Non-conventional Energy Resources
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Lecture – 11

Hello there, Namaste; [FL] and welcome to this Southern Indian state of Tamilnadu; the city of Chennai. I am sure you are aware that Tamilnadu and Chennai are popular for many things ancient temples, South Indian food and of course, the ancient language of Tamil. One of the things we are very well known for is the amount of sunlight we get here and the amount of heat that we get here through our summers which are very hot and humid.

In this class we are going to look at solar energy and some ways in which we can harness it, capture it and use it for energy in our day to day applications. So, that will be the focus of today's class.

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I hope you are ready; I am sure this is familiar to all of us, this is our planet where we live. And briefly as we look at solar energy let's get some idea of what it represents with respect to where we are on the planet.

So, here we are in India that's our country; this is our equator and due north of the equator some way up north of the equator, we have tropic of cancer. So, if you look at

India for the most part a fair bit of India is above the equator and below the tropic of cancer. So, in our seasons that we see through the year; we get a lot of sunlight through summer we get considerable amount of sunlight.

And in most places in India you are going to have sun beating down on us through the summer months. Even during winter in some places in India, it doesn't become too cold; it only becomes marginally cold and so the potential for us to pick up solar energy and utilize it is actually very high; relative to many other places in the world.

Of course, if you are looking at the inclination of the planet, then during the winter months we are a little bit up north and the sun is a little bit with respect to the axis of the earth it's a bit below the equator and so we are getting sunlight in a little bit of an oblique manner. But as the earth goes around the sun, we will soon come to an orientation where the earth tilts this way and then the sun is more or less vertically down on us.

And so there are months in the winter half of our year; that basically the sun is coming to us in an oblique angle and during the summer its coming more or less vertically down on us. So, this is the range of sunlight that we have; some places in the northern hemisphere as well as the southern hemisphere, as the world goes around the sun; sometimes for a certain number of months in the year, they will receive no sunlight.

So, if you look at the regions which are closer to the poles; both the north pole as well as the south pole, there are places where you are not going to receive any sunlight for some months in the year. And this basically means that those are places where you cannot utilize solar energy throughout the year whereas, we are relatively fortunate from that perspective that we do receive sunlight throughout the year.

Of course, for the most part we grumble about it when we are out in the hot sun saying you know it's so hot and that is why you need to have some coverage for your eyes and as well as for your head. But basically it is something that we should not look at as a disadvantage, it is something that we should look at as an advantage.

It is something that we can capture, utilize and really benefit from and so it is something that we should really apply our minds to and spend some energy trying to harness this energy. So, this is what we are trying to do in the next several classes we are going to basically look at solar energy. And today I am just going to show you one particular manner in which we capture solar energy.

Broadly solar energy consists of a thermal energy and a photovoltaic kind of energy. In other words, you can capture solar energy as heat; you can also capture solar energy as electricity. So, these are two possible ways in which you can capture solar energy for use. In today's class, I am going to look at the first version which is the thermal energy; how we capture thermal energy.

And in particular I am going to look at a particular manner in which we capture this solar energy. So, that is what I am going to describe; briefly going to set up something that looks like the unit which will capture solar energy for us. And I will explain various aspects associated with how that unit functions? What are parameters that we have to keep in mind as we utilize that unit? And what are some you know limitations and capabilities of that unit?

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So, we have solar energy coming down to our planet and if you look at the top part of the atmosphere of our planet what arrives from the sun is about 1400 watts per meter square. So, this is some calculation that we did in our class; so you have seen how it comes down to about 1400 watts per meter square or about 1.4 kilo watts per meter square. So, if you look at the earth's atmosphere and the various layers of the earth's atmosphere; about 30 percent of what arrives at the top part of the atmosphere, actually gets reflected away.

And so only about 70 percent of what arrives at the top part of our atmosphere actually comes down to our planet which is what we feel, when we step out in the sun and you have you know this harsh sunlight coming down on you or the heat that you feel as you walk down on a road without any cover. The heat that you feel coming down at you is about 70 percent of what comes to the top surface of the atmosphere.

And so, if you do the calculation 70 percent of about 1400 watts is about 1 kilo watt. So, 1 kilo watt per meter square is what we feel on the surface of the planet. And so that's actually a number that is relatively easy for you to remember; it is just a number 1; 1 kilo watt per meter square; that's the amount of solar energy or the intensity with which the solar energy comes down to our planet. So, that is what we will feel on the surface of the planet.

