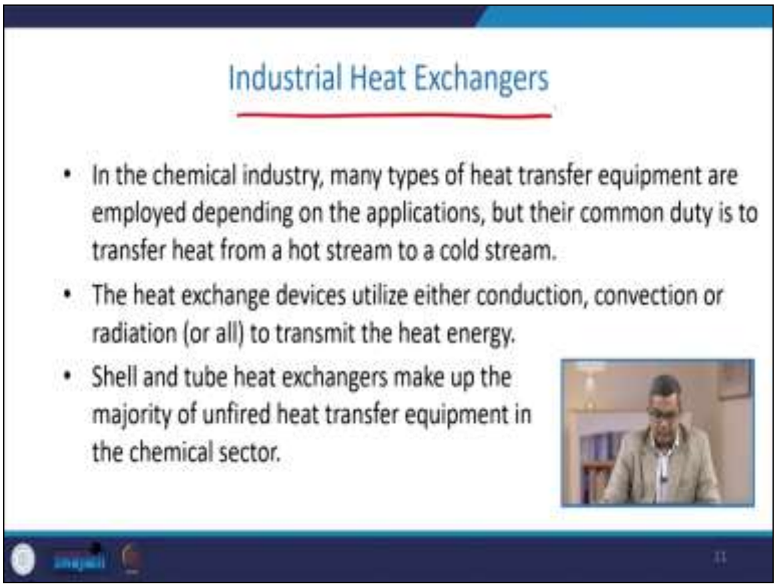

Now let us talk about the industrial heat exchangers. Many types of heat transfer equipment in chemical industries are used depending on the various types of applications in question. Because there is n number of products available for this, you need to have n number of different applications. Their common duty is to transfer the heat from a hot stream to a cold one.

The heat exchange devices utilize either conduction convection or radiation. These three are the major phenomena of heat transfer. The basic objective of all three phenomena is to transmit the heat energy shell and tube heat exchangers. They make up the majority of unfired heat transfer equipment in the chemical sector.

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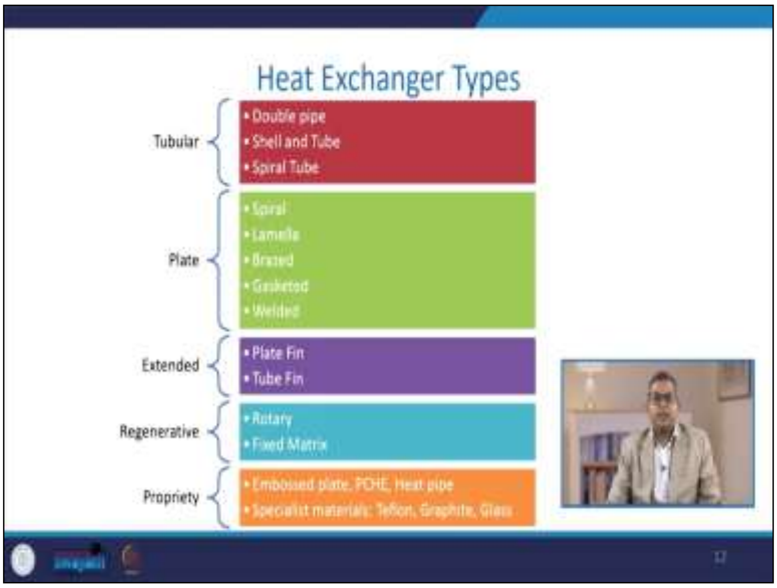

Now let us have a discussion about the different types of heat exchangers. There are tubular types of heat exchangers. This may be the double pipe shell and tube spiral tube type of heat exchanger. Then plate and frame type of heat exchanger again they offer the spiral type of heat exchanger than lamina braised gasketed welded. Then there is an extended type of heat exchanger, plate-fin type of heat exchanger then, two fin type of heat exchanger then regenerative they are of two types one is the rotary and then fixed matrix.

Then propriety they are imposed plate PCHC heat pipe etc. specialized material like Teflon, graphite, glass, etc. are being used.

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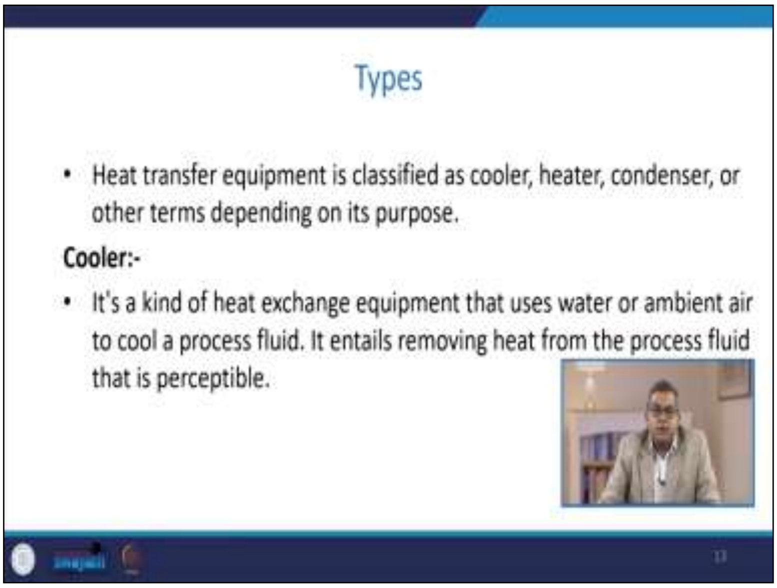

Now, when we; talk about the different types; so the heat transfer equipment is classified as a cooler heater condenser or other term depending upon its purpose and application.

Now cooler is a kind of heat exchange equipment that uses water or ambient air to cool a process fluid. The other parameters can be fixed according to the requirement. Now it entails removing the heat from the process fluid that is perceptible.

