Power Plant Engineering
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Lecture – 27
Nuclear Power Plants–I

Hello, I welcome you all in this course on Power Plant Engineering. Today, we will discuss the Nuclear Power Plants.

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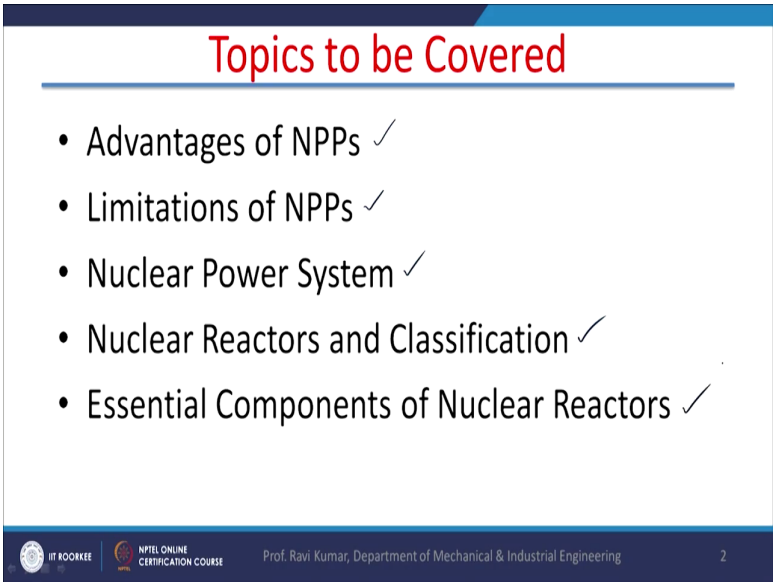

The topics to be covered in today's lecture on first of all advantages of nuclear power plants, then there are certain limitations also for nuclear power plants, nuclear power systems, nuclear reactors and their classification because there are different type of nuclear reactors so they are classified on different criteria's, essential component of nuclear reactors.

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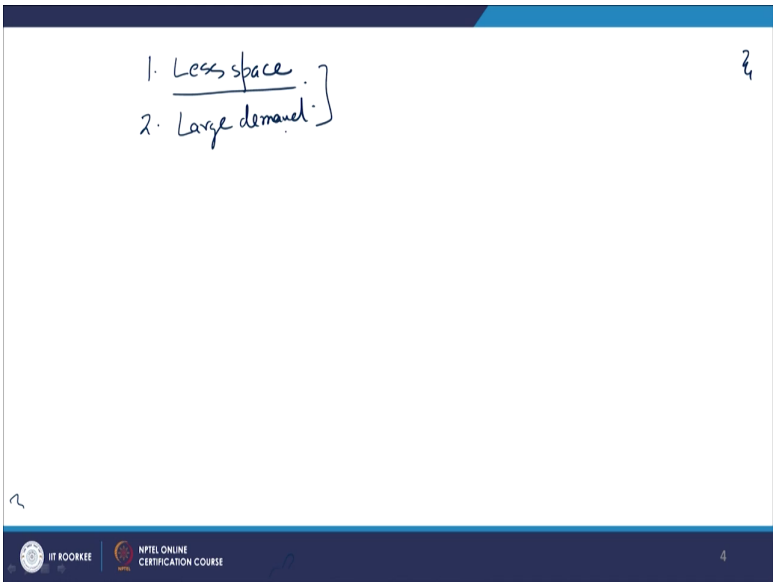

So, first of all advantages of nuclear power plant. The first advantages of the nuclear power plant is it occupies less space; it means the power density of the nuclear power plant is quite high that is why you will find very large capacity nuclear power plants in a very comparatively left less space. Therefore, these power plants can meet the large demand. So, nuclear power plants they can cater the large power demand, in a country like India where there is a power requirement is very large. So, these power plants are more suitable if you compare with the thermal power plants or the hydro power plants.

As I said earlier in earlier lectures that for though we may have a plenty of coal, but we cannot go for a thermal power plants because the concentration of carbon with increasing in atmosphere, so in coming days the use those thermal power plant will reduce. Hydro power

plants have some environmental related issue. So, if you want to generate huge power, we are left with the only option that is nuclear power plants.

