

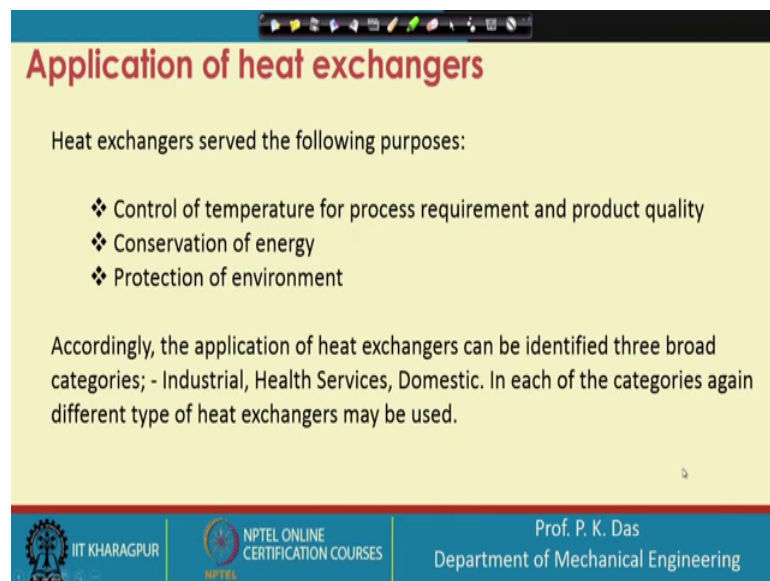
Heat Exchangers: Fundamentals and Design Analysis
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Lecture - 02
Applications of Heat Exchangers

Hello everyone, welcome back to the second class of Heat Exchangers; Fundamentals and Design Analysis. In the first class, we have got some idea regarding heat exchangers and we also try to see that how the concept of heat exchanger evolved in the very dawn of civilization when people have invented fire and started learning cooking. So, that is what we have seen and then of course, over the years, there have been a lot of change and heat exchanger has now become such an important industrial equipment so, we will see more of it

In this present lecture we want to see the application of heat exchanger. We have to understand; why we should study heat exchanger, what is its importance and that is why I like to give some application of heat exchanger to you and then we probably towards the end of this particular lecture, we will try to see how heat exchangers can be classified.

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Application of heat exchangers

Heat exchangers served the following purposes:

- ❖ Control of temperature for process requirement and product quality
- ❖ Conservation of energy
- ❖ Protection of environment

Accordingly, the application of heat exchangers can be identified three broad categories; - Industrial, Health Services, Domestic. In each of the categories again different type of heat exchangers may be used.

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Heat exchangers serve different purposes, but if I see that what are the main purposes served by heat exchanger, first point is control of temperature for process requirement

and product quality. Let me explain it little bit, it is like this that temperature control is important for many cases; for the for that matter where I am delivering this lecture, this room is air conditioned. So, in this room, the temperature of the room is maintained within certain level so that the person who will be occupying this room, they will feel comfortable.

So, due to some sort of a process, we have to maintain the temperature this way. Similarly, suppose we are making some sort of metallurgical product and either it has to be heated or cooled because we need certain attribute of the product; certain property of the product. So, temperature control is very important and heat exchanger often plays a very important role in controlling temperature.

Then comes conservation of energy; in these also, the conversion of energy should be included that when we have some sort of energy conversion process. So, then heat exchanger is; essential examples are many, but if we think of that; how we are generating most of the power? Most of the power in this in the modern age, it is being generated from fossil fuel source; that means, the chemical energy is converted into thermal energy and then from the thermal energy, we are getting mechanical energy or electrical energy.

So, the chemical energy that is getting converted into thermal energy, some sort of combustion process is involved and we will see at each and every state, we have got number of heat exchangers, if we think of a power plant, I mean how many different varieties of heat exchangers you can you can expect to see? It is better to give some time and think that how many different varieties of heat exchanger you may expect in a power plant.

Then protection of environment; actually these 2 point goes hand in hand. Conversion of energy; in certain cases, it is essential to use a heat exchanger, but during the conversion, what we do? We waste a good amount of thermal energy and we waste also energy in different form using heat exchanger. These can be reduced, these wastes can be reduced and reduction of any waste is a gain. So, when we are stopping the waste or reducing the waste of thermal energy, what we are doing?