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This is an example of evaporating cooling of industrial processes and applications. So, sometimes people may ask how a wet surface air cooler works. So, some of the air is induced downward over the tube bundles, water flows downward along with the air, and the heat from the process stream is released to the cascading water to the cascading water. Now the vapourization causes the heat transfer to the air stream.

Now air stream is usually forced to turn around, say 180 degrees Celsius creating maximum water removal, and at last, the fans discharge air vertically at a very high velocity. So, usually, in this particular aspect, the process fluid being used as hot water and cooling food fluid is ambient air.

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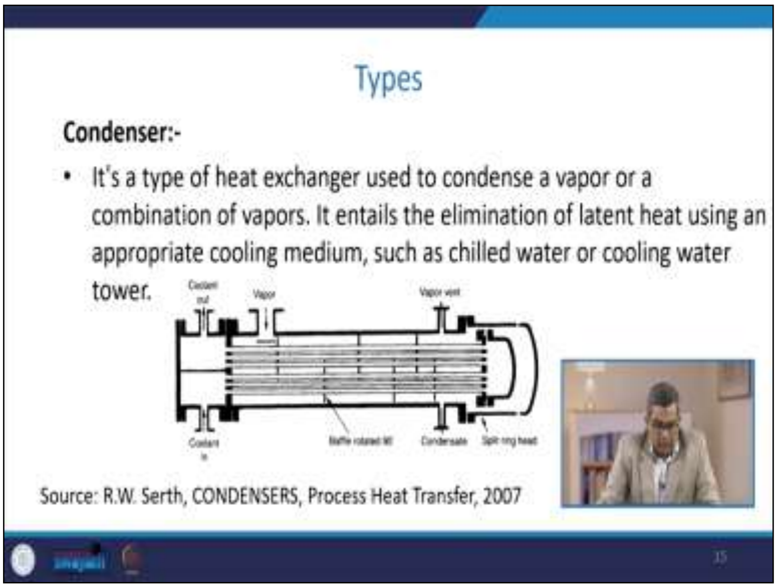

Now let us take a condenser, the most common type of thing being used in various chemical industries. Now, this is the type of exchanger used to condense a vapor, or a combination of different vapors may occur in any kind of chemical process. Now it entails the elimination of latent heat using an appropriate cooling medium, maybe sometimes chilled water cooling water or sometimes any kind of synthetic fluid which can be used or which can extract the desired quantum of heat from the fluid.

Now here this is you can see the this is vapor inlet, and this is the vapor vent, and here you are introducing the coolant which can surpass through this way, and heated coolant can come out from this way. There are certain baffles to provide the maximum heat transfer surfaces, and from here, you can get the condensate out. So, very you can say the simple type of condenser and be popularly used in various chemical industries.

Similarly, one of the basics is that you can always see in a chemistry lab when we perform the alcohol water solution to distill the alcohol out because alcohol has a lower boiling point than water. So, you supply the heat, and thereafter this is the alcohol plus water mixture, and here you can have a condenser which is sometimes the cold circulating water, and here you can observe the drops of alcohol. So, this is again one type of simpler type of condensation phenomenon.

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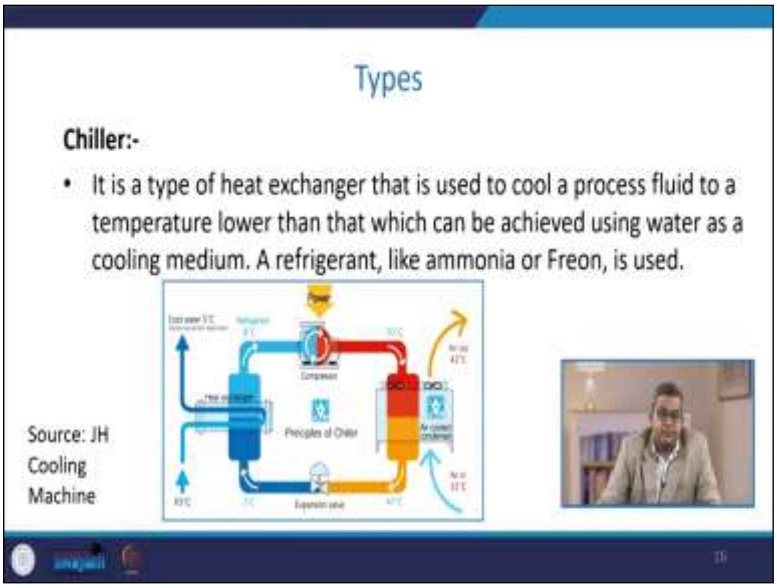

Now there are chillers. Now, this type of heat exchanger is sometimes used to cool a process fluid to a temperature lower than that, which can be achieved using water as a cooling media. And in this particular operation, a refrigerant like sometimes ammonia or a freon is used. So, this is the simplest form of a chiller here, you have a refrigerant, and this is the heat exchanger supplied with the cold water, which is where you require, say at a lower temperature.

So, you supply a little bit of hotter water and then get a lower temperature cold water. Again usually, your refrigeration cycle prevails here. You have the condenser, your power supply, and the expansion wall. So, we have already gone through the refrigeration cycle. So, the usual refrigeration cycle prevails at this particular chiller. Let us talk about the most popular type of heat exchangers: shell and tube heat exchangers.

