Power Plant Engineering
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Lecture – 31
Solar Thermal Power

Hello, I welcome you all in this course on Power Plant Engineering. Today we will discuss about the Solar Thermal Power. So, solar energy can be used as a solar thermal power and in the form of direct energy conversions conversion also with the help of solar pvs. So, this is not a direct energy conversion type of system solar thermal is not a direct energy conversion type of system.

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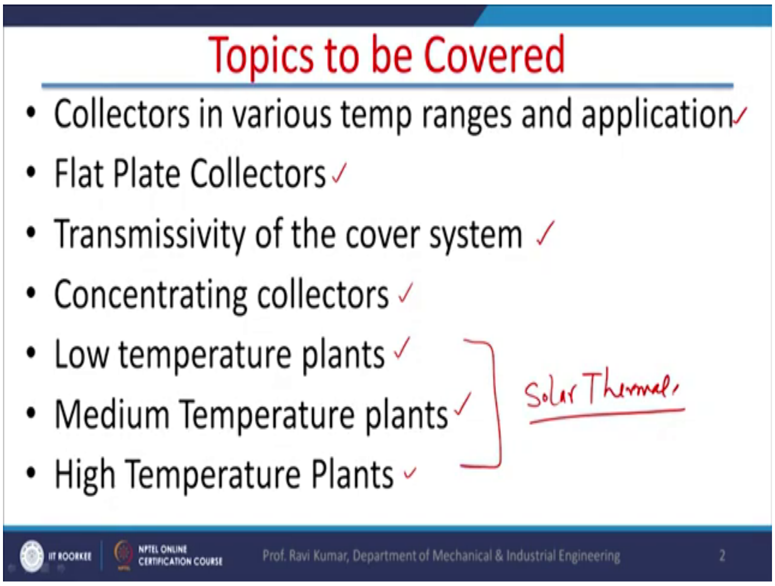

And topics to be covered here today's lectures are collectors in various temperature ranges and application. Flat plate collectors, transmissivity of the cover system, concentrating collectors, low temperature plants that is power plants; medium temperature power plants and high temperature power plants and their all solar thermal power plants. So, it is a sort of nonconventional type of energy system, but it is becoming very popular day by day due to various reasons.

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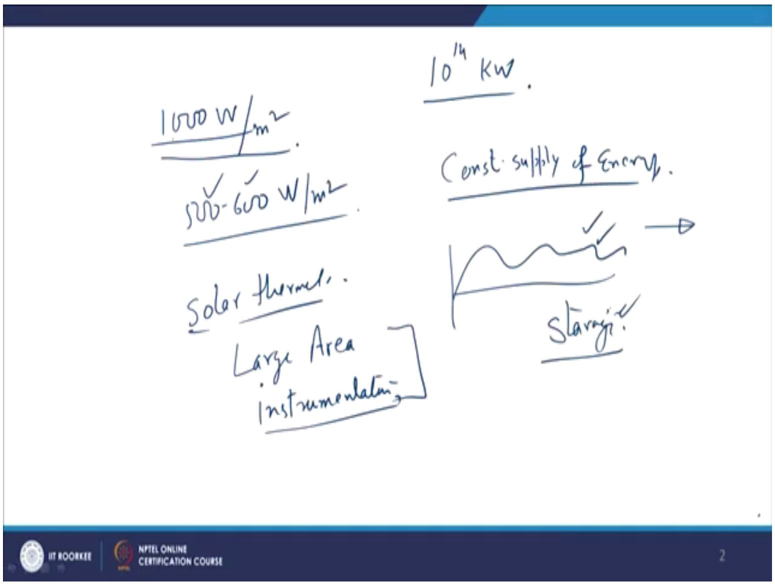

If you look at the solar energy earth receives around 10 to power 14 kilo Watts of energy from sun and when it reaches the earth surface it is around 1000 Watts or 1 kilo Watt. 1 kilo Watt of energy means. So, earth receives around 1000 Watts per meter square of energy from the sun in that case when the sky is clear.

When there are diffuse (Refer Time: 01:53) radiations also directly we get around a 500 to 600 Watts per meter square. It can go up to 700, 700 is also very rare. Normally, it is between 500 to 600 Watts per meter square. And sun is not a constant supply of energy, sun does not provide constant supply of energy. In the light we get no energy from the sun. Second thing in the day second thing in the daytime there is the variation in the supply of energy right and on different dates we get different type of solar radiations right.

So, this has to be I mean taken care with the help of the electronics so, that there is at the output we get solar constant supply of the solar energy. Further storage is required, when there is a variation in thermal energy for electrical solar PV we can do some electronics, but for the solar thermal energy some storage is required. So, that the energy can be stored in thermal storage and when the sun is not there or there is a less amount of solar energy available the energy from this storage can be used right.