And, if you are trying to capture solar energy; that's basically the kind of energy that we are trying to capture; so, one of the ways in which we do that is to use something that is called as a flat plate collector okay. So, it's a flat plate collector it's easily the simplest way in which you could capture solar energy.

So, what we are going to do in the rest of this class is to look at this flat plate collector. And I am going to show you various parts associated with this flat plate collector, how it is put together? And give you some brief idea of you know how the energy is captured. So, as the name suggests the main part of this collector is a flat plate collector. So, if there's something that's a flat plate; so, I have here a flat plate, it is it's a copper sheet that I have here.

You could use any material; potentially you can consider using any material for doing this process, but clearly we have some material restrictions on what can be selected. So, the point being that first you have solar energy coming down on this surface. And this energy has then got to be picked up by something that is a heat transfer fluid of some sort.

Usually, we use water or we use air; so it often the solar heaters; solar thermal heaters are trying to do one of those two things. They are trying to heat water or they are trying to heat air; so, many of the units that we buy for our homes or maybe even the hostel that you stay in or dorm that you stay in; those are units which are typically trying to capture solar energy for heating water.

But if you go to many of the food industry applications there; they actually use hot air to dry various items. So, there the solar energy is used to heat air okay; so broadly those are the two different things that; we are trying to do with solar energy heat water or heat air. And I will start by first describing what you would do to heat air am sorry water and then we will also add the detail that is required to understand how you would go about heating air.

So, the first thing that we need is a flat plate and as I said you know you could use any material. But first of all this the heat that falls here should get absorbed by this material easily and it should get transferred by conduction; it typically it is going to get transferred through this material by conduction to the heat transfer liquid which is or fluid which is either water or air.

So, since you need it to get conducted from the location where it is falling to the heat transfer fluid; the material that you select needs to have good thermal conductivity okay. So, that’s a very important criterion for this material, so you could consider using something like if you were to use a thermocol board; that will not work because that has very poor thermal conductivity. So, you need something that has good thermal conductivity.

So, typically a metal is a good idea to start with and a good thermal conducting metal is copper. You could use stainless steel and so on, but copper is typically much better conductor than stainless steel. Of course, there are better conductors than copper, but then it becomes a question of economics. So, if you were to use silver that would be even better than copper, but clearly that’s a very expensive material to use.

So, typically we work with a copper plate; I will also add that this copper plate is since it is the color that it is it is also going to reflect sun light. All metallic surfaces tend to be very reflective that is a property of the metallic surface and so that is not really a great feature to have in a unit which is trying to capture solar energy. You don’t want to reflect the solar energy, you want to capture it and therefore, having a shiny surface is not really a good thing for a solar capturing unit okay.

So, therefore typically even though they use copper and which is what I am going to show you through this class; in the actual implementation; they will paint this with something that is black in color. So, it will be coated with something that is black in color to enhance the extent to which it is absorbing the radiation and reduce the extent to which it is reflecting the radiation.

So, even though I will show you a copper version of it; please keep in mind that at the end of it; it’s all going to be black, the unit that you actually see in a lab setting or in a commercial setting will typically be black in color because that absorbs all the radiation that is falling on it. So, what we are going to do now; is we are going to actually assemble some of the parts that go in towards making a flat plate collector. So, primarily on top of this plate, there are going to be some tubes and those are the tubes through which the heat transfer fluid is going to flow.

In this case, it’s going to be water. So, I am just going to assemble those tubes and then I am going to talk a little bit on how the system works and then we will talk about how it works as a unit to heat up air.

So, we have with us some of the parts for this flat plate collector. So, we have the copper sheet as I said and we have a bunch of copper tubes here; four copper tubes that I have. And basically all I am going to do is; I am going to place these on this copper plate. So, you have here one, the second one is out here; roughly evenly distribute them; so that’s three and four.

So, basically in the real setting this would need to be fixed to the plate and in fact, since I am just doing a demo here; I am going to find a simple way to get them to stay on the plate. And so I am just going to use a sticky tape here to get them to stay there and so first we will do that. The idea being that there has to be good contact between the plate and the tubes that are there on top of the plate.

And therefore, it needs to be fixed pretty well to the plate only then any heat that is coming to the plate will then also arrive at these tubes. So, here for our just for our explanations purpose; I am just using a sticky tape to get them to stay in position, so that I can explain the process to you. In reality, they would actually either weld it together so that it stays put and also improves the kind of contact between the plate and the tubes.

