Energy Resources and Technology

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Lecture - 15
Solar Thermal Energy Conversion

… about the conventional power generation sources. Most of that stems from the fossil fuels essentially solar energy concentrated and stood over millions of years. Now, it is available to mankind, but as we have already seen that that would be exhausted in a very short span of time. For example, 80% of the petroleum resource will be exhausted in a matter of 60 years only. So, this way we can see that the fossil fuels are close to exhaustion and we need to turn to the non-renewable, the renewable sources. Renewable means the ones that are, that do not exhaust like the solar energy, like the tidal energy, like the geothermal energy.

I mean if you, if you talk in terms of the absolute meaning, obviously solar energy is exhaustible, but in a matter of something like another 10 billion years. So, it is obviously too long in human time scale. Similarly, geothermal energy is also a finite resource, you might argue, but it is also finite in a sense of mathematical finiteness, but for comparison with the human time scale that is obviously infinite. So, these are the renewable sources of energy. So, you have the non-renewable sources of energy, the fossil fuels and the renewable sources of energy.

So, now we will take the renewable sources of energy.

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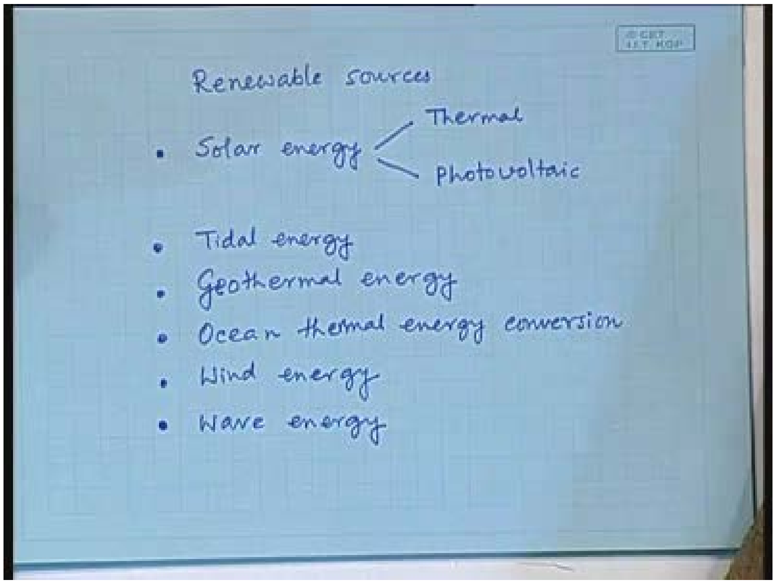

So, renewable sources, so what are the renewable sources? Obviously, the first thing that comes to one's mind is the solar energy. Solar energy can be used both as heat, also as a direct conversion to electrical energy through photovoltaic means and we will treat both, so, solar thermal and solar photovoltaic. Then we have, what other source of energy? Tidal energy; then you have geothermal energy. Can you imagine anything more? The thermal energy as observed in the vast expanse of the oceans can also be used. That is ocean thermal energy conversion. That is of course solar energy but nevertheless available in a specific form. What else? Important; wind energy. What do you have? What more do you have? Can you think of anything else? Well, there are also energy in the waves.

Right now, I cannot think of anything more, so let us take these as our things that we will have to treat in the next half of the course. So, solar energy that is what we start with. Solar thermal, in fact and we will go to solar photovoltaic, then we will treat tidal energy, then we will treat wind energy, then we will go to the others, because these are solar energy. Both thermal form as well as photovoltaic, are now commercially used, viable and economically competitive. Wind energy is so commercially used, viable, economically competitive. Right now, India has something like 3000 megawatts of wind power capacity. So, it is already big. Tidal energy in India does have few good spots where tidal energy can be used. So, these are the things that we should concentrate on and then geothermal, wave, ocean thermal, we will treat, but somewhat cursorily.

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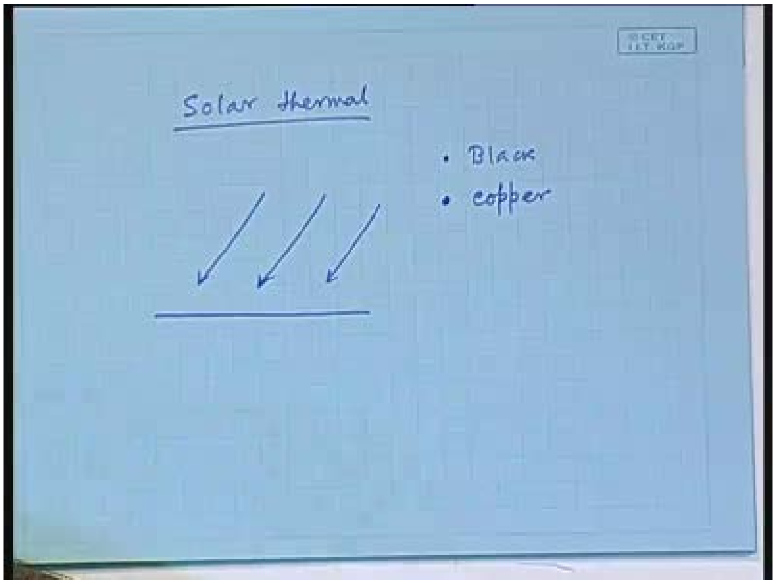

So, now we come to solar thermal energy. Well, solar energy is actually an admixture of various frequencies, electromagnetic waves of various frequencies. A portion of that is visible in the visible range and you also have the infrared radiation, which is directly heat. You also have the ultraviolet radiation. So, all that put together is the solar energy that is available and there are as I told you two ways of utilizing that, either converting the whole energy into heat or using a part of that directly to produce electrical energy. So, we will first consider the ways of converting into heat.

Now, suppose you have got a plate on which the solar energy falls. Obviously, as per common experience the plate will be heated up. But then, that is you know very primitive and intelligent people should always think of how to maximize this. So, how to maximize the conversion of all those frequencies which are not really heat energy, heat waves, heat is only the infrared part of it, into heat. How to convert and how to make that conversion most efficient? Can you tell?

Well, what does the conversion depend on? Suppose it is a white plate and it is a black plate, which one will convert more? Obviously, the black plate, right. What is the difference? It is that the white plate reflects most of the visible range, while the black plate will absorb all the visible range. So, since much of the energy is in the visible range, so you get a larger amount of energy absorptions. So, first thing is that it should be black. Second, what is the material, what should be the material which is using, you use as the absorbing plate?

Now, it could be wood, blacken it, still it is black; it could be iron, steel. So, what should be the criterion of choice? Wood is a, is wood good for this, this purpose? No, why not? It is non-conductive, it is a bad conductor and ultimately this heat that is absorbed has to be given out to something. So, it has to be good conductor of heat. Naturally, intuition tells you that it should be metal. What metal? Which metal is a good conductor of heat?

Student: Aluminium, silver.

Silver, my goodness; you make, people will steal. People will take the whole solar collector and run away if you make them in silver. So, what kind of, we make them with, the next, the next, next good one?

Student: Copper.