So, solar thermal energy first of all it requires large area; because the intensity of the energy is not very high right. So, it requires the large area instrumentation because sometimes solar tracking system is also required to tap the solar energy. But the benefit of the solar energy is the it does not contaminate the environment.

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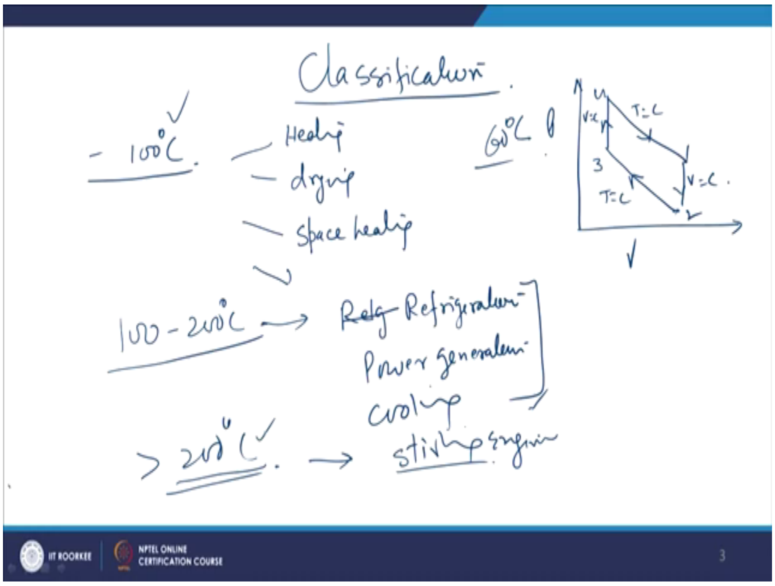

Classification of temperature ranges. Classification of different temperature ranges, if we are able to store the thermal solar thermal energy up to let us say a 100 degree centigrade what is the use? When we are storing solar thermal energy up to 100 degree centigrade it can be used for the heating, drying, there is space heating right. And so many other uses right.

For example, for taking bath, we need water approximately at the temperature of 60 degree centigrade. So, this type of system fits for that another is the temperature range between 100 to 200 degree centigrade; between 100 to 200 degree centigrade if solar thermal energy is available in that case it can be used for the refrigeration. It can be used for the power generation right, it can be used for the cooking also.

So, there can be a many application for this and with the solar thermal is available greater than 200 degree centigrade, then we can we can run the stirling engine. If you remember the stirling cycle, if you dumping the stirling cycle on pv diagram, it has caused two constraint volume processes and two constant temperature adiabatic processes. So, constant sorry constant temperature processes.

So, 1 to 2 is constant volume process 2 to 3 is temperature is equal to constant, this is volume is equal to constant and 4 to 1 again temperature is equal to constant. And the stirling cycle can be coupled with the solar consultative. So, that is another way of generating power, otherwise we can run a solar power plant using 200 degree centigrade temperature. And this can be generated by parabolic mirror if we use I will discuss it later on parabolic type of mirrors this much of temperature can be attained.

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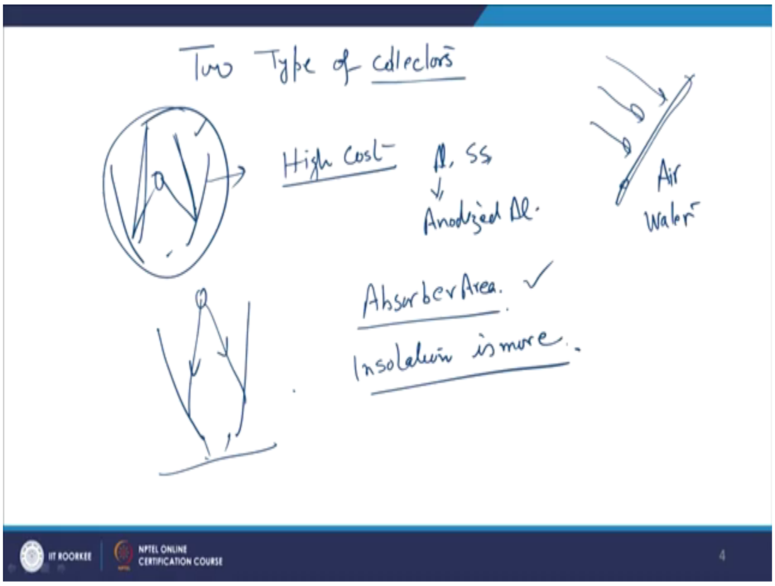

Now, there are two types of collectors; collectors means solar collectors one is flat plate there is a flat plates as solar radiations are falling on the plate the temperature of the plate is increased. Subsequently there is a working fluid it may be air or water normally it is water. And subsequently heat is transmitted to the water and the heat is used for different applications. There concentrating collectors also which consulted the solar radiations and there we can attain high temperature.