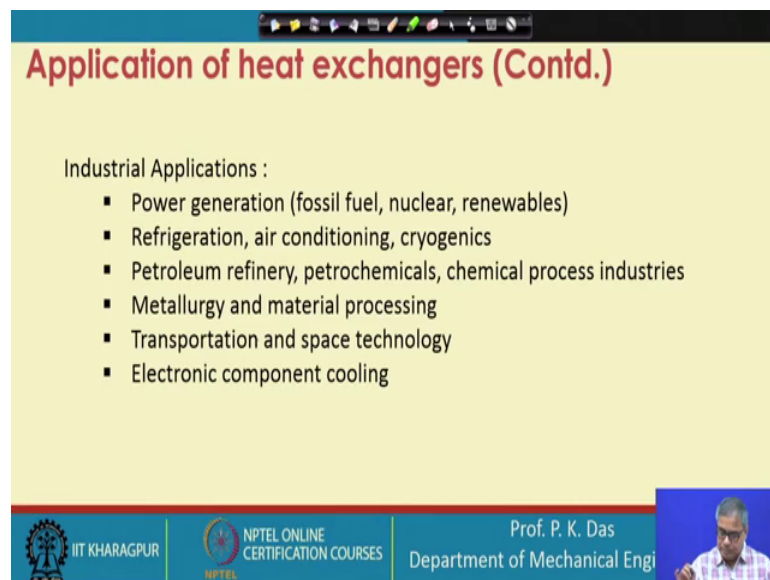
We are protecting the environment, apart from that; there are direct action by which environment can be protected and; obviously, heat exchanger plays a very important role. The 3 point which I have told they may not cover all the aspects why heat exchanger is

to be used, but they give some main aspect why heat exchanger or rather what is the purpose of heat exchange using heat exchanger.

Accordingly, the application of heat exchanger can be identified in 3 broad categories. Again, there could be controversy, people may say that there are other areas, but what we think are important that is in the industrial sector; that is the main use of heat exchanger, many varieties of heat exchanger will be used and then health services; there will be large number of heat exchangers and in domestic obviously, in our day to day life, we need heat exchanger for our comfort for some unique processing for our survival. So, we need heat exchanger; obviously, when I talk survival, the room heating the importance of room heating in cold countries, in arctic region, nobody can deny.

So, it is not some sort of a luxury, it becomes then the essential step for surviving; one essential step for surviving. So, heat exchanger plays that important role in each of these categories. Again there are different types of heat exchanger and we will see slowly; what are the different types of heat exchangers, etcetera.

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The slide is titled "Application of heat exchangers (Contd.)" in red text. It lists industrial applications in a bulleted format. At the bottom, there are logos for IIT Kharagpur and NPTEL, along with the name "Prof. P. K. Das" and "Department of Mechanical Engi". A small video inset shows a man speaking.

Application of heat exchangers (Contd.)

Industrial Applications :

- Power generation (fossil fuel, nuclear, renewables)
- Refrigeration, air conditioning, cryogenics
- Petroleum refinery, petrochemicals, chemical process industries
- Metallurgy and material processing
- Transportation and space technology
- Electronic component cooling

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So, let us get familiarised with different demands and the different kind of heat exchanger which can meet the demand. Industrial application; already I have mentioned power generation. This could be fossil fuel power like your coal or oil or it could be nuclear, it could be renewable, whatever may it be, there will be a large number of ferry unique heat exchangers.

Refrigeration, air conditioning and cryogenics, notionally, they indicate generation of load temperature. So, in all these cases, we need to have heat exchanger of various designs. In fact, some sort of a cryogenic plant, the performance of cryogenics plant, the energy utilisation in a cryogenic plant is so much dependent on heat exchanger that I mean, a plant cannot be designed properly or rather cannot operate properly, unless we have designed and selected heat exchangers correctly and operated them very efficiently.

Petroleum refinery, petrochemicals, chemical process industries, again, these are the main places where number of heat exchangers are used. Very unique heat exchangers are used, some of the heat exchangers which has been evolved for this type of process requirement only. So, again this is one important user of heat exchangers.

Metallurgy and material processing; I have already mentioned that some sort of material property that we can get only by some temperature control. So, again cooling is very important, sometimes, heating is very important and that can be done with the help of heat exchangers.