Or you could also use instead of this kind of a tape; you could also use some kind of a good heat conducting compound which could then be used to hold this together. So, you do have certain compositions of these compounds; so, for example those of you who are familiar with how say desktop computers are used. Often you know that there is a specific part called the heat sink; which is then fixed on top of the processor in the computer. And this heat sink needs to stick; convey the heat away from the processor so that the computer doesn't processor doesn't heat up too much.

So, this is a part of the process that is typically there in the computers that are present; the typical desktop computers that are present. And so that is a pretty common requirement in most of these cases. So, when they do that; when they attach that heat sink to the processor, one of the things that they apply there is a heat sink compound; it's called a heat sink compound.

It does help the transfer of heat between the processor and the fan that is on top of it; so, that is done. So, that's just an possibility that you could use, but that's typically not necessarily the kind of item that is used, but the point being that you have to use something that has got good conductivity and can also hold these copper tubes to that copper plate. So, for example, I have now got this assembly here which essentially has these four copper pipes; which have been fixed to the copper plate.

So now, we have now moved from just a plate which is gathering heat to a small assembly here. Just you know somewhat crudely put together, but primarily to demonstrate the process; where essentially you get heat on the plate and it absorbs the heat. And then it transfers the heat, so it laterally transfers the heat. That laterally transferred heat comes to these pipes and then when you have water flowing through these pipes, they pick up that heat and then they can be stored.

So, in a typical application you will actually have a feeder tube here and you will also have a tube out here; which would then pick up the water. So, usually you will have cold water at the bottom and it will just gradually as it heats up; it will move up this pipe and it will come to the top and then from there it gets gathered. You may have a tank a separate tank in which the hot water collects and then the water is piped from the tank to the bottom.

So, if you just set this up as the day progresses; it keeps getting hotter and hotter the water keeps getting hotter and hotter. And typically this kind of a unit with the black coloring is what can get used as a flat plate collector. So, there are a few more aspects of it that we have to keep in mind; when we talk of this kind of a collector. There is atleast one more critical part that is not yet here; which is what I am going to show you now and then I am going to discuss what that part does to this unit.

So, you will typically find that wherever you go and you look at this kind of a unit. First of all that it’s not copper in color its black in color, but there is a glass sheet on top. So, for example, I am just going to put a glass sheet on top of it just to show you how it is going to look. And then we are going to discuss what does that glass sheet do for us? So, that’s what we going to discuss in the next few minutes.

Okay so, here we have a glass sheet and this is the unit that we have put together so far. So, in the typical application; installation you are going to have this glass sheet sitting on top of this unit okay. So, this is how the unit would actually look like there will be a glass sheet on top of this copper unit. The purpose of it is not just cosmetic; it has actually got a very specific application which is why this glass sheet is put like this.

And the basic idea is that when you have a sunlight falling on this unit right; it goes in and it heats up those the copper plate and the copper tubes. Now any hot surface; any surface that is not at absolute 0; it is actually giving out energy as well and so when this is hot; it is typically giving out energy in in the infrared part of the spectrum.

So, heat is leaving this unit in the infrared part of the spectrum as radiation and so that is not something that we want we want the heat to remain here; we don’t want the heat to be lost. And therefore, we want that infrared radiation which is leaving this copper plate do not leave the copper plate to get stuck inside this unit. And that is the actual application of this glass.

So, this glass typically if you take a glass its property is that it is transparent to visible light, but it is actually opaque to infrared. So so, when you put this glass on top what you find is that even in the incoming solar radiation there is infrared. So, that infrared does not get in; so we are losing part of the spectrum by putting this glass on top. But once the radiation goes in heats up the water and heats up the copper plate; the infrared that is coming out of it which is the loss of heat from that water is minimized or in fact, eliminated.

That heat stays within this unit and just gets reflected repeatedly within this unit and therefore, stays within this unit. And therefore, the heat that you have gained in the system stays with the system and so that's a very important application for this glass that I have placed on top.

So, together this is the unit that would then actually serve; these are the main parts of the unit that would then serve as a flat plate collector. And this is very good at connecting heat for the purpose of heating water to get hot water.