But these type of concentrators first of all high cost, cost is high if you compare with the flat plate collector. These type of concentrators have high cost normally made of aluminum stainless steel aluminum alloy or stainless steel. And it is anodized aluminum anodized aluminum. For this concentrating collectors strong direct normal radiation is required. If the direct radiation is there, only then it will work it will not work for the diffuse radiations.

So, that is the limit of the concentration type suppose there is the weather is partly clouded, in partly clouded whether it will not be very effective. And for this type of concentrator normally tracking system is also required. So, that it moves with the movement of the sun it follows the it tracks the movement of the sun. So, there the maximum energy from the sun is trapped right. Further they require a strong foundation, because of vibration may also be there due to win. So, strong foundation is also required.

But they have more absorber area is more in case of concentrated type of system. So, insulation; insulation means solar intensity or solar radiation insulation is more insulation is more in case of concentrated type of a solar collector. Now, we will further discussed the flat plate collector the working of flat plate collector.

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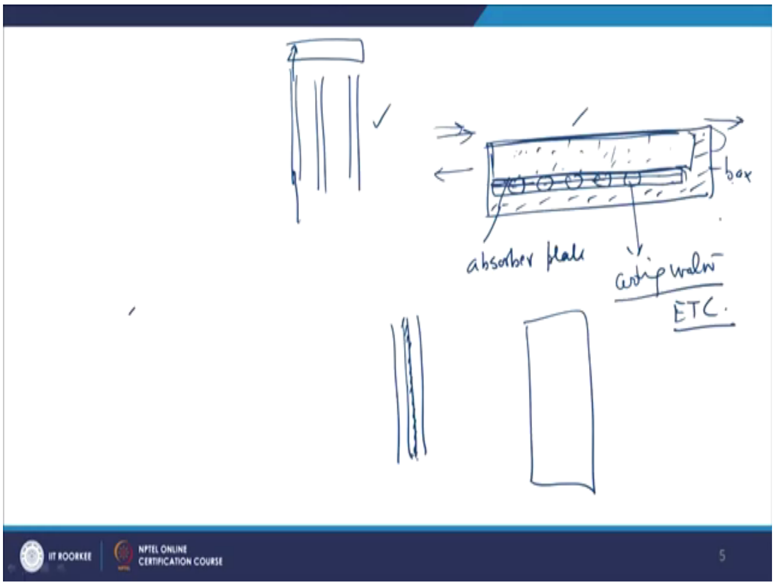

So, flat plate collector has a box there is a box, it is very simple in construction it can be a wooden box or a metallic box or nowadays pvc box are also available. Now, this box has an absorber plate this is a box and this box haves has absorber plate this is absorber plate.

Where absorption of solar radiation takes place and it has cover plate that is it because this is the simplest form of flat plate solar collector. We can fill this peg it we can peg this bed with some material absorbing material that is known as peg bed collector. It can have suppose the air suppose we have use working fluid is air; air is coming from here leaving from here then it is single pass.

Then air is entering from here and then taking u turn and coming from here then it is double pass and so, working is clear by nominator itself. In some of the collectors there are tubes and in tubes the working fluid flows right. And the heat which is coming to the absorber is subsequently taken away by the cooling water. The temperature of the cooling water rises and this water can be used for different applications.

Now, their evacuated type of collector also evacuated tube collector in this on the bed instead of having absorber their tubes, evacuated tubes individually evacuated tubes the glass tubes and in the glass tube concentrically fixed there is a water tube. And there is an array of evacuated tubes on the bed. So, water is flowing from this side and leaving from the another side there is a header and subsequently in a tank the water is collected.

So, these evacuated type tubes type of solar collector has they are more effective than the flat plate type of collectors. And so, in this type of flat plate type of collectors, collectors the insulation is important if we insulation proper insulation is not done, their efficiency may go down drastically.