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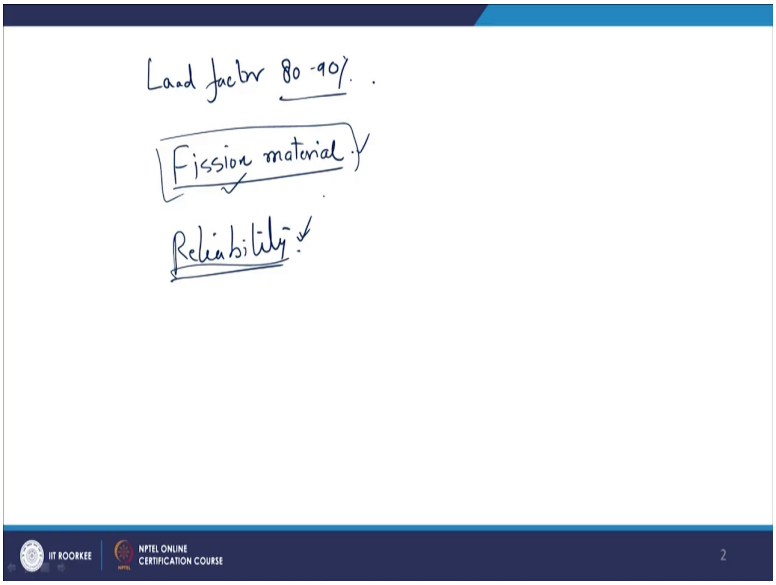

They have high load factor, load factor is 80 to 90 percent that is quite high for a nuclear power plants. And in nuclear power plants the fuel transportation cost is less if you compare with a thermal power plant, we are vegans of the coal is transported by the rails. However, in the case of nuclear power plant, this transportation cost will also be saved. And it produces fission material which can be used for other purpose other than the power generation.

So, end product is fission material which can be used for the other purposes. And one thing more this fission disposal of this fission material is also an issue. So, around the world the scientists are working on the issue that this fission material can it this we used as a fuel in a

nuclear power plant ok. So, recycling of the fission material is nowadays is a focus of nuclear research is one of the focus of the nuclear research.

Operation reliability; operation reliability is quite high in the nuclear power plants. And you have heard some of the accidents there were these accidents were caused when the protocol was a disturbed or standard operating procedure was disturbed, on that case only these accidents are caused, because the reliability is quite high in a nuclear power plant. If the weather is a adverse, so nuclear power plants are not affected, so they can operate in the adverse weathers also. And expenditures of pipes and material is less if you compared with the thermal power plants. So, there are certain advantages of nuclear power plants, but there are certain limitations also. Nuclear power plant nuclear power is costly.

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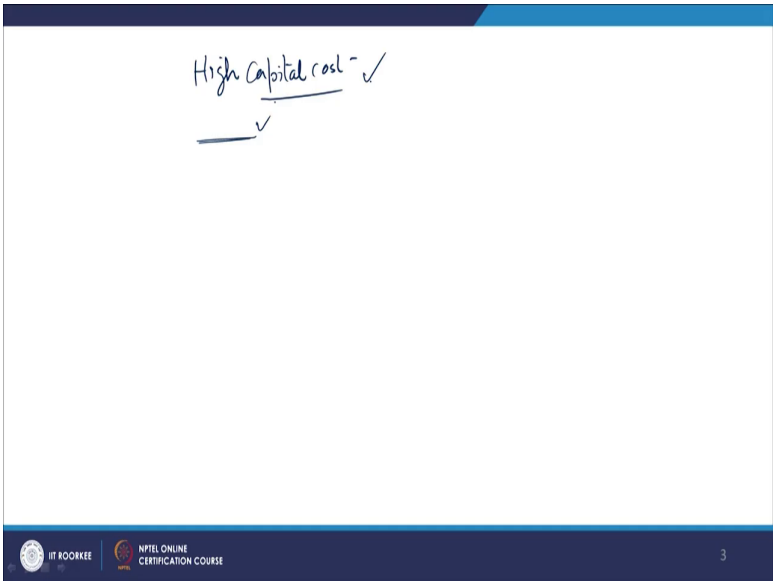

So, high capital cost. And danger of radio activity is always there though there may not be any radio activities surrounding the plants, but in our back of the mind or the in the peoples back of the mind it is always there, there is a danger of radioactivity. So, this is also one of the limitations of nuclear power plants. And another one is they cannot operate on varying load. So, load has to remain fixed in nuclear power plants that is why their power factor is high, load factor is high. Maintenance cost is also high for nuclear power plants, because they work on they operate on a high temperature.

Disposal as I said disposal of fission material is still is an issue burning issue for the scientists. And it working conditions I mean the those who are working in the power plant they have always apprehension that they are under radiation though it may not be the case, but it is always in the back of the mind. This is also one of the disadvantages of nuclear power plants.