Copper, yes; so, copper is the next good one, so you should use copper. So, normally these are made of copper then. So, you have to have a blackened copper plate as the absorber and there has to be something to take away the heat, something to be heated. Now, what would you like to heat? Water, air? So, then naturally there are two types of collectors really, the air heaters and the water heaters. Now, what do you need the air heaters for? Normally, in the kind of industrial plants where you need drying, there air heaters are very useful, because you can heat up the air and use that for the drying purpose. There is large number of industrial process that needs drying and also heat. The hot water is needed both in domestic situations as well as industrial situations, so there are two.

Let us first consider the water heaters. So, naturally water has to be in contact with this plate. Someway it has to take away the heat from the plate. How? What is the nicest way of doing that? How to put the water? Will you just pour a bucket of water on it? No, obviously not. So, there has to be some, some nice way, engineering wise nice way to take away the heat.

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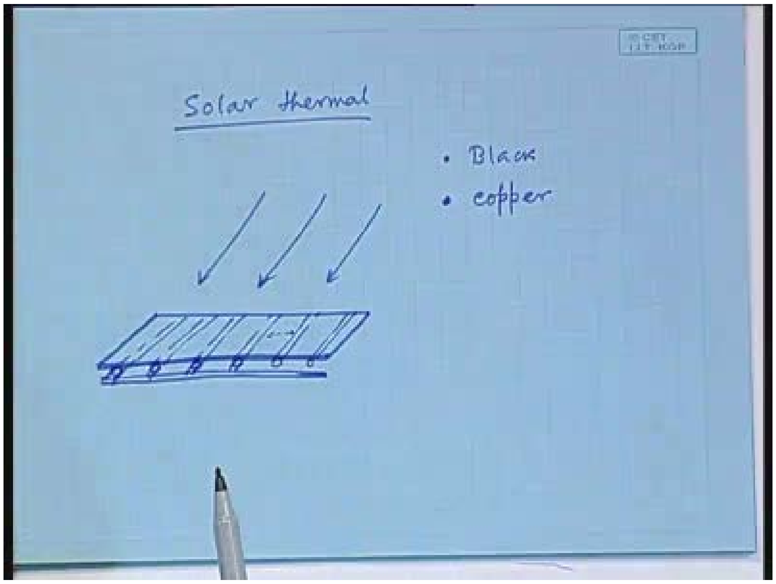

A nice way is imagine that if the plate is, let me put the plate as a two dimensional structure, so that you can feel what I am talking about and then if you have tubes running through like so, that are welded to the copper plate, then the heat is absorbed in the copper plate and that is carried. For example, if heat is absorbed here, it will carry it to the tubes and that will go into the tube. Naturally, the tubes also have to be a conducting substance, namely copper. So, the copper tubes are welded to the metal plate and that makes a good heat contact and you have a reasonably good absorber as well as a reasonably good collector of the heat.

There has to be some means of having the water flow through these tubes. You can do it in two ways, either you force water through the tubes by means of some kind of a pump or allow the water to flow by natural circulation. In order to have natural circulation, this has to be inclined, bent, right. So, the whole thing will have to be bent, inclined and there will be one kind, one, here in this side there will be, imagine that it will ultimately be inclined. In this side there would be a tube going that is connected to all these and up there will be another, so that the heat, the water flows from the bottom to the top as a continuous process. I will draw the total picture later.

So, we have understood that we can make a good absorber as well as a good collector and the water can circulate. It can be stored, the hot water can be stored. It can be used, whatever, but that is not the end of the story. The heated plate will also radiate. It will also be in contact with air. That means it will lose heat in the form of both radiation as well convection, conduction, everything. So, the next engineering decision is how to arrest the heat, not allow it to go to any place other than the water to which I want it to go? So, how do you do that?

First, we need to have something that does not allow energy to be radiated out. Now, it so happens that there are some substances that allow the electromagnetic radiations other than the infrared to go through, but does not allow infrared to go through. Can you name one of the substances? Glass, simple glass; glass has the property of not allowing the infrared to go through, but the other radiations are through, because that is transparent. It is not transparent to infrared, which means that if you put a plate of glass above it, true, it will arrest the component of electromagnetic radiation coming in that is in the infrared range it will not allow it go through, but that is a small component of solar energy.

Most of it is in higher frequencies, either visible or infrared is or ultraviolet is more or less arrested by the ozone layer, but nevertheless it does comes through a bit, but most of the energy is in the visible range, so that is allowed through. But, when this fellow is heated up and it radiates back, because the temperature is not as high as that of the sun, so it radiates almost the whole of the energy in infrared and that is, that is arrested. So, all you need to do is to put a glass cover on it that will not allow the heat that is escaping from it. In the form of radiation, it will not allow it to go out, it will be arrested.

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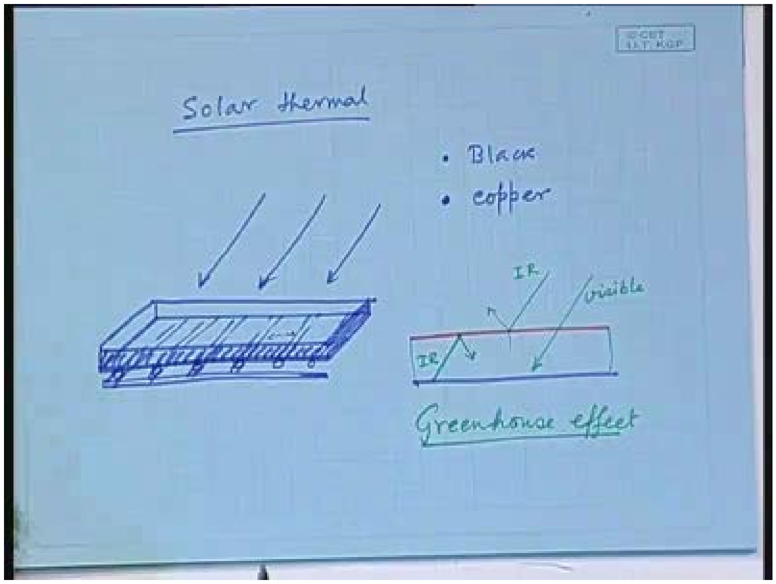

So, then you can easily imagine that the design would be something like this and there would be a glass cover. Can you see? This is the side stuff and on top of it, this surface is a glass cover, as a result of which, let me, let me draw it like this. Here you have the metal plate and here is the glass cover. The amount of energy that comes through in form of the visible radiation goes through. The amount of radiation that is in the form of the infrared is reflected out, but this amount is very small. What this fellow reflects, this fellow emits out, is almost entirely IR, so that is reflected back. As a result, the heat is trapped in this part, heat is trapped in this part.