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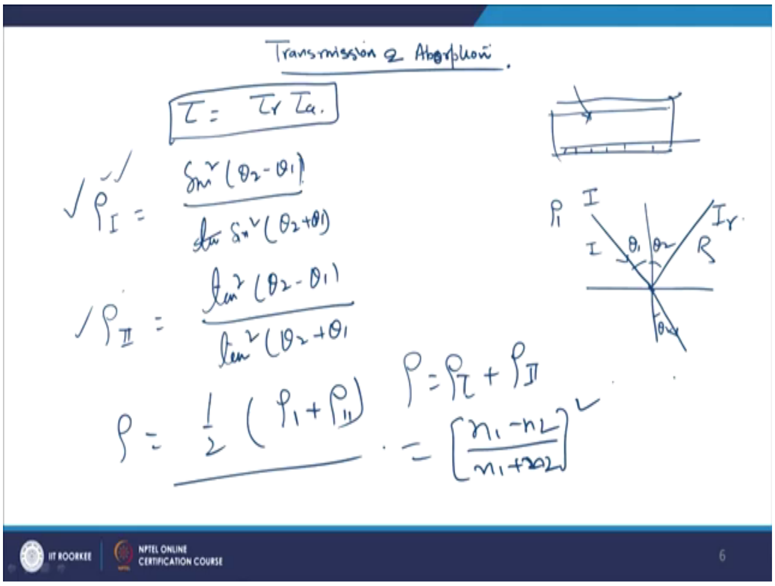

Now, the where from the energy is coming in the collectors it is coming from the plate transmission plate cover plate right and it is coming in two forms. First of all transmission energy to the absorber by transmission an absorption there are two ways. Now, total energy transmitted is total energy by transmission total and total energy by absorption that is total energy coming to the plate.

Now, if you remember the Snell's law, there is the plate there coplanar incident place reflected then this angle of incident is equal to angle of reflection but, 100 percent reflection will not take place. The intensity of the radiation which is falling on this plate part of this intensity will be reflected, it will enter the glass and part of the energy will be reflected right.

So, this is the reflected beam this is intensity of a reflected beam and part of the energy will be entering the plate right. If you measure the reflectivity of the medium 1 and medium 2 this is a reflectivity of the medium 1 and that is a rho. Because suppose it is a light having polarization components. Then first component is equal to sin square theta 2 minus theta 1 divided by sorry, sin square theta 2 plus theta 1 that is one component and that is 7 component of transmittivity transmissivity sorry this is reflectivity this is reflectivity.

Tan square theta 2 minus theta 1 divided by tan square theta 2 plus theta 1 this is theta 1. And the average reflectivity it is going to be half because there are two component of the polarization of the light right. So, both component we have taken the transmissivity, transmissivity 1 transmissivity 2. And suppose there is a normal radiation so, if there is a normal incident, when there is a normal incident. In that case rho is equal to rho I plus rho II and it is going to be n 1 minus n 2 divided by n 1 plus n 2 whole square.

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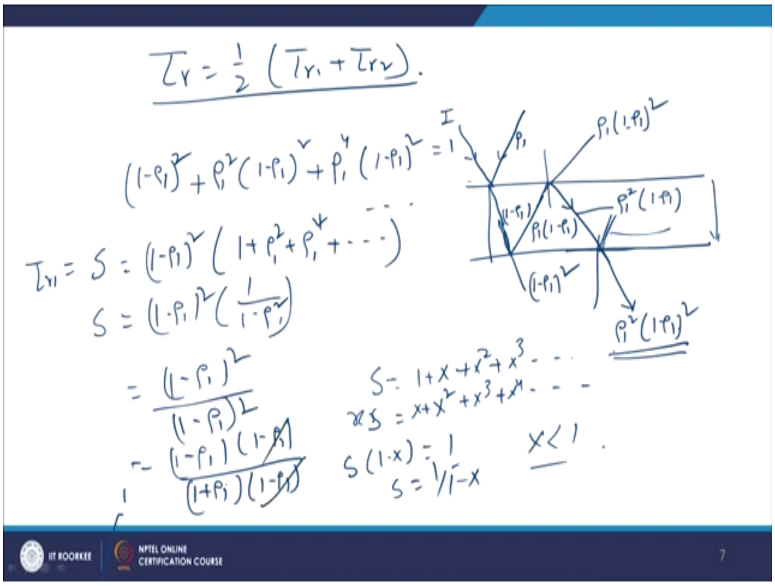

Now, transmissivity is also average of both the components. Now suppose on a plate let us assume there is a plate there is a cover plate there is this incident of light I reflected rho I. So, the light which is entering the cover plate is entering the cover plate is 1 minus rho 1 right. Now this 1 minus rho 1 light intensity of the light will again reflected from the bottom of the plate. So, it is going to be the rho 1 1 minus rho 1 right.

And light which is coming out is 1 minus rho 1 whole square. Then, light is again getting upper side of the plate and then power of the light will be passing through the plate and that is going to be the rho 1 1 minus rho 1 whole square. And then part of the light will be coming back, part of the light will be coming back and this is going to be equal to again because it is reflected rho 1 square because this is rho 1 rho 1 multiplied by the rho 1 square 1 minus rho 1. Now part of this light will again reflected and part will be reflected.