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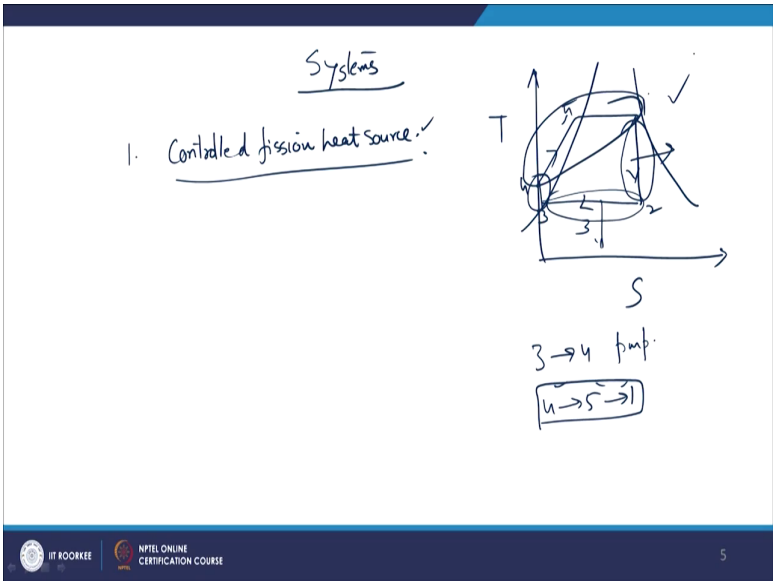

Now, nuclear power systems, what are the systems which are involved in the nuclear power plant, so it has to have controlled fission heat source fission heat source, because nuclear power plant also works from the Rankine cycle. If you look at the Rankine cycle on temperature-entropy diagram right, so 1 2 is expansion in the turbine, 2 3 condenser, and 2, this is 3, 3 to 1 4 1. So, process 3 to 4, 3 to 4, and this is 5, and this is 1.

So, 3 to 4 is pump pumping, and 4 to 5 to 1 this is heat addition in a boiler. If you look at the Rankine cycle typical thermal power plant, so this 4 to 5 to 1 takes place in a nuclear reactor in a nuclear power plant, rest of the things are same. So, there is a controlled fission heat source in a nuclear power plant. There is a heat removal system here condenser, the power plant has a turbine and it also has a pump. So, this nuclear thermal nuclear power plant also convert heat into the useful work. And for this purpose the same Rankine cycle is used.

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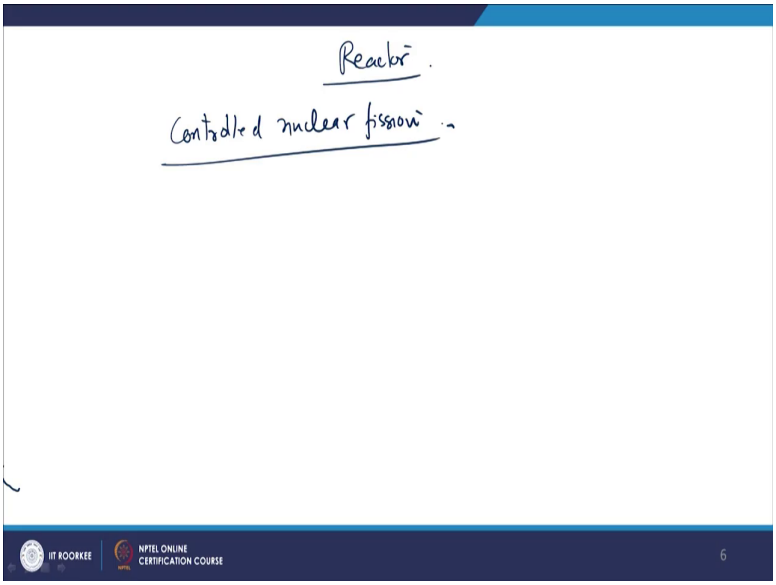

So, for the generation of heat there is a term which is known as nuclear reactor where chain reaction nuclear fission it is a controlled nuclear fission. In controlled nuclear fission, the heat is produced, and this heat is using the Rankine cycle, this heat is converted into the useful work.

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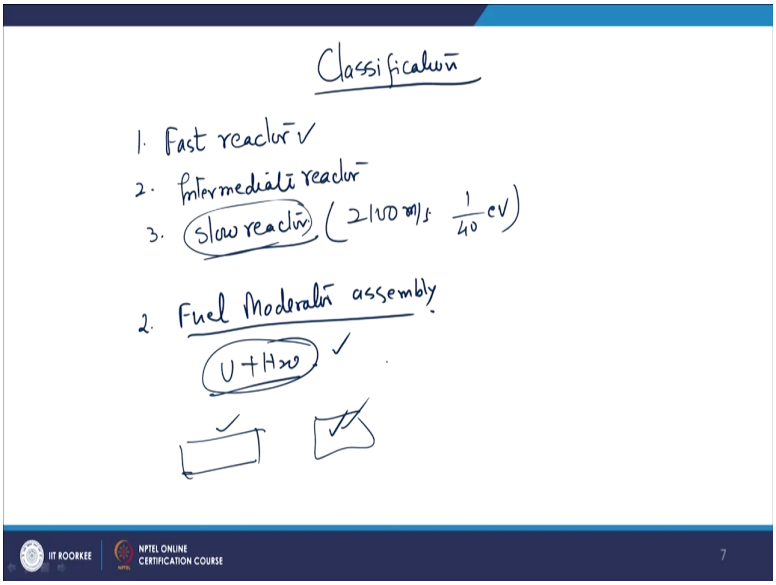