Now, let us come to the question of conduction and convection. Air is a very bad conductor. So, we are not really all that worried about the conduction part. But convection, obviously the amount of air that will come in contact with the bottom plate that will heat up, that will go up. So, a convection current will set, but then that does not, if this top plate were not there, that would be going out. But here, because of the top plate, because the whole thing is encased, the circulation remains confined within this region, the small part between the plate and the top cover and naturally the heat is again arrested. Now, this particular phenomenon where you allow the visible range, visible radiation to come in and do not allow the infrared radiation to go out, this is called the greenhouse effect. So, this is called the …

Probably we have talked about the greenhouse effect while talking about the environment, right, did I? No, I did not, oh. The same effect also happens in the atmosphere, the same effect also happens in the atmosphere. So, the solar energy from the sun is, again mostly higher frequency energy, energy in the range of the visible as well as ultraviolet that comes into the Earth, that heats up the surface of Earth and that what goes out is infrared, because it is heated up and the frequency at which the emission is done depends on the temperature of the emitting surface and in case of the Earth that is moderately heated, so that will, that will radiate out the energy in form of the infrared.

Now, in order for the temperature of the, of the planet to remain constant, the incoming energy must be equal to the outgoing energy. Now, if the atmosphere of the Earth contains many of the gases that does not allow infrared to go out, then the heat will be trapped. That is exactly what is happening in the atmosphere today. That is what the problem of global warming is. But, at the same time if you look at the planet Venus, you know what actually happens? In Venus, the atmosphere is about 98% carbon dioxide. That is a greenhouse gas. As a result, all the energy that comes in cannot go out, the energy is trapped. As a result, the planet, even though the distance from the Earth is not very large, it is almost like a hell …..

The temperature of the surface is something that will melt even lead. That has happened not because of its proximity to the sun. It has happened because of the greenhouse effect. So, the Earth is also sort of moving in that direction, because you can see the climatic changes that is taking place. So, that is not the topic of discussion today. We are discussing this particular effect, you know the effect, which we productively use in case of these collectors.

Now, we can, we have now come to see a particular kind of design of the collector. The plate is flat and therefore it is called flat plate collector. We are not concentrating the solar energy, so it is called a non-concentrating collector. There are also concentrating collectors, I will come to that later, but this is the most economic design that we have, which is you must have seen on the top of hotels and other places. I do not know whether these are in your hostels, because when I was in a, I was a student my hostel had one. So, people, people say that it gives hot water in summer and cold water in winter, but nevertheless, it did give reasonably good warm water in the winter season.

So, how will the whole thing look like? It will look like, firstly it has to be inclined; it has to be inclined , so let me draw it this way.

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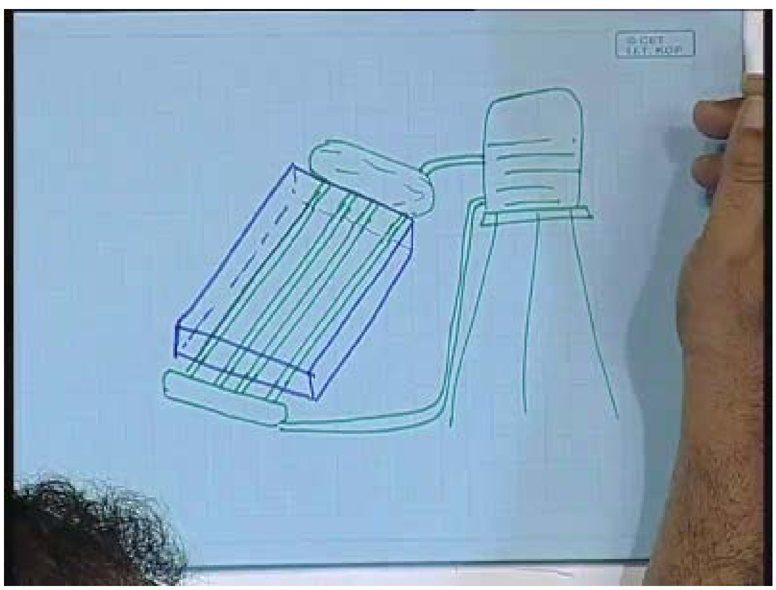

So, through the, this top plate is the glass and the bottom plate is the absorber plate, right. Absorber plate will have the, let me draw it in another color, the tubes of copper going through. There would be many more of course, but I am drawing for the sake of simplicity only four. Now, these will be attached to a cylinder in this part and there also there would be another cylindrical storage device and then there will be, if you want, a storage tank. Here is a storage tank which will have to be on top of a, some kind of a, it has to be elevated. From here water will have to be put in like this and from here, again this is full of water, that goes out, so that there will be a circulation of water like this, like this. So, here is the water storage tank.

Now, you might ask what should be the inclination, how much is inclined? If it is inclined, then it can be facing North, South, East, West, any other angle. So, what should be direction that it faces? South; why because, we are in the northern hemisphere, right. If you have a facility of being able to turn it all the time, then it is not convenient to make it face South, because then in the morning it should be facing East, in the evening it should be facing West, so on and so forth. But, such a device, it is rather difficult to do that; I mean somebody has to sit there and go on turning it all the time, know that is not very convenient. It is convenient to make it static. If it is static, then of course, it will be convenient for it to face South, because, why? Because, we are in the northern hemisphere, most of the time the average sun's inclination is towards the south, so you have the inclination towards the south. But, that inclination of course depends on the, depends on what?

In the, see, the sun's motion is like this from east to west only in the summer; in the winter, it is like so. At an angle it moves and this angle goes on increasing as we go into the winter. Again, as we go back to the summer, it becomes more or less like this, right. So, if you want to make it look at the sun, then obviously this angle has to be changed; depends on the season. So, supposing you have a facility of changing the inclination once a month, then obviously you will make it more or less horizontal during the summer months and in the winter months it should be facing rather much to the South. That might not be very convenient. Why because, during the summer month, it will be almost horizontal. How does the natural circulation take place then? It will not happen, right.

So, normally what is done is it is made static. If it is static, then obviously you have to make it inclined at an angle where it will, it will absorb the maximum amount of energy over the whole year, even though the sun's average angle is going up and down. Then, what should be the angle? What does your school day geography lessons tell you? Nahi bhai; it will be exactly the angle of the latitude, it will be exactly the angle of the latitude, latitude angle. So, for us it is somewhere 22 degrees. So, if it is in Kharagpur, it has to be inclined at 22 degrees; that is it.

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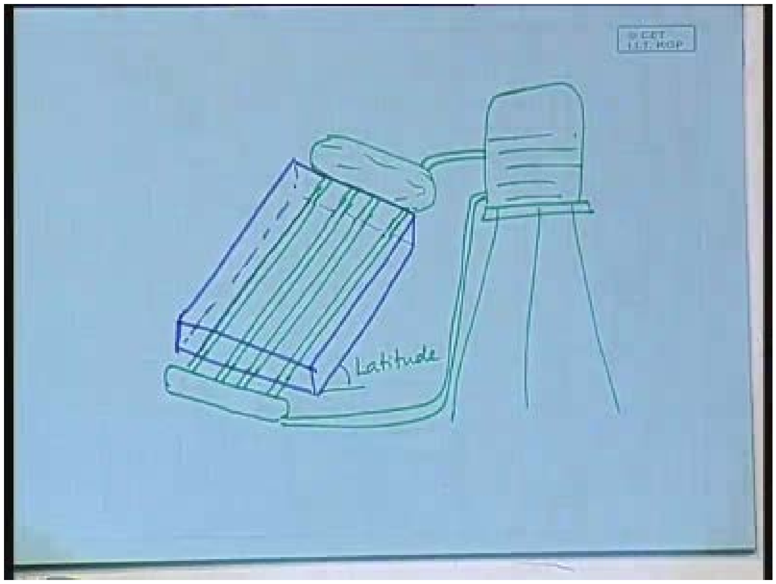

So this angle, so that should be latitude angle if it is static. If it is moving, if you have the facility of allowing, allowing the angle to change, then obviously you can absorb more energy, if you allow it to change. But then, you will have to have some kind of a forced circulation mechanism during the summer months, otherwise it will not work.