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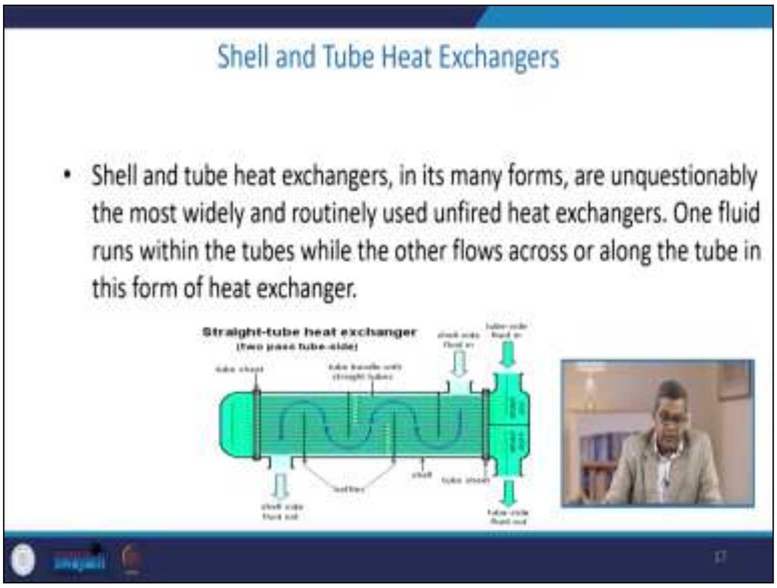

In its many forms, the shell and tube heat exchanger is unquestionably the most popular, most widely, or routinely used unfired heat exchanger. One fluid runs within the tubes while the other flows across the tube in the form of a heat exchanger. Now here, you can see there are two fluids one is the tube side fluid, and this is the shell side fluid. So, this is why because it offers the wide spectrum of uses with the help of different baffles and a lot of choices etc.

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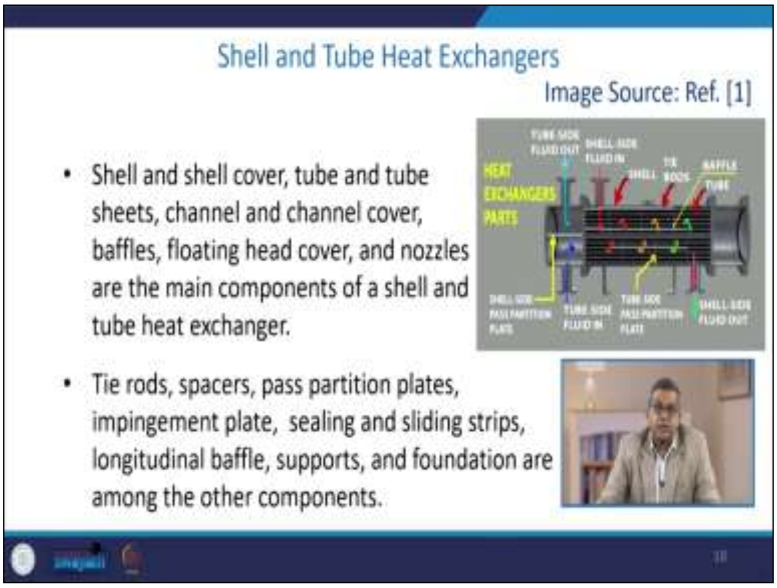

Now shell and shell cover tube and tube sheets channels and channel cover baffles floating head cover nozzles they are the main component of any type of a shell and tube heat exchanger you can see here this is again the anatomy of shell and tube heat exchanger. Now tie rods spacers pass partition plates impingement plates ceiling and sliding strips longitudinal baffle supports and foundation are among the other components which are required in the shell into the heat exchanger.

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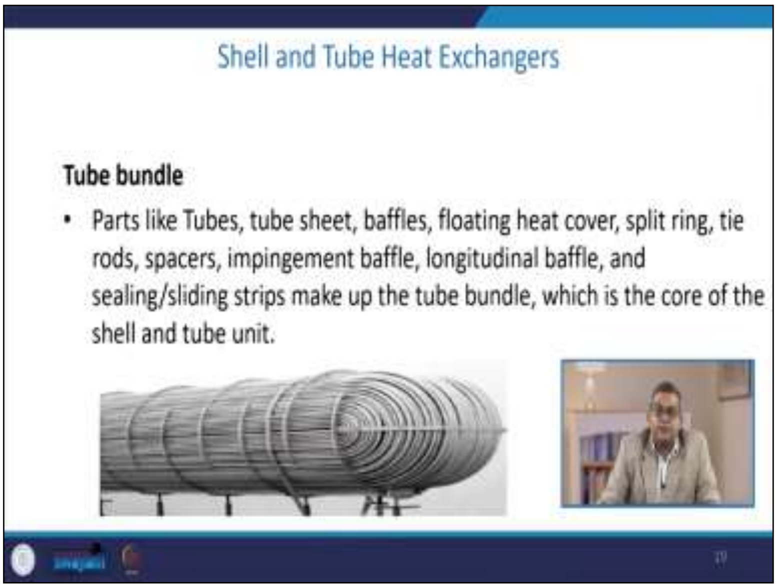

The tube bundle is again the integral part of the SNT or shell, and tube heat exchanger like parts like tubes, tube sheets, baffles, floating heat cover, split ring, tie rods, spacers, infringement baffle, longitudinal baffle, sealing/sliding strips they make the tube bundle, you can see over here the tube bundle which is the core or you can see the heart of any shell and tube heat exchanger.

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Tubes are the most important component because actual heat transmission or heat transfer occurs via the tube wall. Here you can see the bundle of tubes. One fluid circulates inside the tube while another circulates over or along the tube side here. Now tubes are usually defined by the outer diameter, which is sometimes referred to as OD and wall thickness.