If you look at the classification; classification of a nuclear thermal power plant, so number 1 it is a fast reactor, another is intermediate reactor, and third one is slow reactor. In slow reactor also the neutron velocity is around 2100 meters per second or it carries the energy equal to 1 upon 40 electron volt.

So, slow reactor we have fission reactor which are slow reactors. Fast reactor the high the fission takes place through high energy neutrons or intermediate is between these two. So, we have slow reactors where the using a moderator using a moderator the kinetic energy of or the

velocity of the neutron strike neutron which is a striking the nuclei is reduced right and it is purposefully done, so that a successful fission reaction takes place right.

Now, the second type of classification is fuel moderator assembly. One is called homogeneous reactor? In homogeneous reactor fuel and moderator are one right. If one means suppose dust particles of uranium are mixed with the water, right. We have thermal power plants which have solid fuels. So, they are heterogeneous type. And fuel and the moderators are separate, but there are there are nuclear power plants with the fuel is mixed with the moderator right.

So, this is known as fuel moderator assembly. So, there are two types of fuel moderator assembly, one is homogeneous, another is heterogeneous. And in homogeneous dust particles of the fuel normally uranium is are mixed with the moderator, and in heterogeneous the fuel and the moderator are separate right.

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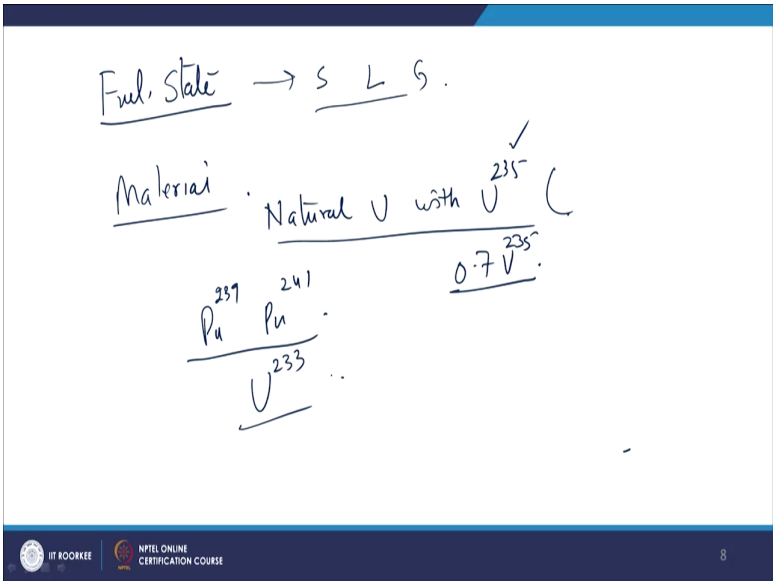

Now, fuel is state, state of the fuel, fuel state solid liquid and gas. Fuel can be in the form of solid, it can be form of the liquid or it can be in the form of the gases. Fuel material right, natural uranium, uranium with uranium 235, this is founded nature only. When we enrich the when we increase the quantity of uranium 235 by some nuclear reaction, and when it is more than 0.7, uranium 235, then it is known as enrich uranium. And there certain manmade material also fuel that is plutonium 239 and plutonium 241, they are manmade uranium 233 is also manmade. So, there are different type of fuels material which are used as fuel in nuclear power plants.

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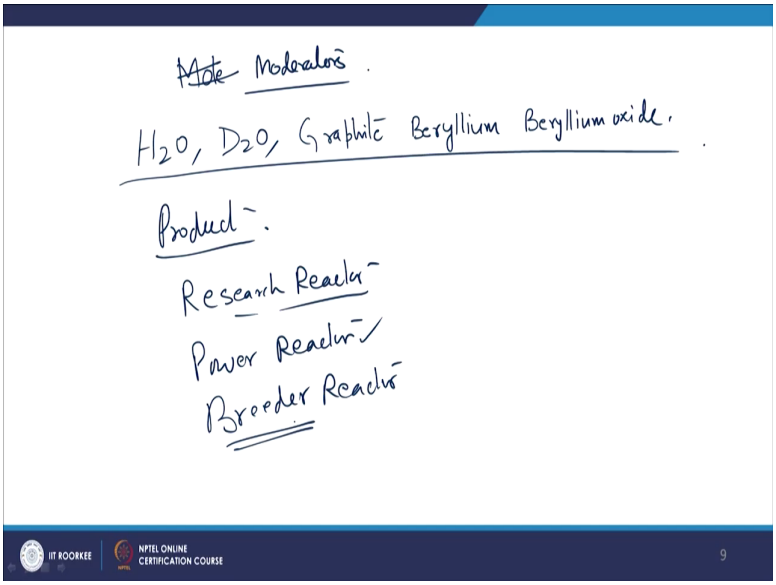