There are situations in which you do not need this hot water in the summer. For example, in the hotels or the domestic appliances, where you will need the hot water for taking bath or cleaning purposes that is mainly needed during the winter months. So, in those times you can make the device inclined at an angle that absorbs the maximum amount of energy, clear. Any question on this flat plate collector?

Student: Sir, why 22 degrees?

Why 22 degrees? Ah, I have to go back to the school day geography.

Student: …

Hanh; it is to be at an, at the latitude angle. Sometimes it is, sun, suppose it is inclined at that angle, sometimes the sun goes like this, during the summer; during the winter it goes further down. So, there is an average angle. Now, that angle is the latitude angle. But why it is the latitude angle, that proof you must have come through in school days. That is why I did not want to do it all over again. So, you have the idea about the solar flat plate collector. Let me tell you that the solar flat plate collector is commercially produced in India. There are many companies that produce these things.

For the purpose of domestic water heating this is very good. You avoid using the electrical current during the winter months when you really need the hot water. Especially in the, in the cold region in India, for example in the Himalayas, the places that are close to Himalayas, this is very good, because there you have a lot of sunshine even though it is cold. The cold is because it is elevated, but you have the same amount of sunshine and therefore these are very, very useful.

A quick detour from here will let you understand how to make a solar air heater. In case of air heater obviously, one major problem is there. Air is a very bad conductor of heat. If air is a very bad conductor of heat, the rate at which it takes the heat away from the collector will be, will be bad. But still you want the heat to be transferred. So, what needs to be done? You will somehow have to increase the area of interaction between the collector and the air. In this case, the area is very small really, because these are flowing through the tubes and the inside of the tubes are the only area in which the air can come in contact with the, with copper, to the heat absorbing surface. In case of the air heaters then what do you do?

The other problem is that if the absorber is a flat plate, then that flat plate means, it itself has a very bad area. Now, the area seen by the sun is only the flat surface and area seen by the air is also the same flat surface. For the sun it is no problem, but for air, it is a problem. You need to increase that area. How can you increase that area? What?

Student: Sir, fins

Fins, yes, you can use fins.

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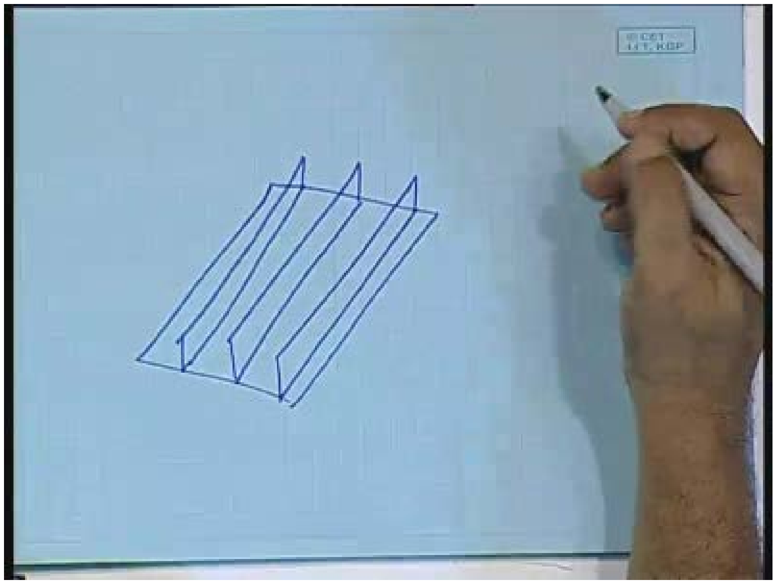

So, you would imagine it something like this that you have got a plate and you have fins like this. This is what you mean? Yes, you can do that. So, the fins are welded to the absorbing plate and the air circulates through. Air does not have natural circulation much. So, air has to be forced through. That means there has to be air blower that allows the air to circulate, but here also the amount of area that we have, though we have increased, it is not really terribly high.

How can you further increase? Well, there is a very simple way of doing that. There is no reason why you need a flat plate as an absorbing plate. Anything that is, that is made of copper and that is, you know that is seen by the sun will absorb the energy. So, instead of this, one simple mechanism is to put iron filings. You know, in lathe machines, wherever you have, they use lathe, there is a lot iron filings that come out; just blacken it and put it here, sprinkle that. What happens? That itself becomes the absorbing surface then and since it has a large surface area, a very large surface area is exposed to the air. So, you have a fluffy thing, metal; the whole place is covered with that kind of thing and air goes through, through that material. As a result, the heat transfer is good. But, then also the air faces resistance, because it is a, it is no longer a very smooth surface. So, naturally you have to have a good blower to blow it in. But that is, that is what is found to be most suitable form of doing things.

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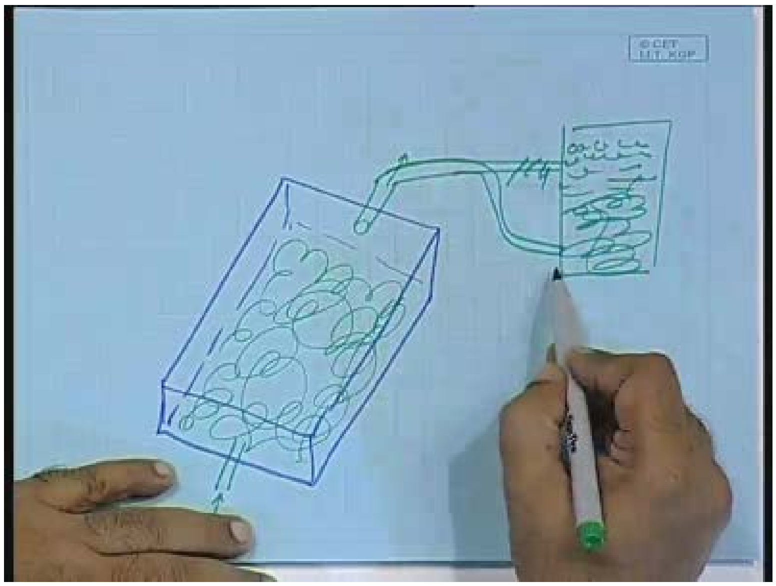

So, in this case you will have the design something like this. You have the casing anyway, you have to have the casing; you have to have the top glass plate. But here, but here you have those iron fillings and then, you have one hole in this. This side is a copper side, side plate; one hole through which air is blown in, another hole here through which the air is taken out that is it. The air naturally goes through all this and goes out. In case of air there is no question of storage, but we do have storage means supposing there is an industry that works on drying. Most of the food processing industries need some kind of drying, so you need hot water, hot air. So, that hot air can be produced this way, but of course, there can be cloudy days, there can be, you know, lack of sunshine or you may want the work to continue till the evening. So, in these cases there has to be some storage of the heat.