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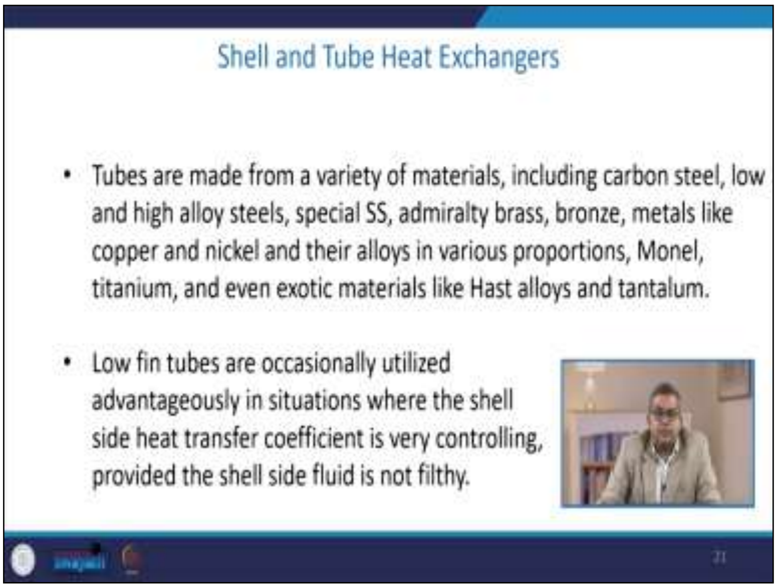

Tubes are made from a variety of materials, including carbon steel, low and high alloy steel, a special type of stainless steel, admiralty brass, bronze, metal like copper and nickel, and their alloys in various proportions, monel, titanium, and even exotic material like hast alloys and tantalum. Low fin tubes are sometimes utilized advantageously when the shell side heat transfer coefficient is very controlling, provided the shell side flute is not flitty.

While selecting the tube material, there are a couple of important things: minimization of a scale formation. The second is that non-corrosive third is that it should be non-reactive etc. So, there are various issues that we should address before selecting the different types of tube materials. Now, these two bundles are held together with tie rods like this here, you can see.

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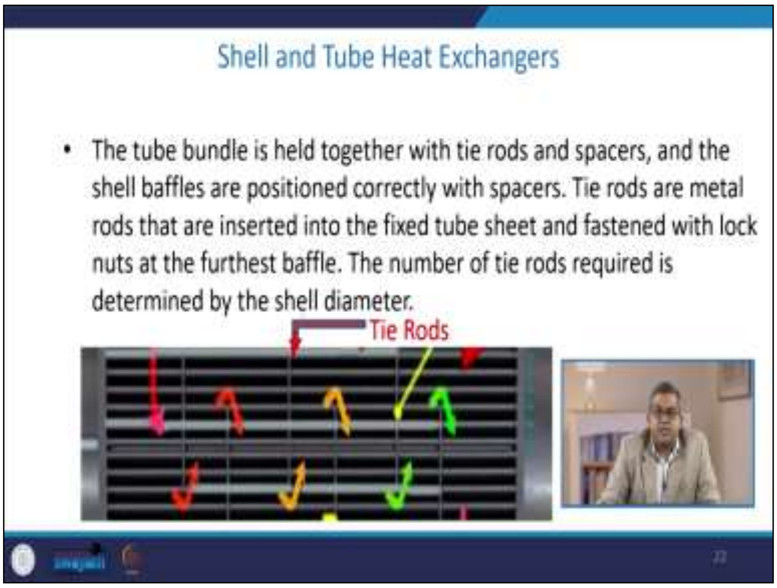

And spacers, the shell baffles are positioned correctly with a spacer. Now tie rods are metal rods that are inserted into the fixed tube sheets and fastened with the lock nuts at the furthest level. The number of tie rods required is determined by the shell diameter what is the shell diameter. So, based on this one, you can assess how many tie rods are required.

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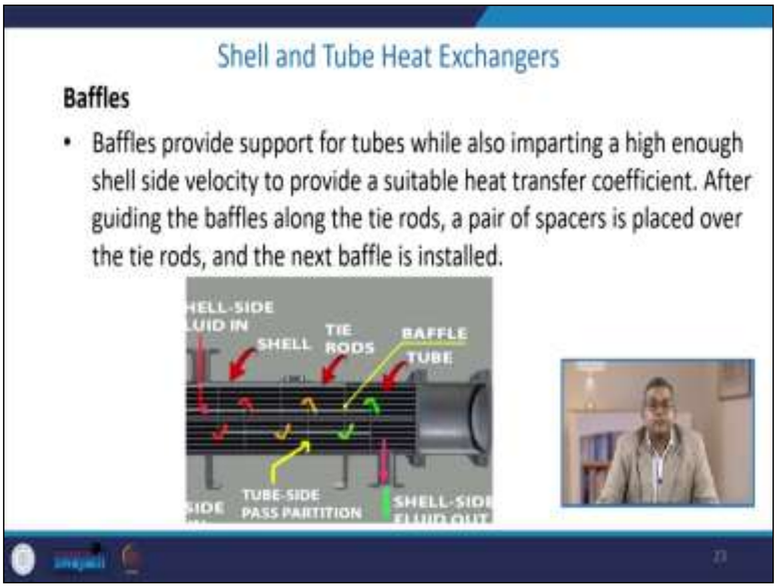

Then baffles provide support for the tubes while imparting a high enough shell side velocity to provide a suitable heat transfer coefficient. After guiding the baffles along the tie rods, a pair of a spacer is placed over the tie rods, and the next baffle is installed. So, you can see these are the tie rods these are the baffle tubes.