The part of the light which is reflected reflective is going to be the rho 1 square 1 minus rho 1 square and part of the light which is reflected from the bottom side is again this is rho 1. So, part of the light which is ok. So, part of the light which is transmitted with the glass is rho 1 minus 1 minus rho 1 square.

So, I am repeating intensity of the 1 suppose light is entering the glass upper rise of the upper side of the glass, part of the radiations will be reflected that is rho 1 part of the radiations will be transmitted it is 1 minus rho 1. Now, at the bottom side again some reflection will be there that is again this radiation multiplied by the rho 1. And remaining part is going to be 1 minus rho 1 square, this rho 1 1 minus rho 1 again it will be reflected.

So, it is going to be the rho 1 square multiplied by 1 minus rho 1; remaining radiations we will pass we will come back to the atmosphere it is going to be the rho 1, 1 minus rho 1 square because this is 1 minus rho 1 this is 1 minus rho 1 square. Now again this will strike the plate and transmitted radiation are going to be rho 1 square 1 minus rho 1 square the series will continue.

So, if we see the total transmission through this plate of radiation of this plate is going to be equal to the radiation suppose its falling 1. Then it is going to be 1 minus rho 1 square plus rho 1 square 1 minus rho 1 square plus rho 1 raised to power 4 1 minus rho 1 square and so on up to infinity. So, S is equal to 1 minus rho 1 square or is equal to tau r 1, 1 plus rho square plus rho, rho 1 square rho 1 raise to power 4 plus and so on now this is infinity series. So, suppose we have an infinity series for example, S is equal to 1 plus x plus x square plus x cube and so on.

So, simply what we do we multiply x with the S and when we and then we get x x plus x square plus x cube plus x raised to power n infinity. Then we take the difference S 1 minus x is equal to 1. So, S is equal to 1 by x 1 minus x. Here the x has to be less than 1. So, rho is less than 1 here. So, S here now this S is different from this S 1 minus rho 1 square 1 by 1 minus rho.

Sorry, 1 minus rho square, the intermatic ratio is rho square or is equal to 1 minus rho 1 whole square divided by 1 minus rho square. And this is going to be equal to 1 minus rho ok, this will be canceled out.

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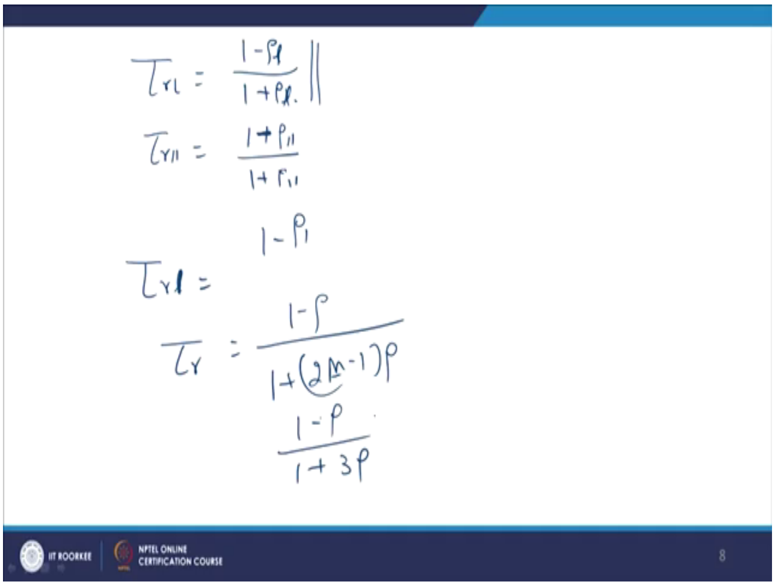

So, finally, we are going to get is equal to 1 minus rho l 1 plus rho l. So, this is the energy which is coming to the absorber seem is the case for II right. Now, if it is a multilayer, if it is a multilayer there number of glasses multilayer of glasses then in that case it is going to be the rho 1 or we can simply take rho 1 minus rho divided by 1 plus 2 m minus 1 multiplied by rho.

So, m is a number of layers suppose number of layer is 1, then we are going to get this formula. Suppose number of layer is 2, then we are getting 1 plus 3 rho and so on right.