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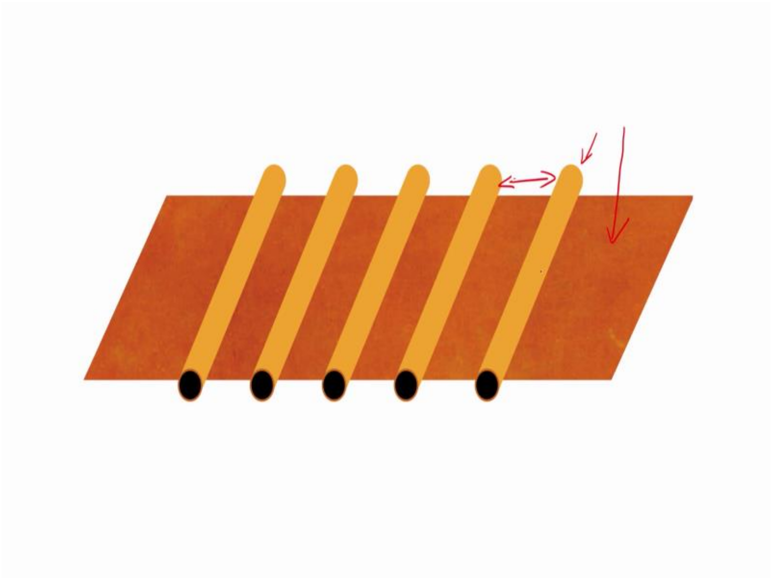

These are the parts of a flat plate collector you can see here the copper sheet. So, that is the your starting point on these are going to be placed a series of copper pipes, which will be placed and therefore, any solar energy that comes onto the copper sheet is then distributed to the pipes closer to it.

And then water flowing through the pipe picks up this heat. So, this is a flat plate collector that is being designed for picking up heat in into the water and. So, it is basically a water heater and so therefore, it will have pipes as the conduit through which the water will flow. So, this is how those parts would come together and then we would also have an arrangement by which let's say you will have incoming water that is available.

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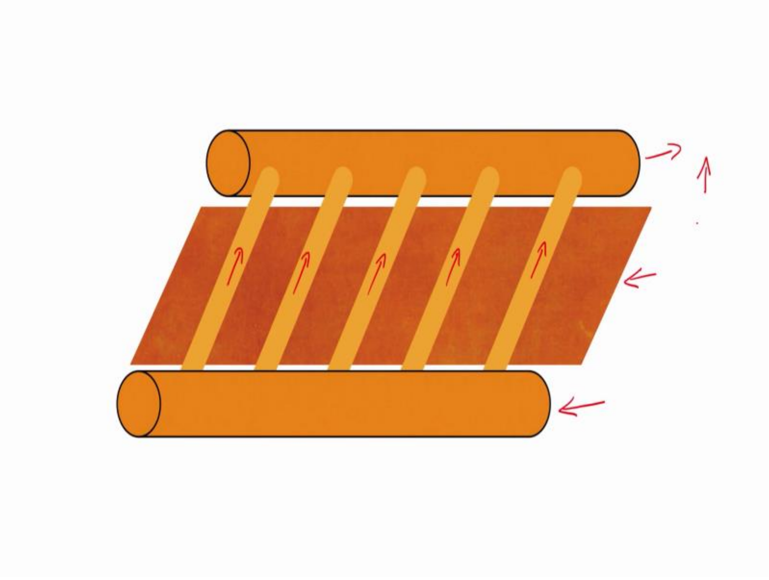

And then the hot water can be tapped from the tube on the top and the arrangement in the middle then does the heating of the water through the pipes that are there. And if you incline it such that the top side is inclined upwards; then the water flows in the direction that I have just pointed in this using these arrows; simply because the hot water will start moving upwards and cold water would remain at the bottom.

So, in this process you can get hot water to start collecting at the top and then take it away to a reservoir of some sort. This is all of course, shown as a schematic here in copper color.

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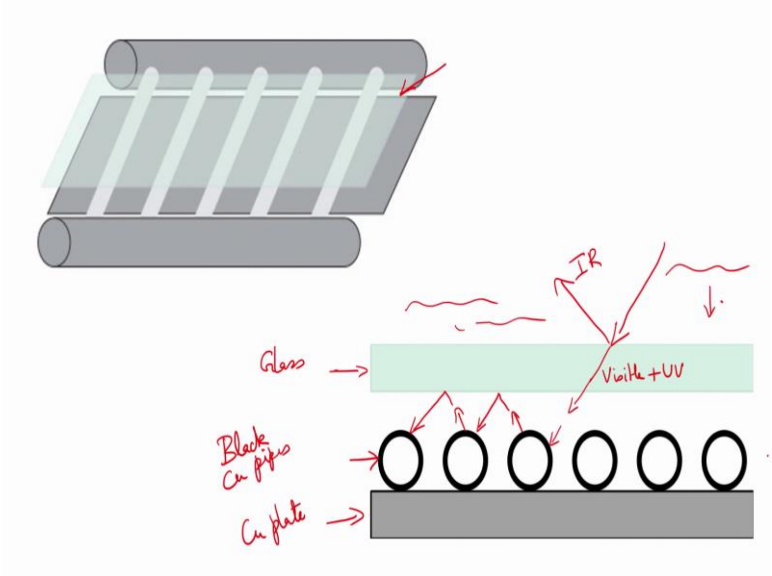