There are different moderators also. Moderator the function of the moderator is to reduce the kinetic energy of fast moving neutron. So, in moderator normally it is it can be water it can be

D 2 O, it can be graphite, it can be beryllium, and it can be beryllium oxide. So, there are few options which are available to be used as moderators.

Now, product this is also what sort of a reactor it is? It can be a research reactor, then it be power generating reactor, research reactor where nuclear research is being carried out right. There is a power reactor, which are used for a power generation, and we are concerned with this reactor only. Now, another one is breeder reactor. In breeder reactor, fuel is generated. The breeder reactor is such a reactor which produces the fuel more than the fuel which is being used to run the reactor, suppose input is 1 kg, 1 kg of fuel, it will produce and product is 1.5 or 1.3 or 5 kg of fuel, and this is achieved through nuclear reactions.

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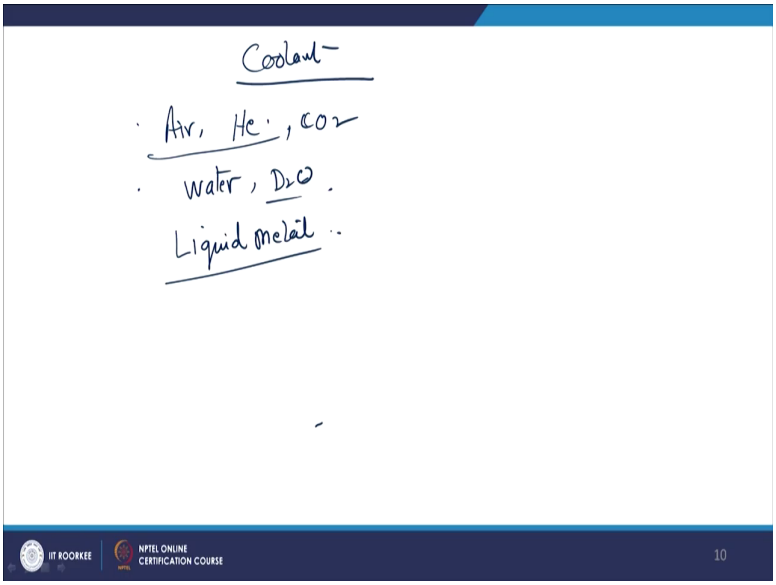

Every reactor has a coolant. The purpose of the coolant is to take away the heat from the reactor. So, coolant can be air, it can be helium. So, these are the gases which can be used or

carbon dioxide, they can be used as a coolant in a in a reactor. If you want to go for the liquid, then water or D 2 O, heavy water, this can be used as a coolant. There are reactors which are liquid metal coolants also metal liquid metal coolant like sodium; sodium is used as a coolant also.

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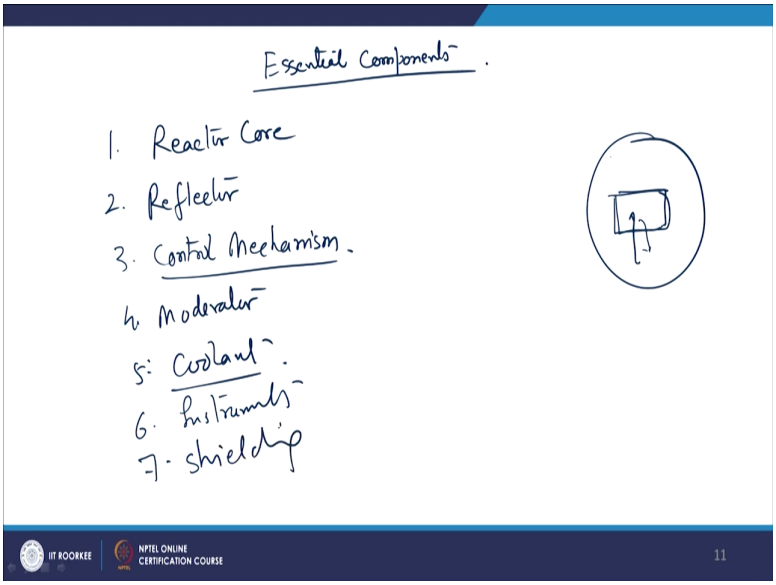

Now, we will go for the essential component of a reactor essential components. Now, essential component is one of is reactor core where this fission takes place and the heat generated. Another is reflector; the purpose of the reflector is to reflect the neutrons when the it is in the containment wall they are put near the containment wall, so if suppose this is the containment and here is the reactor.