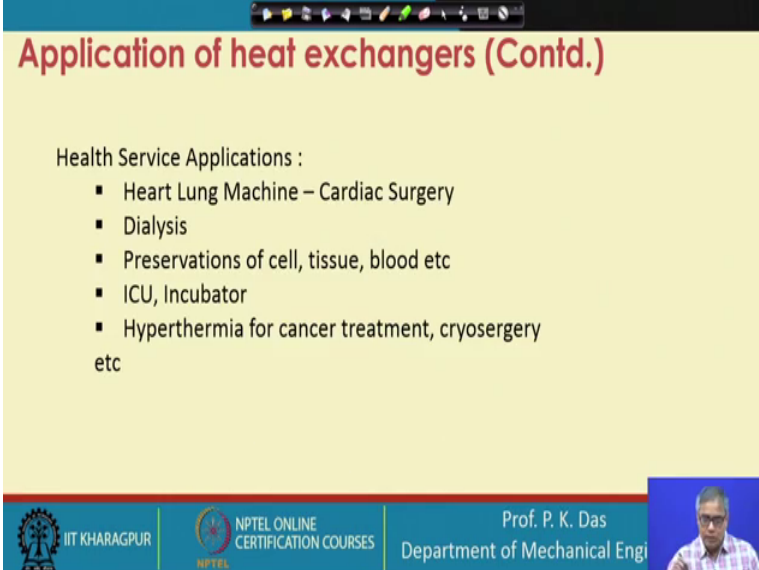
Electronic component cooling; these are again cursorily, I have mentioned somewhere, but this has become very very important. The next generation of computational power we can acquire these only by a good thermal management of the electronic components and that can be done with the help of heat exchangers. Efficient heat exchangers, compact heat exchangers and obviously, the cost should also be low. The maintainability should be high and all the other aspects which one can expect from a good industrial component.

So, electronic component cooling are needed not only for computation, but also for other purposes and for that; good heat exchangers are needed.

of fans will come and this height, this chimney height provide some sort of natural draft this is not finished one, but you can see the size comparing though no dimension has been given, but here some people and cars are visible. So, you can see, you can have some imagine some imagination that what could be the size of this heat exchanger. So, there is so much of variation in size of a heat exchanger; very small to very big so; obviously, you can understand; that what is the challenge in designing or analysing this kind of heat exchanger.

So, left hand side, we are seeing one very small indirect type heat exchanger, right hand side, we are seeing a very large heat exchanger which is a direct contact type heat exchanger and construction material, left hand side, if you see it is metal, right hand side, it is concrete and again we will see that this cooling tower; if we discuss, if we get time to discuss all these things, we will be find that it depends or it is a combined equipment for heat transfer and mass transfer. So, there are many things which are very important and at the same time interesting in the discussion of heat exchanger.

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The slide is titled "Application of heat exchangers (Contd.)" in red text. Below the title, it lists "Health Service Applications:" followed by a bulleted list: "Heart Lung Machine – Cardiac Surgery", "Dialysis", "Preservations of cell, tissue, blood etc", "ICU, Incubator", and "Hyperthermia for cancer treatment, cryosurgery etc". The slide footer includes the IIT Kharagpur logo, NPTEL Online Certification Courses logo, and the name "Prof. P. K. Das, Department of Mechanical Engi". A small video inset of the professor is visible in the bottom right corner.

Health service application; there could be many things, I have just name a few heart lung machine for cardiac surgery for dialysis the system mechanical system which is used that needs heat exchanger preservation of cell, tissues, bloods, etcetera, we have to create low temperature without heat exchanger that is not possible, then ICU; ICU we have to maintain some sort of a condition; temperature condition is very important and then

incubator premature babies are born, before they are scheduled date of birth, these babies are to be nurtured in some artificial environment in some built climate and for that there are incubator temperature control is very important continuous monitoring of temperature is very important. So, heat exchanger placing important role, then for treatment.

So, these are some sort of peripheral thing, but let us think of some treatment let us say hyperthermia; hyperthermia sorry hyperthermia; hyperthermia is a method of cancer treatment, treatment of tumour, cancer, etcetera and they are we need high temperature and; obviously, in the total mechanical system, we have got heat exchanger and then cryosurgery, here by ultra low temperature, we are doing some certain surgery, bloodless surgery, etcetera and here also, we need heat exchanger to have this kind of a system.