But you would actually need to make it black so that the energy is absorbed completely and is not reflected away from this surface. So, it’s the same schematic here shown in grey in fact, here just for ease of observation of what it is, but in principle it could be black in color. In addition to this complete set up we would also need a glass plate on top; which is what I have added in this schematic that you see here.

All the rest of it is the same as you just saw before except that to prevent a loss of heat through infrared radiation; from this flat plate collector we place a glass sheet on top which is what you see here, a glass sheet is placed on top. A sross sectional view of this is shown in the figure below and basically what it shows you is; when you have an arrangement as follows, these would be your copper pipes, these would be the black colored copper pipes black colored Copper pipes.

And this is your copper plate and the incoming radiation which will have a visible ultraviolet as well as infrared. So, from high frequency that would be ultraviolet visible and then infrared would arrive at this surface. Because this is glass; the infrared will not enter this surface it will just get reflected away infrared. But visible and a UV will go in and heat up the tubes and the water inside.

Once this heating is completed or as the heating proceeds as the temperature of this of the copper pipes as well as the copper plate increases; it will try to radiate out infrared because that’s the temperature it is at and at that temperature which is say 60, 70 degrees

C; much of the energy that leaves this system in the form of radiation; leaves in the form of infrared radiation. But since glass is non transparent to infrared, it just bounces right back so it just bounces right back and therefore, the energy that has been captured is not lost. And that's the reason why we place this glass plate on top; the glass plate also takes care of preventing convective losses.

So, whatever gas you have; whatever air you have flowing on top, is unable to access the copper pipes and therefore, does not take heat away in the form of convection from the pipes that are below.

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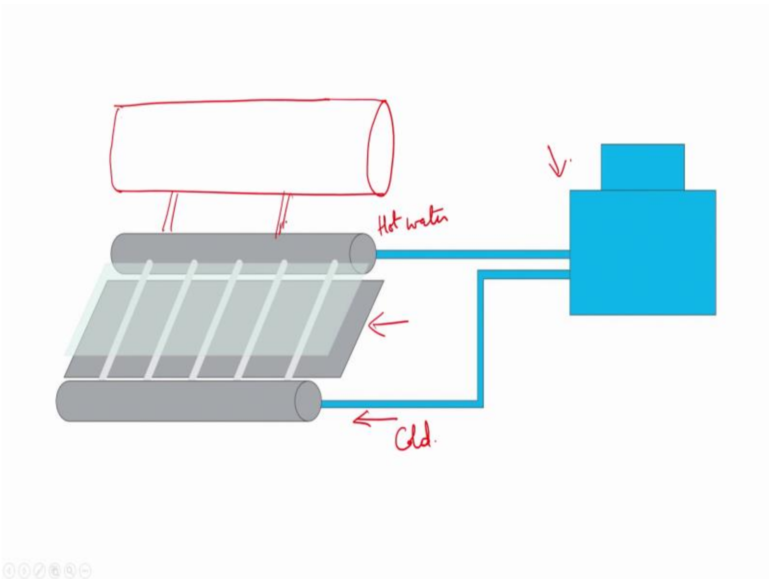

So, as an assemble setup it would look something like this; you would have the the flat plate collector here which is consisting of the copper plate, the copper tubes; the glass tube sorry the glass plate on top as well as the supply and discharge tubes. And essentially it would be attached to the tank that you see out here and basically cold water is accessed by the pipe at the bottom. And hot water is available at the top and this hot water essentially goes into the reservoir and eventually the water in the reservoir keeps getting hotter and hotter and hotter and hotter.

So, this is the basic idea you sometimes see variations on this where you basically have a tank sitting right on top here. And that is typically what you see in the household situation.