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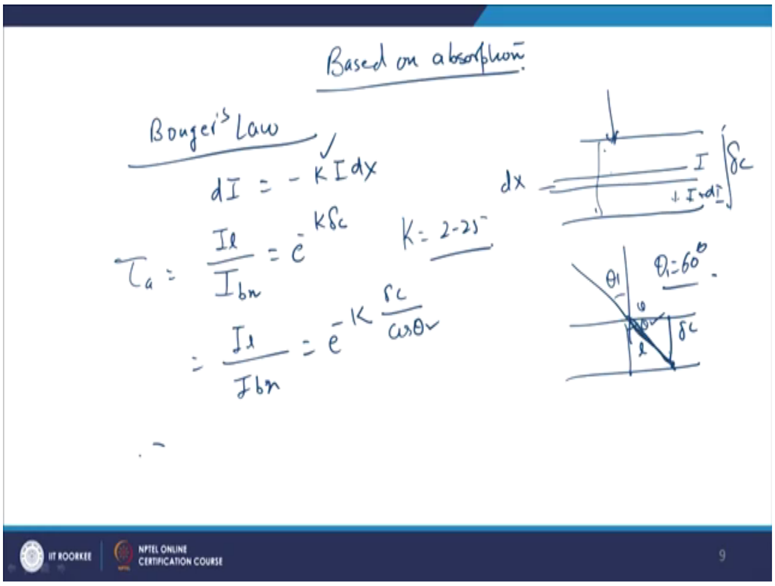

Now, there is another calculation of the transmission the transmission base of absorption transmission based on absorption. Now, there is a glass radiations are coming falling on the glass and the course of traveling through the glass they are getting absorbed. Suppose here the intensity is I this is a suppose dx, here the intensity is going to be I plus d I right. So, from Bouguer's equation Bouguer's law d I is equal to minus k I d x it is a first order equation. And k is the coefficient of extinction, it has to be as small as possible and it is independent of the wavelength. So, value of k varies between 2 to 25 right.

So, the minimum value of k is always good. And from here we get transmissivity, I normal radiation this is I l is equal to e to power minus k. Delta c is the thickness x this is delta c this is for the normal radiation. Suppose they are diffused radiations also. In case of diffused radiations because radiations are coming from different directions. So, normally we assume they are coming at an angle theta, theta is equal to 60 degree normally.

Now, here in this case because we have to take it into the journalize form. Suppose angle after reflection is this is theta 1 suppose this is theta and it has to travel a distance l suppose here. This is thickness delta c. So, this equation will be modified as is equal to e raise to power minus k delta c by cos theta. Or this is if we this if you take this theta 2 then this cos theta 2 over this is the distance which is traveled through the glass right.

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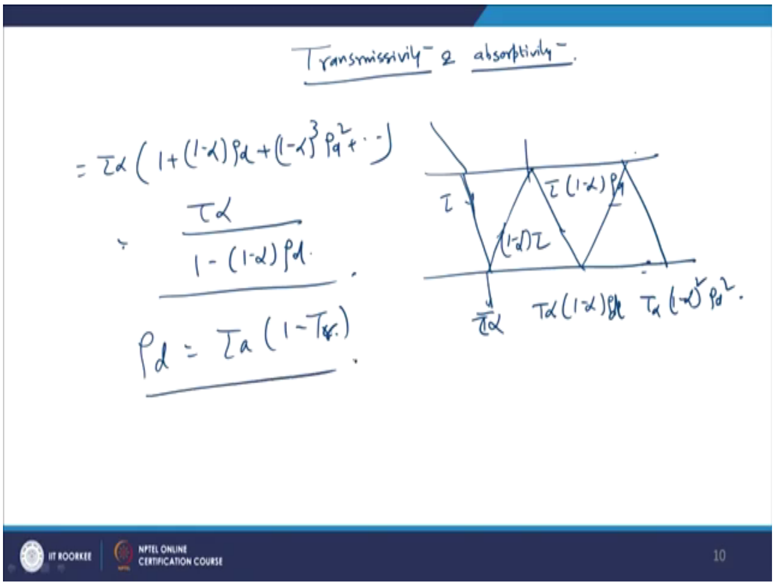

So, transmissivity we have to these for the absorption transmissivity calculations and absorptivity calculation right. If you take both into the account, suppose now we take the glass amount of radiation is transmitted, after transmission it is absorbed right. This is reflected right and it is going up and then again when it is going down it is this is due to reflection.

So, it will keep on going and we will get the series like. And again we will follow the same process to dead fraction absorbed is net fraction absorbed is tau alpha; 1 plus 1 minus alpha rho d plus 1 minus alpha cube rho d square and so on. Again it is going to be an infinite series you will get tau alpha 1 minus 1 minus alpha rho d right. When there are diffused reflection, then in this case rho d is equal tau a 1 minus.