Normally what is done is that that air that is going through that goes through, goes to a cylindrical place, where a lot of the stone pebbles are kept. So the, sorry, it should be like this, not this; these are the stone pebbles. So, it goes through the stone pebbles, as a result, when it is hot, it heats up the stone pebbles and then when it reaches a good temperature, this whole thing is insulated. So, the same air goes through and that is used, but the heat is stored there. As a result, when you do not have sufficient sun sunshine, if you still have the air going through, the air can still absorb the heat from the stone pebbles which is in that case, a storage of heat and then that can be still used. So, you can have a good hot water source, hot air source, all through the day even when there is a lack of sunshine, clear.

So, this is how things are commercially used in industrial appliances, where you need hot air. But, these all are flat plate collectors; these are flat, there is no concentration. But, you can also have a concentrating collector, where you really need temperature to be higher than what you can achieve with the help of the flat plate collectors. By the way, how much temperature can be reached by flat plate collectors? Well, if the flow rate is low, then you can even get steam. You can even get steam if the flow rate is low. We have flat plate collectors in our department's laboratory and we do, we can get steam out of that. But then, the flow rate has to be slow enough, very low.

If it is a reasonable flow rate, the temperature at the outlet will obviously depend on the amount of solar radiation that is absorbed, as well as the flow rate. If the flow rate is large, the temperature will not be large. Now, on an average you can assume, if the incoming water is at 25 degrees, which is the average temperature you can say, the outlet temperature can be anywhere between 60 to 80 degrees. That is very common and heating up from 60 to 80 degrees is very easy in a flat plate collector. By the way, how much energy is there on the surface of the Earth? That means how much solar energy is received by the surface of Earth, any idea? Obviously, it varies from season to season. In winter it is less, in summer it is more. In cloudy days it is less, in clear days it is more. Nevertheless, on an average, the value is very easy to remember. It is like approximately slightly less than 1 kilowatt per meter square.

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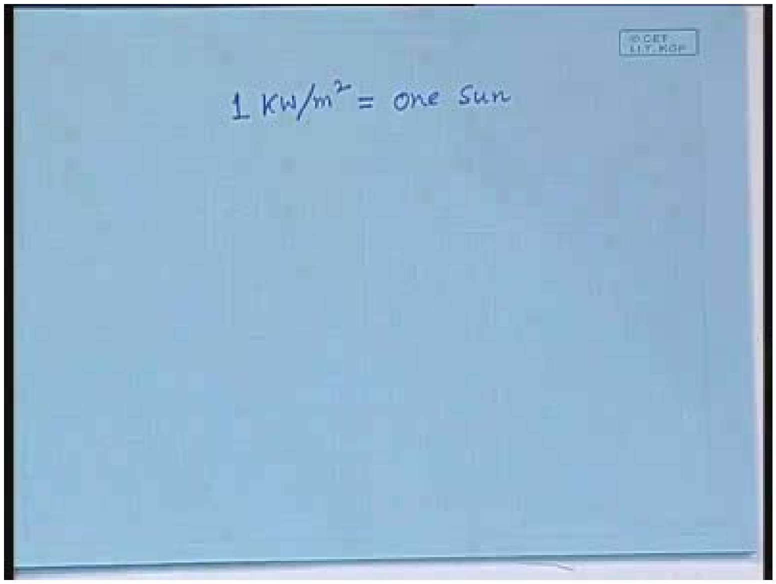

So, the amount is approximately 1 kilowatt. So, 1 kilowatt means the domestic electric heaters mostly are 1 kilowatt heaters. You have seen those 1 kilowatt heaters and over a meter square area, the same amount of energy is really received and depending on the efficiency of the thing, you can obtain that amount of heat from a … So, this is generally called one sun. So, when we say this is receiving 0.5 sun means, it does not mean that that you are cutting the sun into half and then taking part of it, no; that is not, not it. It is essentially half the average value which is 1 kilowatt per meter square. That is a unit that you should remember.

Now, in applications where you need steam or in applications where you need a, I mean water, but very close to boiling temperature, there the flat plate collectors may not be the best option, because the temperature does not go up so high. So, you need concentration. That means you need to concentrate the solar energy. Now one, okay, how do you concentrate the solar energy? Obviously, we develop mirrors. You should not think of lenses, of course.

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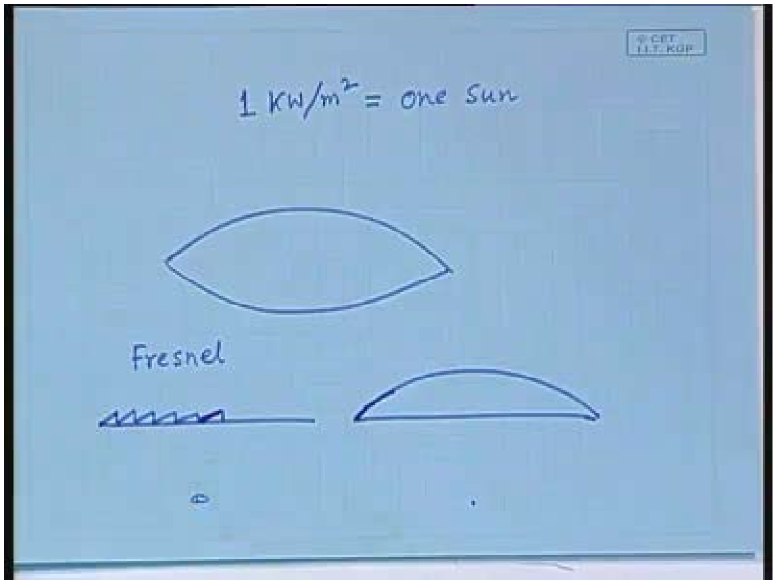

Why because, if you want to make lenses, it has to have a big bulk. It has to be a convex lens. It will have a big bulk. The bigger this is, it will have very large bulk; naturally, the cost will be prohibitively high. So, we never have concentration with the help of lenses. The lenses held before papers and burning papers that you did in your school days that is fine for a school day experiment, but for the practical purpose of generating heat that is not good. Of course, there are ways of overcoming that problem of bulk of the mirror because, what is actually happening is, suppose you have only this. Will it concentrate? It will, because it is doing the same thing really; it will concentrate.

Now, what is actually concentrating? Is the bulk being used in the concentration? No; it is essentially the angle, right, it is essentially the angle. So, if instead you take this and make it this way, here it was this angle, so you make this angle then you come down; here it was this angel, so you make this angle and you come down. Here it was this angle, make this angle and you come down. So, if you do it this way, then obviously you have the same thing. Only in these small parts it will not be the spherical structure that you had here, instead you will have a state structure. Naturally, in this case it was concentrating on to a point, in this case it will concentrate on to some area all right, but nevertheless it will do the same thing, right. Now, this lens is called the Fresnel lens. Notice that the s is silent. It is called the Fresnel lens.