So so,. for example, it would look something like that and you would have the connection to it out here. So, and that's the kind of setup that you would typically see in a household situation put on the overhead tank, but that's the basic idea of a flat plate collector. So, I am going to talk of a couple more things here; one is what needs to be done with respect to orientation of this unit.

And also in terms of what needs to be done to extend this idea to capture heat for the purpose of heating air; so, those are the two things that we are going to discuss. Okay so, we will now look at how we need to orient this unit so that we capture the sunlight effectively. So, to do that we need to consider the orientation of this unit with respect to the seasons that we have and also with respect to the time of the day, generally for a flat plate collector we are not so worried about the time of the day because it is basically flat.

And so we don't necessarily track it hour by hour with respect to the position of the sun. So, for example, for me this is due east I have due east out there and this would be due north for me and then that would be due south for me. So, generally we don't keep this such that it is pointing towards east in the morning and then we keep tracking the sun through the day etcetera; you can do it, it is not particularly necessary to do it.

It is much more important that we sort of track the seasons; so to speak. So, as I said this is due north for me and that is south the way I am presently oriented. So, for us sitting in the northern hemisphere; the sun is typically in the southern months towards the southern side. So, that's the arc that it does through the southern part of the during the winter parts of our seasons. And then as the summer comes this slowly comes more vertical and then the sun is moving from east to west more or less directly above us.

So, we need to orient this unit corresponding to that; so, for example, I have the pipes this way that's not the way I would have to orient it given that the sun is going to be moving this way. And then through the winter it is going to be down that way and then its slowly going to move up as the months progress. So, actually we would have to orient it this way and have it pointed downwards.

So, when you do that basically the as the sun moves from morning to evening as it moves from east to west; it keeps on heating the surface and based on the location of the sun; this is oriented correspondingly, based on the season and then you have cold water at the bottom and you have hot water which is the water that gets heated up slowly moves up the tubes. I mean hot water starts going up, cold water comes down and then eventually hot water starts collecting at the top. So, we would have to orient it like this and during winter as the winter comes in this is oriented more and more vertically.

I mean more and more up in inclination because it has to face the direction that the sun is oriented. So, let’s say once a month you would have to reorient this, so, that your position reasonably optimally with respect to where the sun is located. So, clearly if you are going to only change the orientation once a month; you can do this manually. You don’t need to have any sophisticated instruments to do it.

As the summer comes from this you know fairly high inclination, you slowly start making it more and more horizontal and then in peak summer you are sitting in relatively horizontal position. So, you actually gain a lot in peak summer because strong heat is coming straight down on this surface. So, it heats up a lot the only issue is that if it is relatively horizontal; then you don’t have a natural flow of water from the one side to the other. So, you would actually have to do something to force the water to continue to flow from one direction to the other to heat up.

So, that’s the one small disadvantage if you are in the summer months here in say any place in India, where the sun would then be directly above us. So, that’s one thing that you have to keep in mind, but otherwise the orientation would be like this and slowly with the onset of summer it becomes more and more horizontal. Again as it goes back to winter, you go back to this kind of an orientation.

And then the sun is always coming from our east and moving to the west, so through most of the day this gets heated up. So, this is the type of orientation we would have to keep it in; as I said of course, there would be a glass plate on top of this which I am not keeping it here right now for our ease of demonstration. But that is the basic manner in which we would have to set this unit up. I will also say that one of the other things that the glass unit does if it were on top of this. As I said the first thing it does is it prevents the IR radiation from escaping from this unit; that would just bounce back after hitting the glass.

But the other thing it also does is; it prevents free flow of breeze on this unit and therefore, prevents the loss of heat using convection. Convection with the form of the blowing breeze taking away the heat from this; so, that is prevented by this glass sheet that is on top of it if it is present there.

So, those are the major parts and this is how the orientation is set up with respect to various months of the year. We spoke about how this flat plate collector can be used to gather solar energy for the purpose of water heating. I also told you at the start of this class that two major applications for this kind of flat plate the collector is to heat water as well as to heat air. So, in some ways you can argue that exactly the same implementation can be used for heating air, you simply need to flow air through the tubes instead of water and of course, you would need a blower.

Because that would ensure that you have a pretty good movement of air through this system, it would pick up the heat and then transfer it to some other location where you need the dry air the hot air. So, as I said one typical application is in the food industry where they are trying to dry say some various ; food to prepare food items using the hot air that is available.