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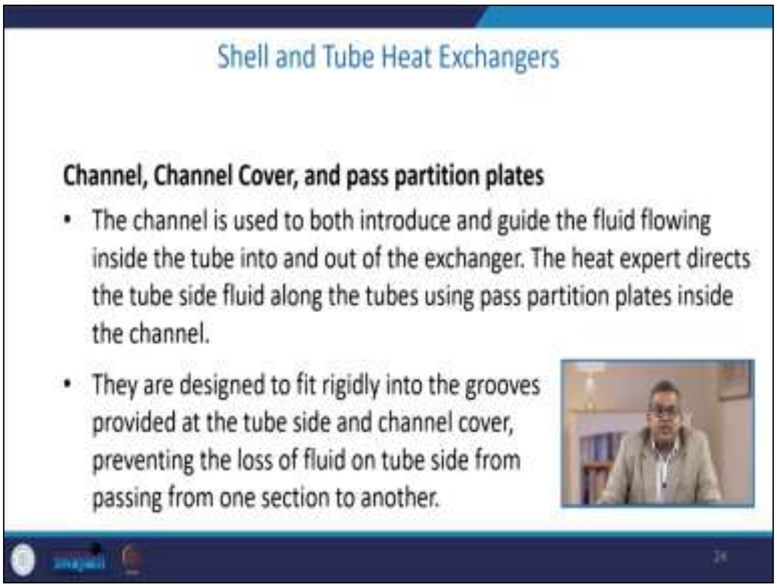

Now let us talk about the channel, channel cover, and the pass partition plates. The channel is used to both introduce and guide the fluid flowing inside the tube into and out of the exchanger. The heating expert usually directs the tube side flue along the tubes using pass partition plates inside the channel. They are now designed to fit rigidly into the grooves provided at the tube side and the channel cover, preventing the loss of fluid on the tube side from passing from one section to another.

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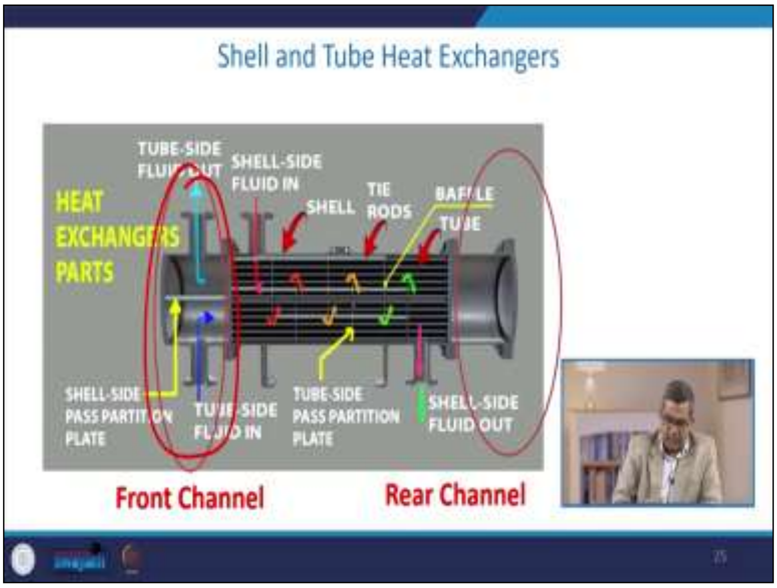

Now here you see the concept of the front channel and the rear channel. Now, this is the shell side pass partition plate, and here you see the shell fluid in, and here the tube side fluid in. This is the tube side pass partition plate shown.

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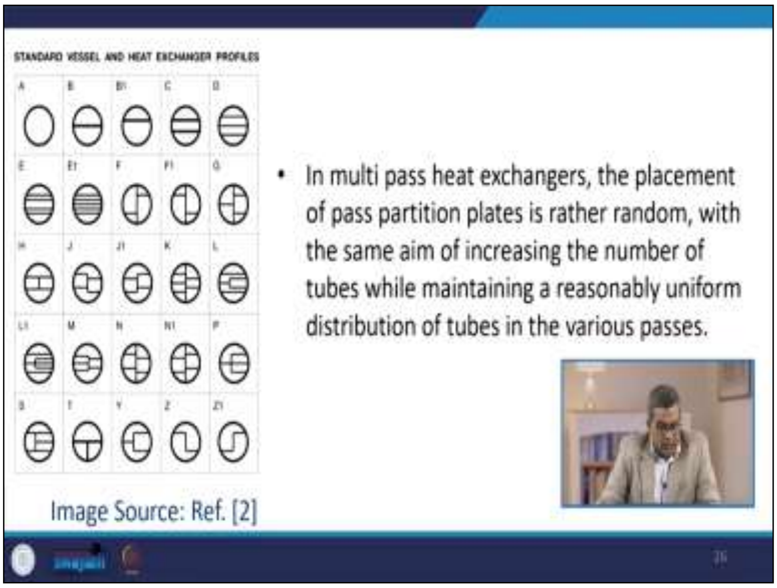

Now there are various standard vessel and heat exchanger profiles. So, in the multipass heat exchanger, the placement of pass partition plate is rather random to increase the number of tubes while maintaining a reasonably uniform distribution of tubes in various passes.

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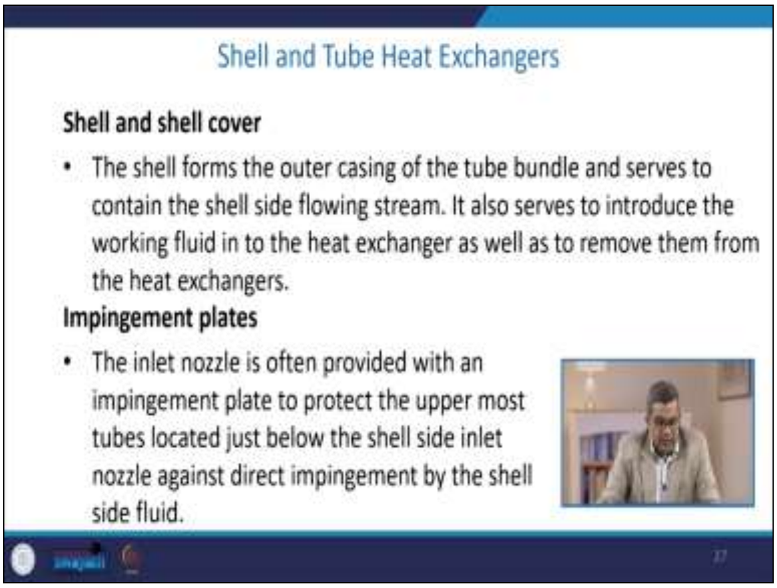

Now shell and shell cover: the shell forms the outer casing of the tube bundle and serves to contain the shell side flowing stream. It also serves to introduce the working fluid into the heat exchanger as well as to remove them from the heat exchanger. Impingement plates the inlet nozzle is often provided with an impingement plate to protect the uppermost tube located just below the shell side inlet nozzle against direct impingement by the shell side fluid. So otherwise, if it is not there, wear tear may occur.