You must have seen these lenses in the overhead projectors. Have you seen that? In the overhead projector, transparency projectors, the top glass is essentially a Fresnel lens that does the concentration. So, if you look at it carefully, next time you go to a seminar room you take a look at that lens carefully. You will find that that is a Fresnel lens. But then, Fresnel lenses are also rather difficult to manufacture in large areas. So, in relatively smaller sizes, Fresnel lenses can be used, but normally concentration, concentrating collectors are done by reflecting means, no refraction. In this case, it was doing it by refraction. Refraction is not economically viable. Even through Fresnel lenses are better economically than the bigger lenses, but they are finally not economically viable.

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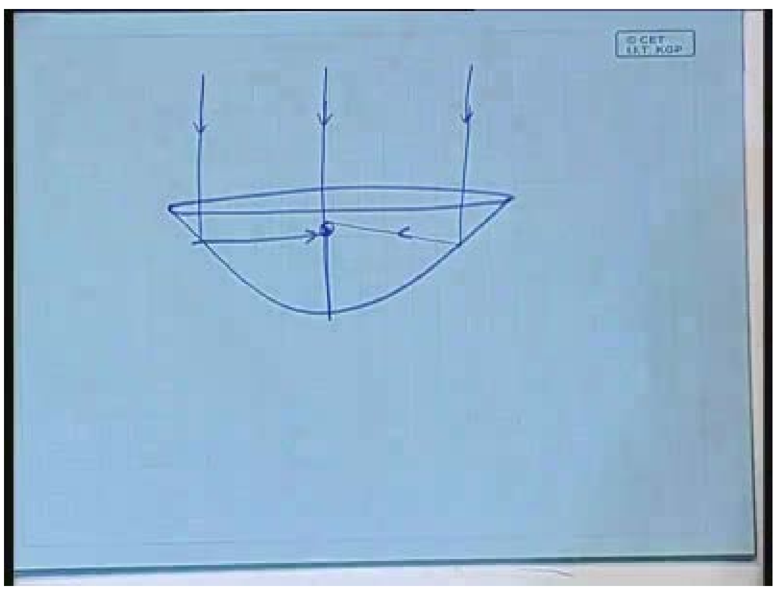

So, you have to have some kind of a reflecting surface and supposing the solar energy is coming this way and I want to reflect it on to here. What kind of reflecting surface do I need? Con, convex mirror? Concave mirror, okay; concave is you know, it can be spherically concave, it can be hyperbolic and parabola, what?

Students: Parabola.

Parabola, yes; it has to be parabola and this point has to be the focus. So, it has to be a parabolic mirror, whose focus is here and then this will be reflected on to the focus. So, imagine that since this is a three dimensional structure, though I am drawing on a sheet of paper, it is actually coming over a 3-D region, so this will have to be a kind of trough, right, bowl which is shaped in a parabolic shape and the inside has to be reflecting surface. Now, reflecting surface is not very difficult to make, because steel if polished well is a good reflecting surface. You do not really imagine that this will be made of glass and with a, you know silvered side; no, that does not, that is good for flat mirrors, but you cannot really make things shaped like this, made of glass. It will be breakable very soon. So, these are not made of glass really; these are made of steel, but made of this size, this shape.

But obviously, making something this particular shape is you know, in terms of manufacturing process, rather difficult. In terms of manufacturing process, how do you make, how do you manufacture a parabolically shaped mirror? It is not easy. That is why the people who manufacture these things or the companies that manufactures these things, make these things pretty expensive. These are really used for optical purposes in case of, yeah, satellites.

Students: …

..… are pretty bad, you know they are not parabolic, come on. Just they reflect forward and there is no advantage for the company to make it perfectly parabolic. So, it is not properly parabolic, it is more or less parabolic. But it is small area, but here we are talking about big areas. Obviously, you cannot use it that way. The other problem is that in this case you have to have something that was not necessary for the flat plate collector that is tracking. You need to track the sun, okay, you need to track the sun. So, what does it mean? You have to, if the sun moves, you have to always move the whole mirror, otherwise the concentrator will not be at this point.

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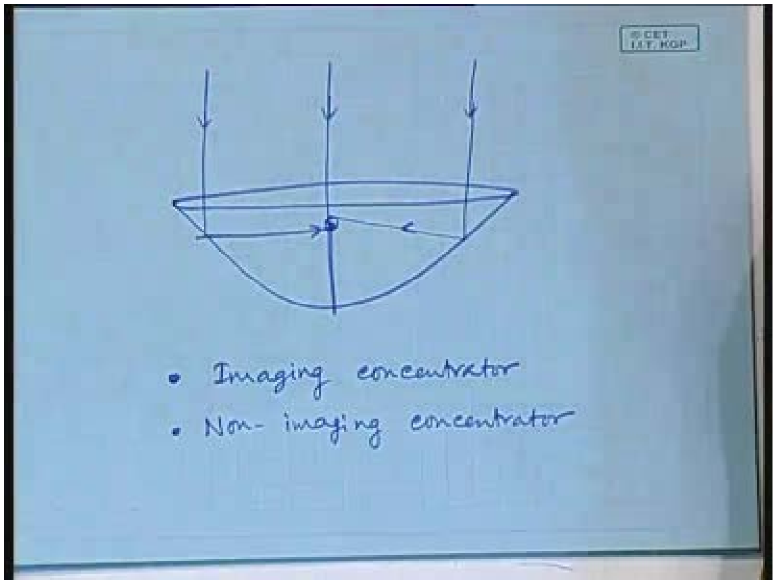

So, at this point, I need to talk about two types of concentrators one is the imaging concentrator, the other is the non-imaging concentrator. The parabolic concentrator is actually imaging concentrator. So, it actually forms the image of the sun on the focus. Not exactly on the focus, it produces the image on the, on the focus if the solar radiation comes axially. If it does not come axially, it does not form the image on the focus. The image then, image position then moves. So, there are two ways of tracking them. Either you have to move the whole mirror or you have to move the absorbing material. The absorbing material can also be moved, but nevertheless you have to have tracking. How the tracking is done, I will come to that little later.

Just understand that at this stage that you need tracking for an imaging concentrator and the parabolic concentrators are imaging concentrators and in this case you will need two axis tracking, right. In this case you need two axis tracking, because it has to, it has to move all the ways. So, both North South as well as East West it has to move and two axis tracking is somewhat expensive. That is why people often do not prefer these kinds of devices, unless they are going for a very big establishment, where the two axis tracking also becomes economically meaningful. So, what is the other option? The other option is if you have one axis tracking, how can you have a one axis tracking? By making a linear concentrator. What is the linear concentrator?