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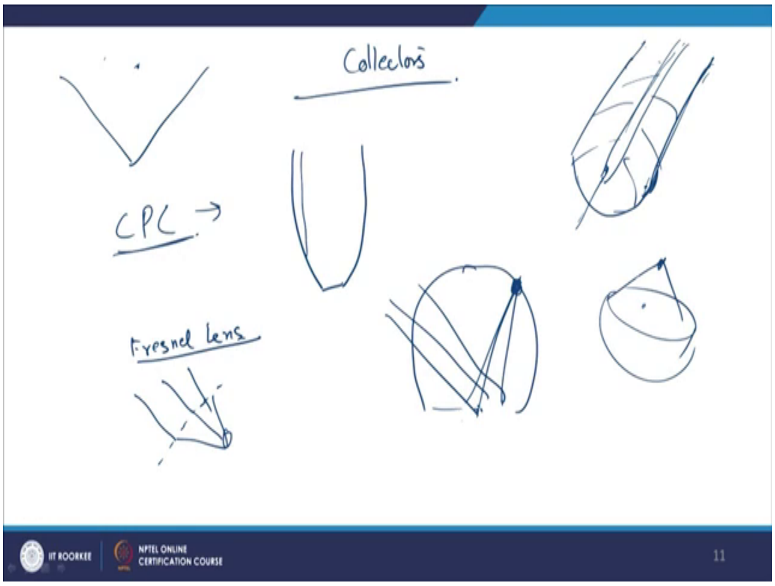

Now, we will go for different type of consolidating collectors. Now, one is flat plate type of collector flat plate type of collector can also be a consolidating type of collector. If you take combination of flat plate collectors they are CPC Compound Parabolic Collector. There were typical shape and where this when the sun rays fall they get consolidated. So, this is known as compound parabolic collectors Fresnel, Fresnel lens collectors Fresnel lens collectors there are fless fringes. And this is how the basic purpose is consolidating of the solar energy.

Cylindrical parabolic collector this is they are very famous. So, the if you look it is a cylindrical parabolic type of shape and in the center of this collector cylindrical parabolic collector there is always a tube. And the working fluid normally water it flows in the tube and it is a parabolic collector cylindrical in if it is a three dimension in geometry. So, it is a cylindrical in nature.

So, while passing through this tube, the solar power is concentrated on this tube and fluid get heated. And we can get up to temperature of 200 degree centigrade using this a cylindrical parabolic collector. There are fixed circular collectors also, fix circular collector there is a moving receiver, receiver also moves the solar radiation they fall on a surface they are reflected. And the radiations are collected at receiver and the receiver keeps on moving in a circular on a circular path.

So, they are these are known as fix circular consolidating and moving receiver collectors. There are parabolic dishes also parabolic dishes which are used for a consolidating the solar power. So, we can have different number of geometries for having a consolidating solar power.

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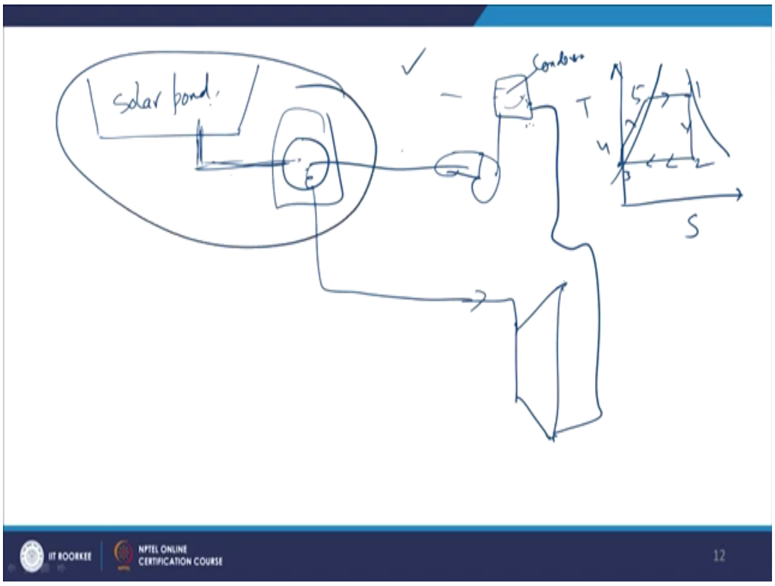

Now, for the low power generation, there is a system which is known as solar pond which is normally used for solar thermal energy storage. So, from the solar pond, there is normally brain it is the salt is mixed in the solar pond. So, there is a the brain and the brain can go to the heat exchanger because power generation method is same the Rankine cycle; the thing is how we get the steam out of the feed water. So, the power generation processes is same old Rankine cycle.

The issue remains how we generate the heat and how we create the pressure. So, this the hot fluid or the hot waters saline water it enters the heat exchanger, it has a pump. And the pump pumps the water in heat exchanger the pressure is increased, the water from the to the pump comes from a condenser right.

And condenser has a cooling tower because condenser also needs water to take away heat. So, there is a cooling tower. So, there is the normal thermal power type of system. And the before entering the condenser the steam goes to the turbine. So, there is the turbine. So, after the pump the heat is attained from this heat exchanger. So, heat exchanger works as a boiler right.