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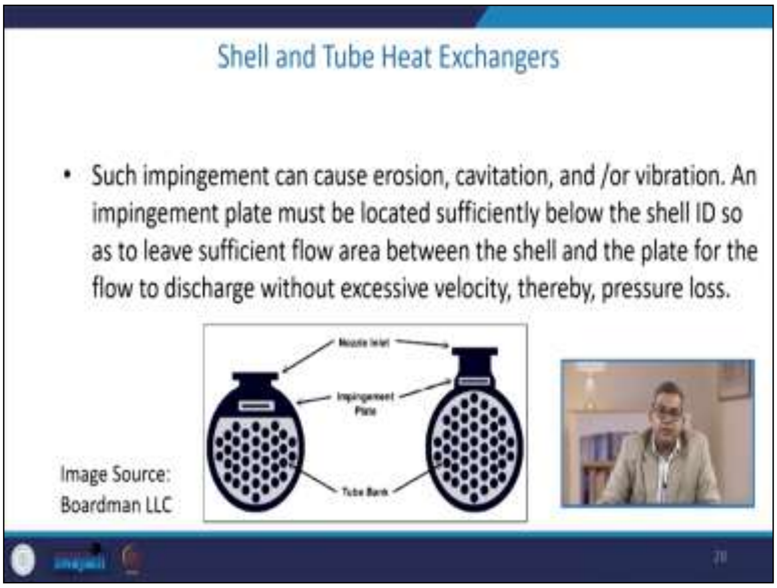

Now such impingement can cause erosion cavitation or vibration. An impingement plate must be located sufficiently below the shell's inner diameter to leave sufficient flow between the shell and the plate for the flow to discharge without excessive velocity and thereby pressure loss. Now here you see that these are the impingement plates, the nozzle and inlet, and the front section of the shell and tube heat exchanger. So, this is the tube bank.

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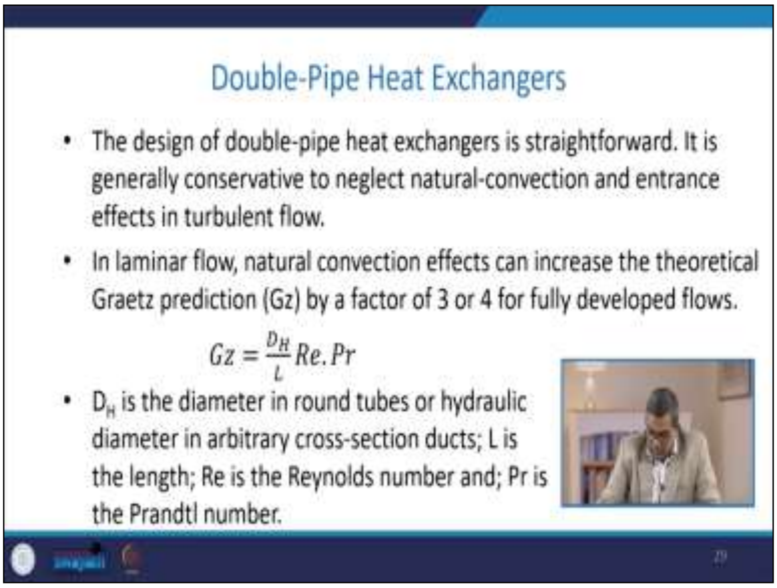

Now let us talk about the double pipe heat exchanger. The design of a double pipe heat exchanger is extremely straightforward. It is generally conservative to neglect the natural convection and entrance effect in a turbulent flow. The natural convection effect in laminar flow can increase the theoretical grades prediction G z by a factor of three or four for fully developed flows.

Now we know that G z is the grades prediction that is

$$Gz = \frac{D_H}{L} Re.Pr$$

D_H, is the diameter in round tubes or hydraulic diameter in arbitrary cross-section ducts, L is the length, Re is the Reynolds number, and Pr is the Prandtl number.

So, this is the usual heat transfer equation.

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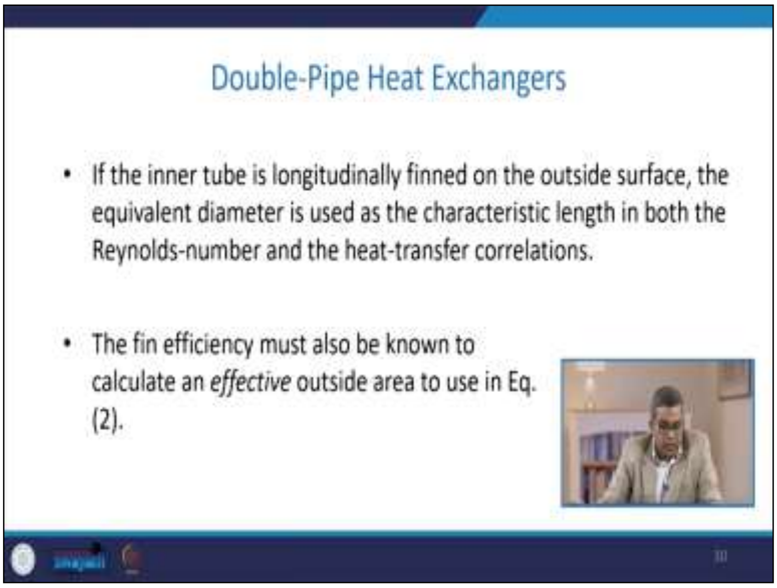

If the inner tube is longitudinally finned on the outside surface, the equivalent diameter is used as the characteristic length in both the Reynolds number and the heat transfer correlation. So, the fin efficiency must also be known to calculate an effective outside area to use in the previous equation.