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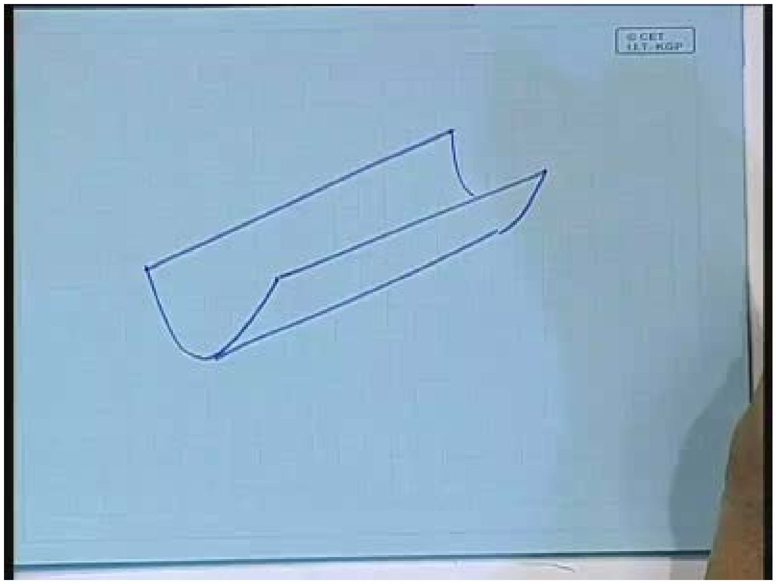

Supposing you have got the parabolic surface like this, but you do not make it round shape, rather you make it … This is also parabolic concentrator. It will concentrate on what? A line, rather depending on the, it will be a line if the parabola is a perfect parabola, else it will concentrate on a region, a region that has some width like a strip. It will concentrate on a region like a strip.

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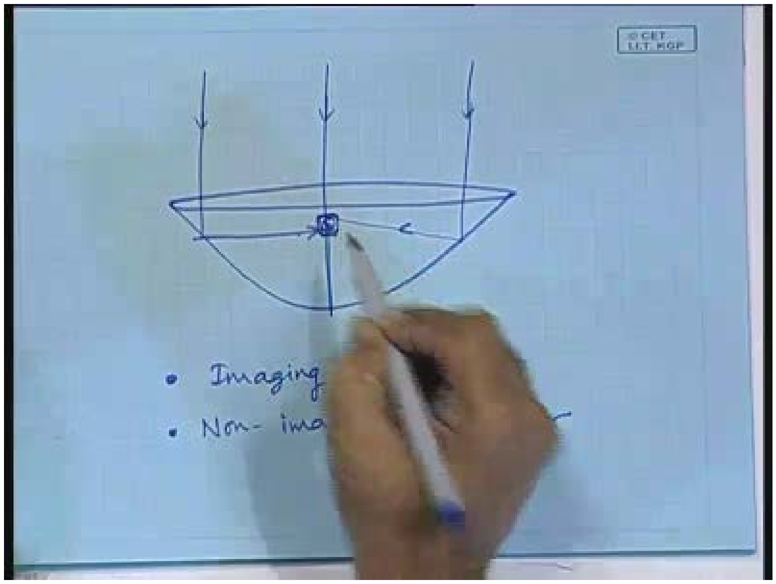

In that case, in this case, the other problem is that what do you make the absorber of with? The absorber of course has to be something like here. So, you can have a bowl like thing, a small container whose outside is blackened, which is made of copper and inside you will have the absorbing material. So, the whole thing has to be packed into a very small region, small area.

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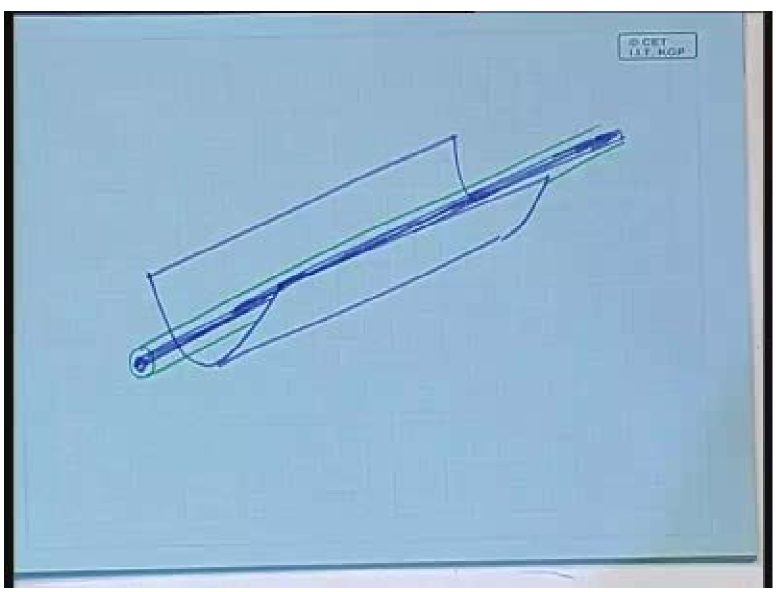

In this case on the other hand, the whole sun light is concentrated on a strip and therefore, you can have a tube going through, you can have a tube going through, which will, whose dimension, whose diameter should be exactly the width of that strip. Why does it have the width? Does it need to have a width? Because, the surface cannot be exactly made to be a parabola, there will be some deformities due to which there will be some deviations that obviously obtains from the manufacturing process, so depending on that, there will have to be a diameter. But, you can always make a simple tube, copper tube of that same diameter, make the external side blackened, so that will be the absorber and the tube itself can carry the water, the tube itself can carry the water. So, here much of the problems are naturally solved.

You have a concentrator, you have the absorber, you have the same tube. In case of the flat plate collector, you have to had the absorbing plate and the tube different; they are, they are welded together. In case of this, the linear parabolic concentrator, they are the same thing. But, you have there the glass plate. So, how do we put the glass plate? Simply, simply as a glass cover like this. So, there are two concentric cylindrical things. The inside one is a copper cylinder, copper tube and outside it is a glass cylinder; that is it, rather simple construction.

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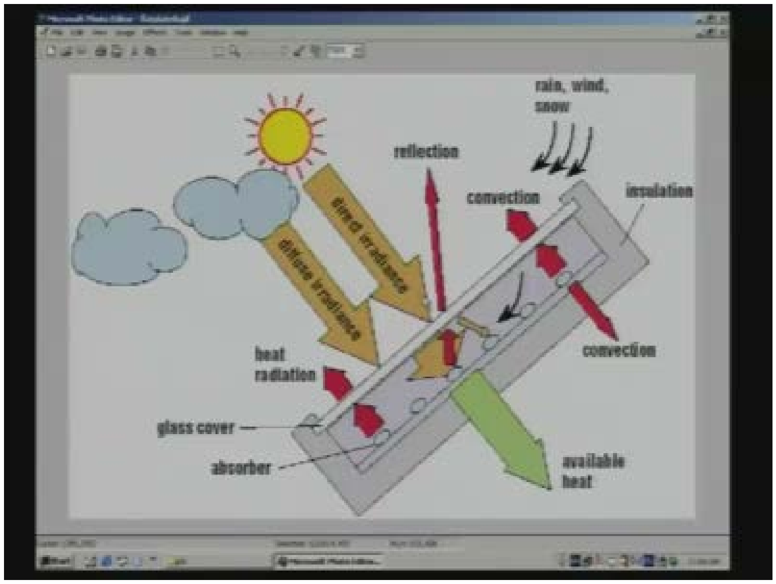

Now, let us see some pictures on the computer screen. Here is a picture of the flat plate collector, a section of the flat plate collector and here is the direct irradiance that is coming, insulation that is coming. A part of it is reflected and a part of it, as the top glass cover is heated up, part of it is lost due to convection. This amount is rather small, because the heat is mainly trapped inside and you have these absorber things, tubes and finally the amount of heat is absorbed in this plate, in these tubes. So, this is what is finally available as the available heat. Some amount of energy is lost through the convection, some amount of energy is lost through the radiation, but mainly the radiation is trapped inside because of the, because of the effect due to the glass cover.