But generally speaking the ability of air to pick up heat is limited by the amount of cross sectional area that it sees which is hot. So, you have to increase the surface area that it sees that is hot and it will then be in a better position to pick up heat; otherwise it’s kind of slow in picking up the heat. So, usually a tubular structure like this is not as effective in transferring the heat that is gathered by this unit on to the air. So, in a typical hot plate I mean flat plate collector made specifically for the purpose of heating air, some modifications will have to be made. The major modification really is that instead of these tubes; you would still have copper.

But instead of tubes you would have it as fins; so, they would be vertical fins here. So, a fin here, a fin here, fin here and fin here. So, you can think of vertical pieces of copper of similar plate kind material which are standing at these locations. So, the general orientation would look same, the general build would look the same except instead of a tube you would have a fin; you would have four fins here in this example.

So, when you do that and you blow air from the bottom to the top; air is able to pick up heat from the plate, it is also able to pick up heat from the fin. By doing this, you gather a lot of heat into the air and then you take the air away. You would still need this glass sheet on top which would then do those two things that I mentioned; which is prevent the loss of heat through infrared and also prevent the loss of heat to the outside atmosphere through convection.

Inside we do one convection, inside the air is going to pick up heat through convection and so that convection inside the unit is necessary, but we don't want that convection to also occur between this unit and the external atmosphere. So, those two things would be prevented by having this glass sheet in front which I showed you a short while ago.

But beyond that this would be the major other modification that you would have fins. So, this is the way in which you would set it up, you would have a pipe coming in at the bottom which would bring in the air. And then it would distribute itself through this unit with lot of fins and then those the exit air would also come out through a pipe which would then have the hot air and then that is taken for some application.

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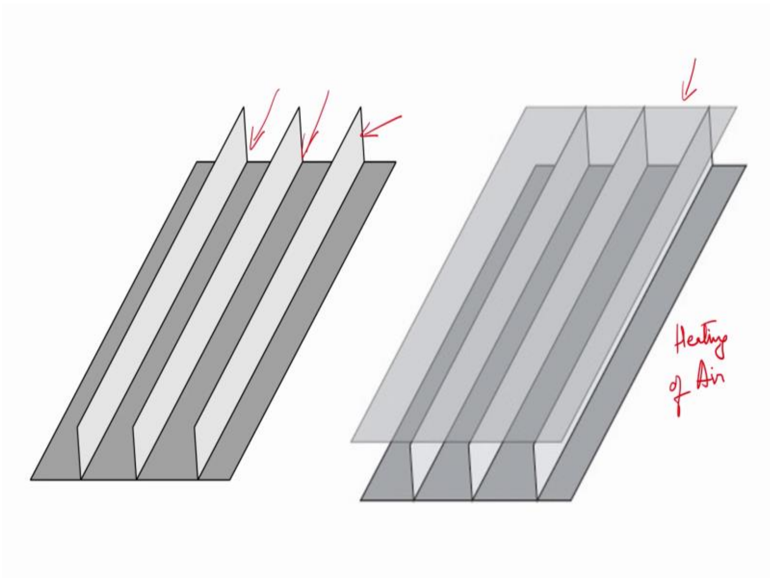

We looked at how a flat plate collector can be used for heating air and so, this is an implementation of how it will be used for heating air. You will notice that the main difference between the flat plate collector used for heating water versus that used for heating air is that previously we had pipes; we now have fins.

Fins which are basically vertical sheets of copper placed the way they are shown in the figure that you see here. And the idea is that it increases the area of contact between the air that is flowing between these fins and the air itself; so and the fins. So, the air and the fins have a much higher surface area of contact relative to simply air flowing through a pipe.

And as a result you have much better heat transfer from this hot flat plate collector and the air that is above it. Even here you can see in the implementation on your right hand side that there is a glass plate placed on top, it serves the exact same purpose that we previously described; which is that? It prevents IR losses from the plate, it also prevents convective losses from the plates. So, both radiation of infrared as well as the convective losses are prevented by using the glass plate and in this process this implementation that you see here is able to do heating of air.

Usually one other major challenge in this unit is how you would store the heat. So, normally in the case of water you just have a insulated water tank which is holding the hot water. So, you have to think of an analogy an analogous situation which applies to the case of hot air. So, what is typically done is they also have something like a tank, but that tank is filled with pebbles; pebbles of different I mean of different sizes let us say and so there’s a tank full of pebbles; which is otherwise empty.