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Application of heat exchangers (Contd.)

circuit for cardiopulmonary bypass

<https://clinicalgate.com/cardiac-surgery-2/>

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Just one example I have shown here, this is the circuit for cardiopulmonary bypass surgery and you can see that there are different component, but there is one heat exchanger, there is one heat exchanger, there is one heat exchanger over here and actually the blood is to be heated or cooled depending on because this is how the body temperature of the patient that can be also control and that is why we need a very good heat exchanger; these are unique kind of heat exchanger which are used.

So, I can I can remind the engineers who are involved in the design of heat exchanger the great responsibility which lies on their shoulder. So, starting from industrial requirement

where we have to be really cautious that we should not waste the precious energy which we are getting from fossil fuel. We should not degrade the environment in which we are living and to the life of a patient that is also dependent on heat exchanger and so, how it should be design. So, that it can cater to the need, it can satisfy the need of such a varying nature, it can be maintained properly, it can be of low cost, it can be of high reliability.

So, all these are attributes and when these kinds of variety of applications are there, then you can understand the challenge.

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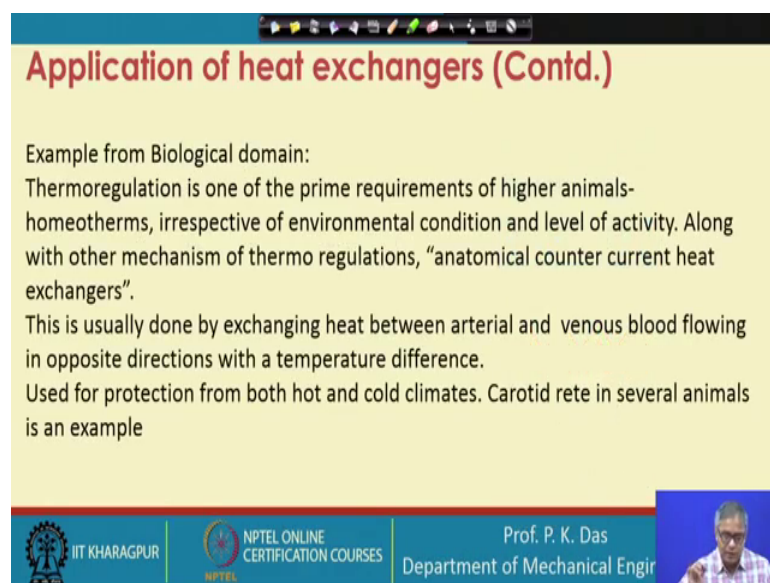
The slide is titled "Application of heat exchangers (Contd.)" and features a diagram of a double steamer. The diagram shows a pot containing water at the bottom, heated by a "Heater" (represented by four flames). Two cans are placed in the pot: "Can 1" is partially submerged in the water, and "Can 2" is fully submerged. The word "Food" is written above Can 1. The entire setup is labeled "Double Steamer". To the left of the diagram, under the heading "Domestic Applications :", there is a list: "▪ Comfort – Air conditioning" and "▪ Cooking and food preservation". The slide footer includes the IIT Kharagpur logo, "NPTEL ONLINE CERTIFICATION COURSES", "Prof. P. K. Das", and "Department of Mechanical Engi". A small video inset of the professor is visible in the bottom right corner.

So, let us proceed in domestic application, of course, compared to industrial need of heat exchanger that is less, but that is not less important. So, comfort and at some point, I have told that that is also some sort of life saving device in cold countries or very hot countries. So, the human comfort or human liveability has to be has to be satisfied that we do by air conditioning room heating, basically has AC and lot of heat exchangers have to be used.

Then cooking and food preservation, it is difficult to get household where there is I mean there is no refrigerator so; obviously, we have to have heat exchangers in the refrigerator and design or analysis of heat exchanger is very important one cooking device is shown in this diagram this is a double steamer.

So, basically what we do for cooking certain food? We need uniform temperature and we need some control temperature. So, it cannot be put on direct flame. So, here we can see there are 2 pots. In the external pot; outer pot, there is water, water will boil and it will maintain a certain temperature. Let us say, it will maintain 100 degree Celsius, then the food can that will be inside surrounded by this boiling water. So, food can will have lot of again a liquid, etcetera. So, basically this is heat transfer between 2 liquids through this wall. So, this is kind of a special indirect heat exchanger. So, you can understand; how versatile is this component that is heat exchanger.