So, reflectors will be surrounding the core, this is core, not reactor, this is core. So, reflector will be surrounding the core, so that if any neutron which is a escaping the reactor it is

reflected back. Number 3 is control mechanism. Now, control mechanism is to control the kinetic energy of the neutron to control, the speed of the neutron. So, for this purpose they are moderators water can also be used as a moderator, there are solid moderators also like cadmium rods. They are put in the reactor to slow down the speed of the neutrons in the in the in the reactor, control mechanism.

Then moderator I have already discussed, now moderator. Coolant; coolant is a real food which take away the heat fission heat from the reactor. And sometimes the working fluid work as a coolant or there is a heat exchange between coolant and the working fluid in the turbine ok, there are different type of arrangements. Measuring instruments, there are several measuring instruments which are used in the nuclear power plants, so that it works effectively. And the seventh is shielding the entire reactors shielding in a concrete containment concrete and steel containment, so the radiations do not go out.

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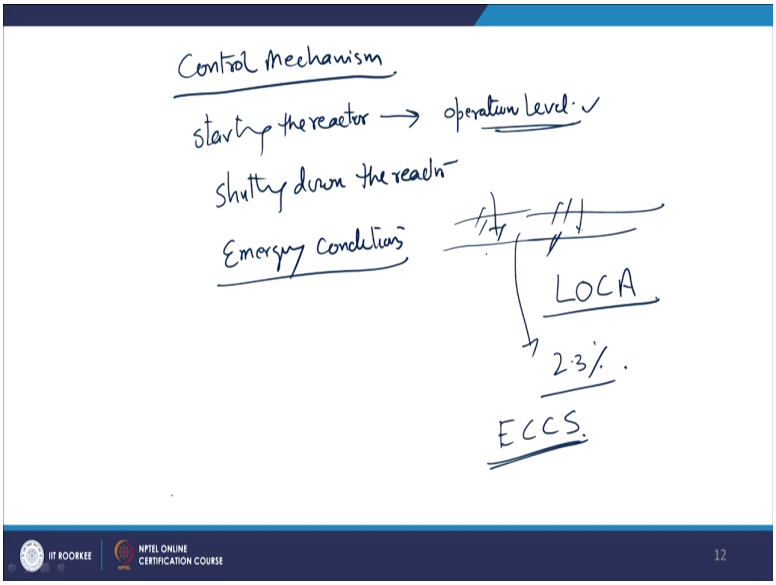

I would like to further discuss here the control mechanism, those rest of the things I have already discussed. So, the control the function of the control mechanism is it is used for starting the reactor and to bring the reactor at a operation level. This is the main function of the control mechanism and maintaining that level because a reactor cannot work on the different levels. So, it has to and for shutting down the reactor. These are the main function of the control mechanism.

And there is an emergency conditions also when there are emergency conditions, emergency conditions means suppose there is a breakage in the pipeline suppose in a core there is a breakage of the pipeline or there is a breakage of the pipeline which is going to the core. So, the coolant will come out. Now, heat will not be taken away from the core. So, temperature of the core will start rising. So, the reactor has to be immediately shut down, this is known as loss of coolant accidental – LOCA.

So, reactor has to be shut down immediately. And for electric circuit is the moment we put the switch off the light go goes off, but thus this does not happen in the reactors. In the reactors because though the fission reaction is a stop, but is still heat will continue to come, it is approximately 2 to 3 percent of the capacity of the reactor. So, there is a emergency core cooling system core cooling system emergency core cooling system which immediately becomes operative and it cools down the core. So, these are the control mechanisms which are there in a nuclear power plant, and they have to work very effectively for the proper operation of the nuclear reactor.

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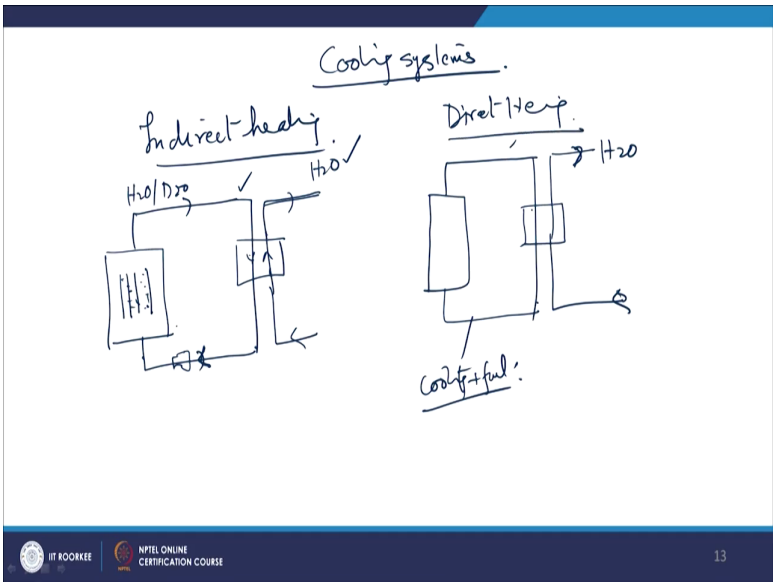