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Now fitting use usually contributes strongly to the pressure drop on the annulus side. Now a general method for predicting this is for this usually they are not reliable and manufacturers data should be used when available and usually all the manufacturers they use to supply such kind of calibration data. Now double-pipe exchangers are often piped in complex series-parallel arrangements on both sides.

The MTD to be used is derived by for some of these arrangements and is reported in the DQ Kern process heat transfer book.

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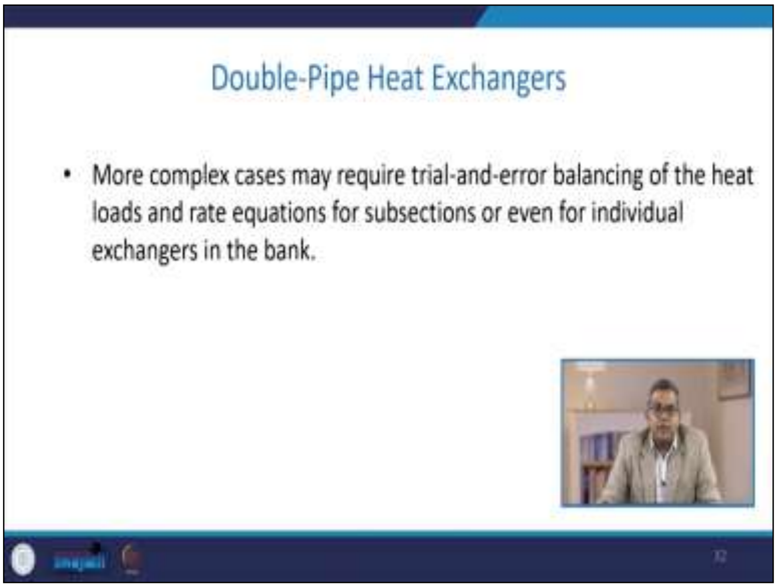

Now more complex cases, sometimes they may require trial and error balancing of the heat loads and rate equations for subsection or even for individual exchanges in the bank. So, that is very important. Now let us have a look at the baffle shell and tube heat exchangers.

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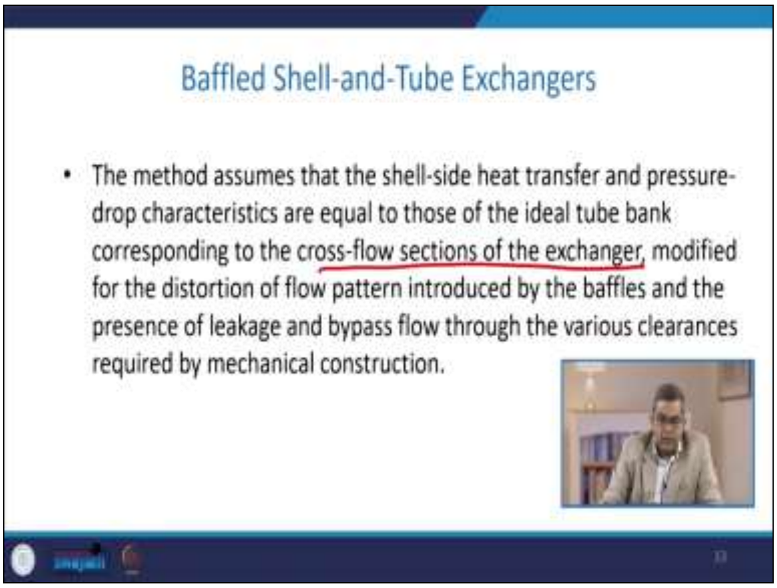

The method assumes that shell side heat transfer and pressure drop characteristics are equal to those of the ideal tube bank that corresponds to the cross-flow section of the exchanger, modified for the distortion of the fluid pattern introduced by the baffle and the presence of leakage and bypass flow through the various type of a clearance they require the by the as required by the mechanical construction.

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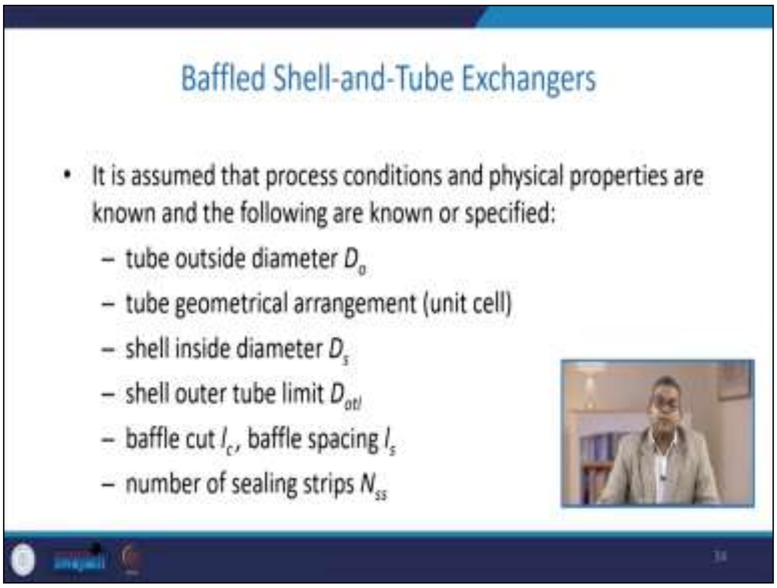

It is assumed that the process conditions and physical properties are known, and different types of parameters that should also be known are enlisted, like tube outside diameter D_o. Then tube geometrical arrangement per unit cell then shell inside diameter D_s, shell outer tube limit, baffle cut, baffle spacing, and number of ceiling strips referred as N_{ss}.