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Application of heat exchangers (Contd.)

Example from Biological domain:
Thermoregulation is one of the prime requirements of higher animals- homeotherms, irrespective of environmental condition and level of activity. Along with other mechanism of thermo regulations, “anatomical counter current heat exchangers”.

This is usually done by exchanging heat between arterial and venous blood flowing in opposite directions with a temperature difference.

Used for protection from both hot and cold climates. Carotid rete in several animals is an example

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Let me give some example from biological domain. Thermoregulation is one of the prime requirements of higher animals; higher animal, higher animals; they try to maintain the same temperature of the body, irrespective of our level of activity because we know that for higher level of activity, we need higher amount of metabolic energy production, if metabolic energy production is high, then the heat which has to be dissipated from the body that should also be high, but the heat which has to be dissipated from the body that does not depends only on the organism or slowly on the living being.

But also it depends on the environment condition because q is proportional to Δt and this environment condition environmental condition environmental temperature, particularly, it varies a lot think of a desert region where easily the temperature could be close to 50 degree Celsius to the arctic region, where it is several degrees below the

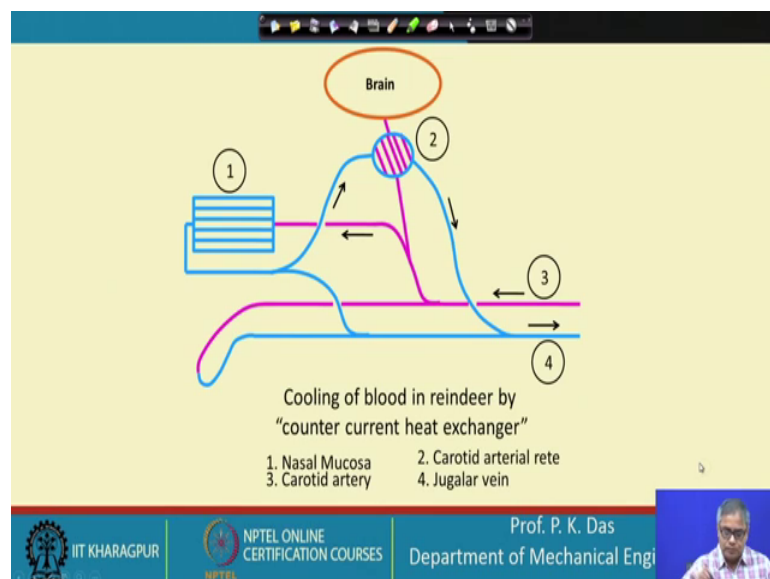
freezing point and a human being has to maintain a constant temperature constant body temperature in all these climate.

So, how it is done? There are very large number of there are very large number of mechanisms, there are some main mechanisms of course, and there are other minor mechanisms, basically, using these mechanisms, not only human beings, higher animals, mammals, etcetera, they maintain their body temperature. Many a time, our body is compared to a heat engine, but often it is not told that our body is a perfect thermostat. So, to make it function as a perfect thermostat which will which will which will operate, keep the body as a complete, I mean constant temperature, many mechanisms are there like sweating, etcetera and this is not the place to discuss all these thing.

But counter current heat exchange as it is done in heat exchanger that is also one of the principal, this is usually done by exchanging heat between arterial and venous blood flowing in opposite direction with a temperature difference and this bloods they passes through tubular type of structure. So, 2 streams are there and these streams are having temperature difference, but the nature has understood in its own way that if they flow in opposite direction, large amount of heat or can be transfer or heat can be transferred in more effective way.

So, there are many examples. There are examples for cold weather; there are examples for hot weather.

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So, let me give one example reindeers; they are in the arctic region, they are acclimatized to withstand cold temperature, low temperature, but suppose there is some sort of a hot condition in which they have to survive. Now when the outside temperature is high or your body is generating more heat due to some sort of action. So, what happens; the brain that is very vulnerable, because the temperature of the brain it should be maintained and it should be maintained slightly below the other temperature; several degrees below the other temperature of the body.