Now, possible reactor cooling system; cooling systems in the reactor. Now, possible cooling system is one is indirect heating. Now, in case of indirect heating as it implies from the name itself suppose this is reactor core, and so coolant is moving in reactor core, sorry in this direction, the coolant is moving in reactor core the fission heat is generated here it takes heat from the reactor core, it goes up and it circulated and sometimes a pump is also used. It may be the natural circulation or fore circulation right.

And then there is a heat exchanger here. Now, heat exchanger through heat exchanger heat is transmitted to the working fluid working fluid is normally light water H 2 O, this coolant can be H 2 O, or it can be D 2 O – heavy water. So, this heat exchange and the pressure is quite high here. So, when this exchange of heat takes place, this heat goes to the this water working

fluid that is water. Water is converted into the steam and this steam goes to a turbine and the condenser and how the power generation is completed right.

Now, another one is direct heating. Now, in direct heating here we have a solid fuel right. In direct heating, there is a mixture of fuel and coolant. And the mixture of the fuel and coolant comes to the heat exchanger, and rest of the process is same, rest of the process is same. Now, here there is a coolant plus fuel mixture. So, the, fuel the working fuel also is also circulated in these pipes right. So, here there is only coolant and here is the mixture of coolant and fuel, and that is why this is known as direct heating type of arrangement.

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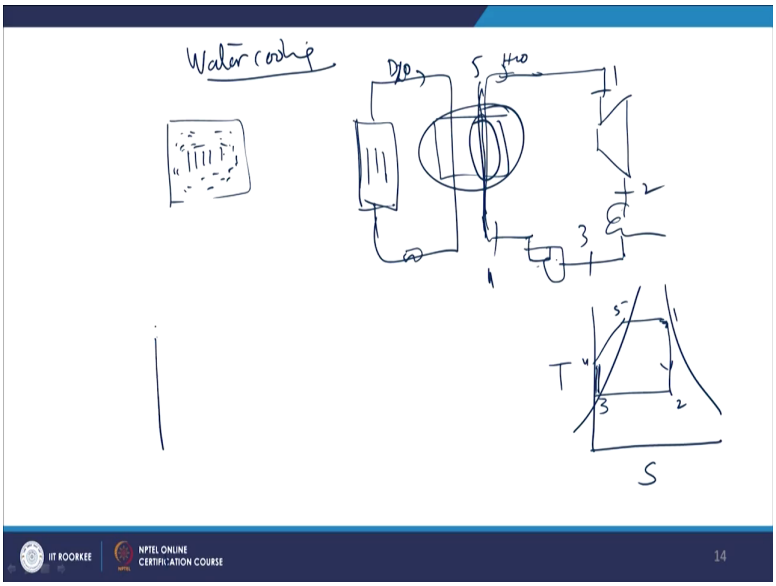

Some of the water cooling like swimming pool reactor, where the fuel rod they remain suspended in a in a pool, it is known as swimming pool type of reactor. Pressurize water reactor, in a pressurize water reactor, there is a core and this D 2 O, normally D 2 O, this is

heavy water. It is circulated it is works as a coolant. So, there is a closed loop. So, it can be a natural circulation or a forced circulation. If it is a forced circulation, then the pump will also be there.

So, whatever fission heat is there it is taken away by the D 2 O, and this heat is given to again the working fluid H 2 O, this is the heat exchanger I explained this earlier. And this heat goes to a turbine sorry this fluid this H 2 O, this steam, the steam goes to the turbine and then there is a condenser also, and here there is a pump right. So, again it is pumped and it goes to the and this is also a closed loop.

If you want to draw this on a temperature entropy diagram, so it is entering from here 1, leaving here 2, 2 to 3, 3 to 4 increasing the pressures through sorry 3 to 4 you are right, and 4 to 5 and 5 to 6, 5 to 1. And this takes place here 4 to 1 takes place here in this heat exchanger right.