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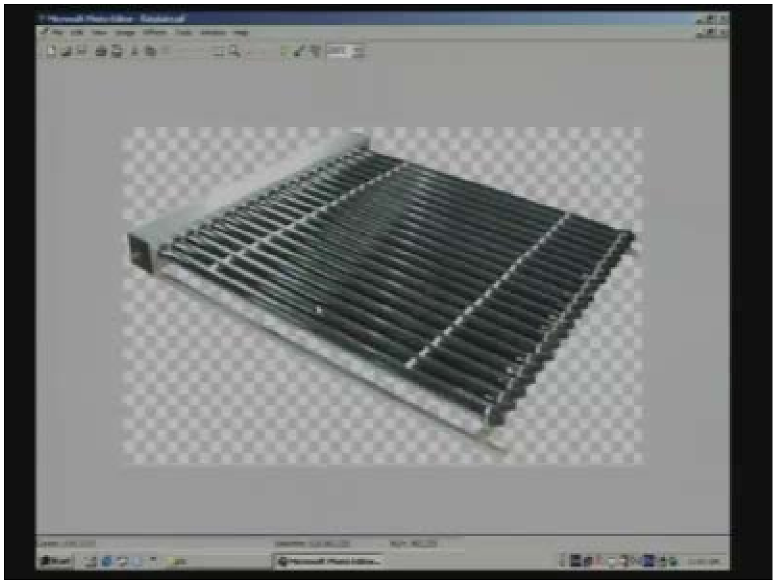

Now, let us see another picture, where the actual photograph of this kind of a solar thermal collector is shown without the glass cover. Here you see, these are the copper tubes that act as the absorber and here is the top big tube which collects the water that goes through. So, the water flows through this in the vertical direction due to the natural circulation and that is how it works. Let us see another.

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Here, this is a picture of an actual photovoltaic, actual solar thermal flat plate collector. You would see that here there is a tube running and here there is another tube running. So, this tube is connected to all these upgoing tubes of the solar thermal collector and water flow in this direction. Let us look at another picture.

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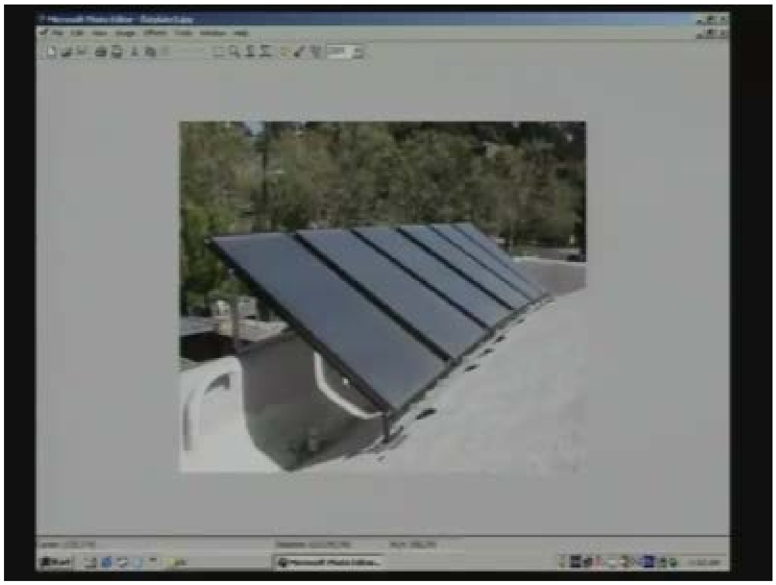

Here you have another picture of the solar thermal flat plate collector and here is another that is stationed on top of a building.

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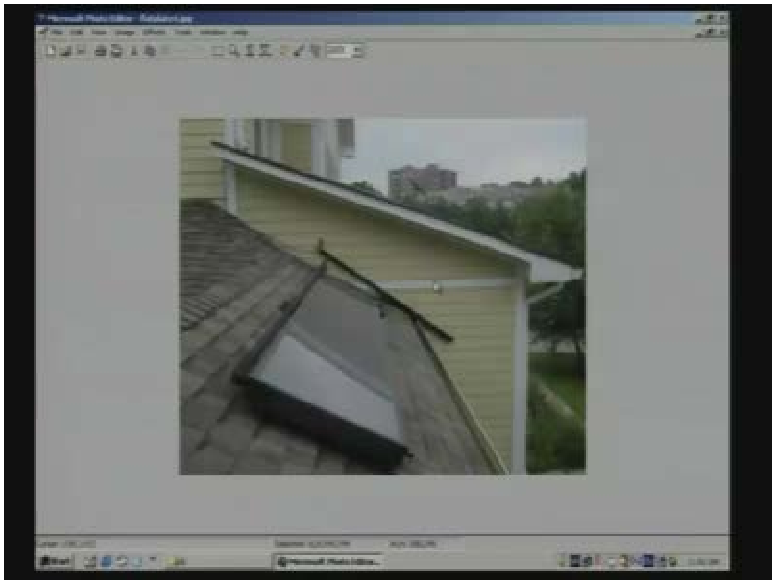

These are naturally used for heating up water mainly for domestic purposes or industrial purposes and these are very practically used.

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Flat plate solar thermal collector - as you can see that here you have the total absorber area. Water is coming in through this pipe and it is going into the pipe that is at the bottom. Through those relatively thinner pipes, both made of copper, blackened copper, the water is flowing up into the relatively thicker pipe at the top and from there it is going, from there it is going out. Now, it is actually stored in this tank, so that the tank water slowly gets heated up and that can be used at any point of time. The tank is insulated at the outside. Now, here you can see that this surface, the top surface is actually glass that is used for the greenhouse effect that I explained in the class. In the bottom surface, you have the copper plate that acts as absorber and the copper plate is glued or it is welded to the vertical pipes that carry water. So, the solar energy is absorbed in the absorber plate that gets transferred, the heat gets transferred into those pipes and that is how the whole thing works. As you can see, this is an experimental arrangement in which the temperature at the inlet is being measured, the water is flowing in and the temperature at the outlet is also being measured and you can, if you go there, you can see about 20 degrees difference depending on the flow rate, of course.