So, what is done here? The you can see this is the arterial blood which is coming, it will also go to the brain and it is going to the brain and this is the venous blood which is returning back. Now when it is returning back, part of it, it goes through the nasal region of the reindeer where there is cooling of blood due to some sort of respiratory effect. So, this cold blood that is taking here which is called carotid rete in the that is basically a typical structure where the hot blood will be inside and there will be very small number of vessels cold blood will be passing through this.

So, the blood; hot blood before going to the brain, it will get cooled and the principle is exactly similar 2 things are there, it is similar to counter current heat exchanger and again, as I have told that compact heat exchanger here large number of vessels are there to increase the exchange area. So, the concept of compact heat exchanger, it not only came to the fertile brain of human being, it is also some invention of nature from its own experience. So, this is for cooling the blood, sometimes, for heating the blood, this is needed. So, there are many bloods who are in the arctic region and their leg has to be protected from frostbite.

So, there the blood is to be heated, not to be cooled or the body part is to be heated and that is done again by similar type of arrangement by counter current heat exchanger between the 2 streams of blood.

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Classification of heat exchangers

Due to the wide variation of heat exchangers it is always convenient to classify them. However, there could be different criteria for classification. Following classifications are based on "Fundamentals of Heat Exchanger Design" by R. K. Shah, Dusan P. Sekulic, John Wiley & Sons, 11-Aug-2003

Classification according to transfer process

- Indirect contact type
 - Direct transfer type
 - Single-phase
 - Multiphase
 - Storage type
 - Fluidized bed
- Direct contact type
 - Immiscible fluids
 - Gas-liquid
 - Liquid-vapor

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Now we go to the classification of heat exchanger. This again, I have taken. I have mentioned here in the source that I have taken it from the design of R. K. Shah sorry; from the book Fundamentals of Heat Exchanger design by R. K. Shah and R. K. Shah and P Sekulic. This is one of the very important book time to time, we will refer this book and this reference has also been given for the course as a textbook.

Now, the classification can be done based on different categories. So, classification according to transfer process is one important way of classification and this is what we like to show here let us say. So, classification according to transfer process; this is very important. So, this is transfer process; how the heat transfer is taking place based on that we are doing the classification.

So, first one is indirect transfer; indirect contact type; that means, the 2 streams; they are not touching each other ok. They are not mixing with each other and most of the heat exchanger are of this category. Already I have mentioned it. So, what could be the different heat exchanger in this category? Direct transfer type; that means, single phase and multiphase. Multiphase means where your boiling or condensation will take place and storage type; what is direct transfer type? Directly from one stream to another stream, it is getting transferred; of course, in between, there is a solid phase solid wall.

So, this is direct transfer. So, there is no storage of heat and it could be single phase; that means, 2 fluids; they are in the either both of them; they are not changing, their phase or

one of them or in some very rare situation, both of them are changing their phase. So, condensation boiling etcetera that is your multiphase.

Then storage type; so, this also I have explained that one stream is giving thermal energy to some sort of a intermediate medium where temporarily thermal energy is getting stored and then that stored energy is transferred to the another fluid. So, that is your storage type then your fluidised bed. So, fluidised bed probably next class I will show some figure of this heat exchanger. So, there will be particulate solid and particulate solid through particulate solid gas is passing.

So, there will be certain amount of energy exchange between the particulate solid and the gas and again from the particulate solid to another fluid, which will pass through some sort of a tube. So, this is a typical kind of heat exchanger, but in none of these cases, 2 heat exchanging 2 heat exchanging fluids are mixing with each other. So, this is your indirect contact type.

Then we have got direct contact type where the where the 2 fluid streams are coming in contact with each other. There are limitations not all the heat exchanger can be designed like this, if there are 2 liquid streams which are invisible, we can go for direct contact type of heat exchanger, if gas one of them is gas and another is liquid, we can go for direct contact type heat exchanger and let us say liquid and vapour let us say steam and water we want to exchange heat between them. So, we can have again direct contact type of heat exchanger. So, these are the three possibilities in general where we can have direct contact type heat exchanger.

So, there are very important heat exchanger in this category; though less in number, in power generation and in other places, we will find that there are direct contact type heat exchanger and for their obvious advantage, we use direct contact type heat exchanger, there are other classification, we will take of them in our next class and a from this classification also, we will try to elaborate certain thing in our next class up to this. Let us have for the present class, again I will request you, if you have got any queries, please interact in the forum and we will try to clarify it.