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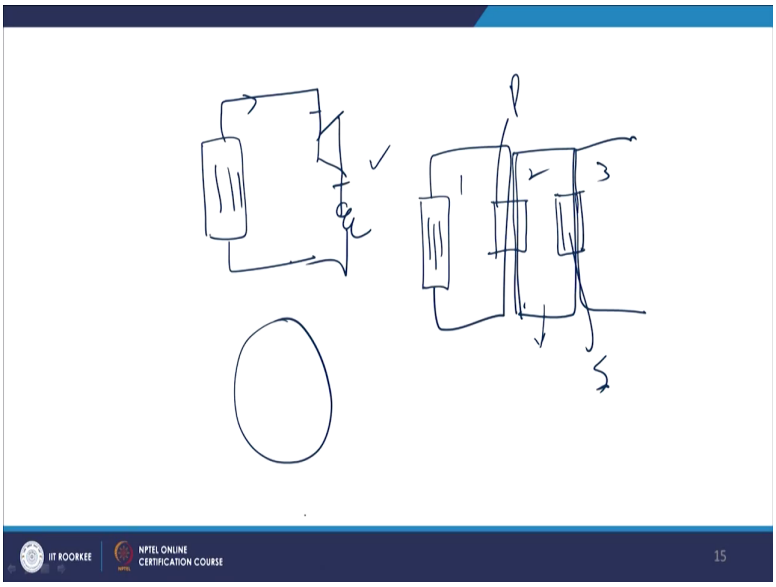

Now, if you go to the boiling water reactor, boiling water reactor does not have this type of arrangement. In boiling water reactor, there is a there is a core, and the coolant itself drives the turbine; the coolant itself drives the turbine. There is no heat exchange and coolant itself drives the turbine. This is known as the arrangement in a boiling water reactor. There are reactors which are liquid-metal coolant; liquid-metal coolant normally sodium is taken into account. So, in the liquid metal type, arrangement is same like there is a core, there is one loop ok, exchange takes place with another loop, and then exchange takes place with the third loop.

Now, here are the question is why there are two heat exchangers? Why they are two? There is one loop, second loop and third loop. Why there are three heat exchangers? Normally, sodium is used in liquid-metal type of coolant. And when the sodium is there sodium reacts I mean

violently with water and air. If air is moist in that case also because it in fact it reacts violently with water.

So, there is a, so that is why in order to avoid such a situation an intermediate provision is made. So, sodium alloy, here sodium alloy is a working fluid here, sodium is a working fluid and here water is the working fluid that is the only reason that is why we have primary heat exchanger, and there is a secondary heat exchanger.

Now, shielding there is a protective wall around the nuclear reactor which prevents the damage to the surroundings, this is known as shielding. And it protects the operators from the exposure also right.

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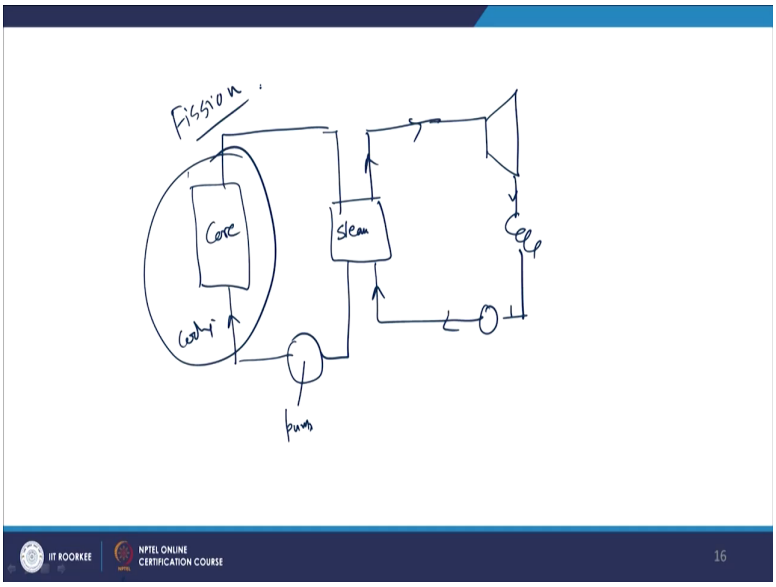

So, if we now take the main component in the nuclear power plant that is one is reactor core ok, and coolant is entering from here. There can be a pump or a pump house. And hot coolant is coming from here; here there is a steam generator we are known as headers also, in headers the steam is generated right. And here then this steam goes to a turbine as I explained earlier turbine to condenser and condensers back to the pump.

Normally the steam which is used in the steam power plant it is a nuclear power plant, it is a wet steam right. And the beam component which is different from the typical thermal power plant is the reactor core is the nuclear reactor; reactor core, where heat is generated using the nuclear fission reaction right. So, this is the basic of a nuclear basic arrangements in a what I explained is the basic arrangement in a typical nuclear thermal power plant. In the next lecture, we will take up different type of nuclear power plants.

Thank you very much.