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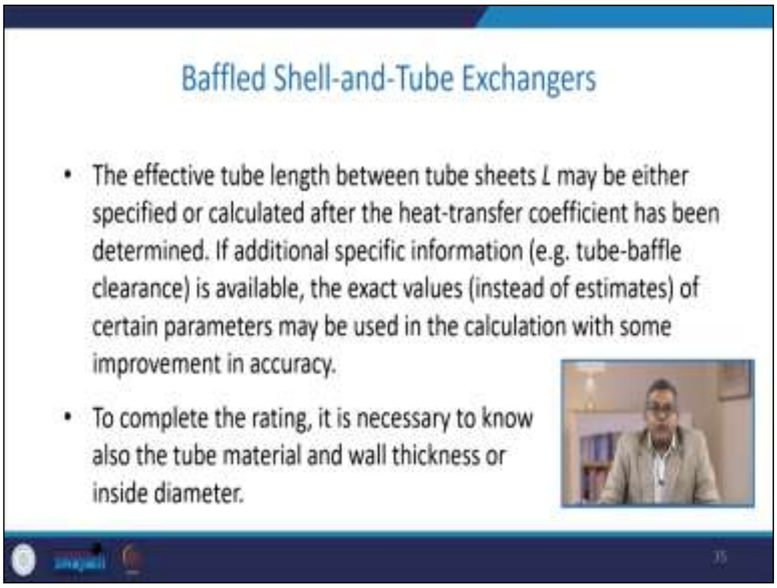

The effective tube length between the tube sheets L may be either specified or calculated after the heat transfer coefficient has been determined. Now, if additional specific information sometimes, like tube buffer clearance etc., is available, the exact value instead of the estimated or assumed value of certain parameters may be used in the calculation of some of the improvements in the calculation with some accuracy.

To complete the rating, it is necessary to know sometimes the tube material, and wall thickness or inside diameter is also required.

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Though apparently the best in the open literature, this rating method is not extremely accurate. So while designing a very complex situation, you need some sort of accuracy.

So, this method predicted a shell side coefficient from about 50% to 100% high while the pressure drop range is sometimes assumed to be from about 50% low to 200% high.

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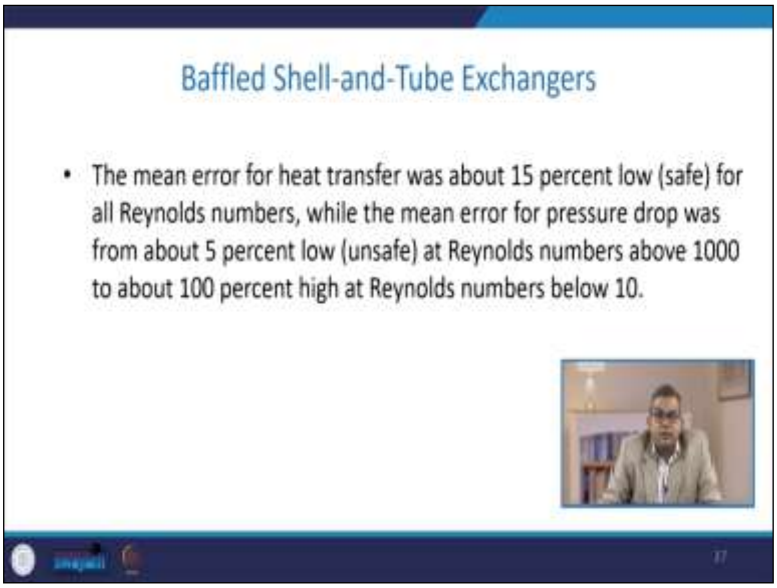

The main error for heat transfer is about 15% low that is referred to as the safer side for all Reynolds number, while the main error for the pressure drop is assumed to be about 5% low that is unsafe at Reynolds number above 1000 to about 100% high at Reynolds number below 10. Now in this particular lecture, we have discussed various aspects of heat exchanger utilities different types of heat exchangers. We discussed direct and indirect types of heat exchanging meat heat exchangers, then shell and tube heat exchangers different types of the anatomy of the shell and tube heat exchangers.

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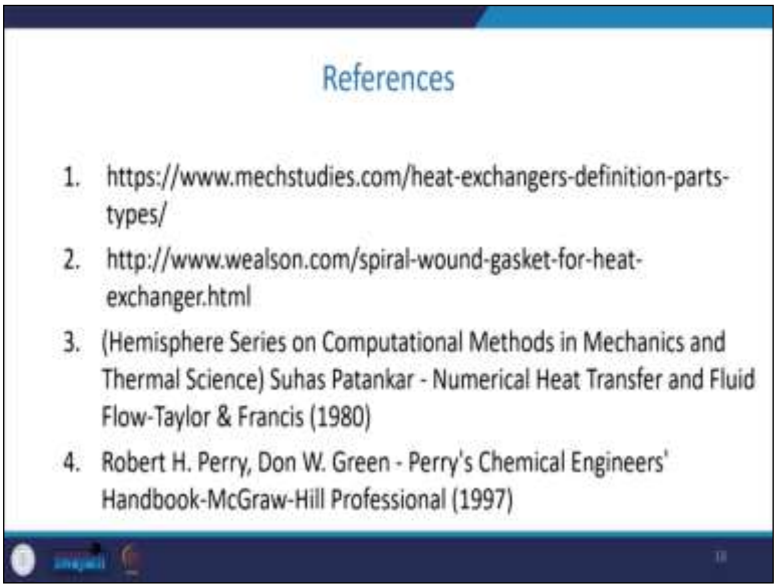

For reference, we have enlisted further suggested materials, although sometimes we have already discussed a couple of the references during the lecture. So, if you wish to further study or further knowledge about this subject you can see these references, thank you very much.