And the heat the steam low temperature steam, it goes to the turbine expansion takes place the low temperature vapor goes to the turbine and expansion takes place. After the expansion it goes to the condenser and after the condenser it goes to the pump. So, the heat source is solar pond here.

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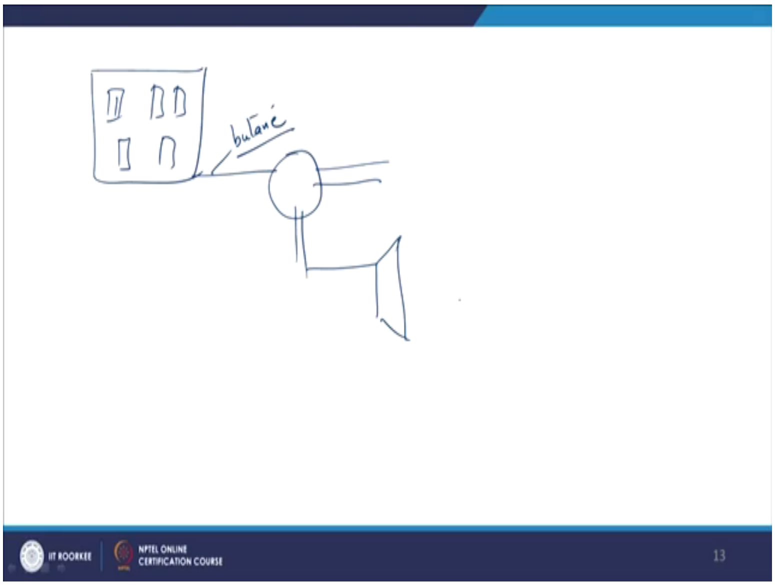

So, similar type of next system is, when we have an array of flat plate collectors. So, solar pond is replaced by flat plate collectors number of flat plate collectors right. And then again there is a heat exchanger rest of the system is same. Here normally butane is used as the working fluid and again when they when the high pressure liquid it takes heat from the heat exchanger it goes to the turbine and expansion in the turbine they are rest of the cycle is same.

But the power is generated at low pressure; the intensity of the power is low in order to if you compare with the conventional power system. If you want to generate the same amount of power more area will be required right. And so, the bulk of the size of the plant will change.

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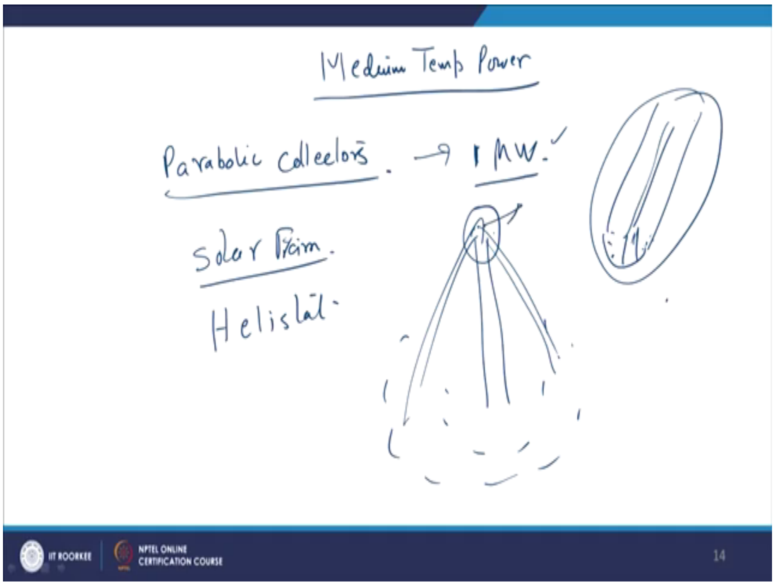

Now, medium temperature or collect medium temperature, solar thermal power. So, medium temperature of power it is normally generated by parabolic collector collectors right. And in parabolic collectors as I said earlier they are cylindrical normally cylindrical parabolic collectors are use, in the center there is a tube and power is concentrated on the tube right.

And up to 1 mega Watt of power can be generated or has been generated using these type of collectors. There are certainly shortcomings because on high temperature with the curvature of this reflecting mirrors may change and that may reduce the power generation. But in general it is quite successful when the parabolic correctors are used for power generation.

Now, high temperature for high temperature we can go for a solar form, it is on large scale because the intensity of the solar radiation is not that high. So, on the large scale power generation or high temperature, power generation or Helislat. So, there is a solar tower it is known as the solar tower and it is surrounded by number of reflectors. And all reflectors are focusing on the solar top power where the heat; where the heat is generated and which heat is subsequently used for running a power plant right. That is all for today.

Thank you very much.