And then you have this hot air go through that tank. So, when it does that those pebbles pick up the heat and they have good thermal mass. So, they pick up the heat and they hold the heat; so, you have a box full of pebbles holding hot the heat inside them. And so later after hours if you want to use the heat or later in the evening, when the sun is not that hot you still want to use the heat; the air flows through those pebbles picks up the heat from there and then it is used for whatever application it is intended.

So, that combination is the combination that we would typically use to heat air using a flat plate collector. There is one final modification of this which is simply that you know although I spoke about fins I told you that you can put four fins here. Clearly that is still a limited implementation because that is just four fins; if you want to greatly increase the amount of area through which the you know heat transfer is occurring, ideally you want actually this area to be filled with something that is you know porous and that porous material would then take the heat.

And so usually what we do is this is a something like a box; it is filled with say iron fillings. So, you would have a lot of iron fillings filings that you get off when you do all the machine work. So, you have some kind of I know mesh like structure that is out here and then the heat gets held there and so, when the air goes through it; it has lot of area across which it can exchange heat.

And that's the heat that comes out through the top and you utilize it. So, that that would then be the implementation, you would have a box inside which you would have these filings and you would have this copper plate at the bottom, a glass sheet at the top and this heat being transferred. Of course, the more you know such filings that you put in there a greater is the resistance that the air will face; as it goes through this unit and and therefore, you have to put in a little extra pressure.

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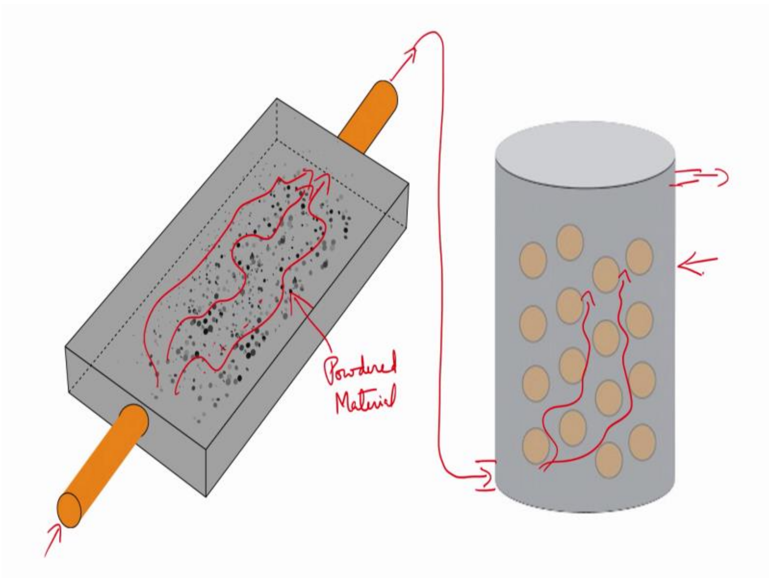

So, this a little extra pressure drop between the inlet and outlet, you have to account for that as you transfer this heat onto the air and use it for some application. Heating of air can also be done in a much more effective way; if you essentially increase the area of contact between the air and the surface that is hot. And we saw how by going from a tube to a fin you have actually increased the amount of surface area of contact.

But you can increase it dramatically more; if instead of just having a fin you actually have a lot of powdered material which is what you see inside this box. A lot of powdered material which is typically metal filings of different forms; which are available even as industrial waste and they are placed within this box. And so air enters the box from one side and then comes out from the box on the other side.

But when it is inside, it travels through this box in various different routes and finds its way through the box and comes out the other side. In this process, it picks up all the heat that is available inside that box and the box essentially has been heated through solar radiation with everything else being the same as what we are previously described; it is a copper box; copper at least the base is copper it is and the top of it is glass; the top surface is glass, the base is copper.

And the copper has been blackened and you have a lot of these metal filings that are present, which pick up the heat and then transfer it onto the air that is forced through them using a blower. The air that comes out can be directly used for some industrial application, but at the same time if you want to store that heat; such that you can use it when the sun is not at its peak, then you also use this kind of a container that you see here which contains pebbles.

And then this air is then fed into this container and then it finds its way through this container and you can have an exit. So, you can have an inlet here and you can have an exit here and then you can use this air for any other purpose that you wish. But in the process of it traveling through this container; it heats up all these pebbles and these pebbles then store heat and so off peak hours or later in the night if you want hot air; you simply have to send cold air into this container and it that cold air will pick up the heat from the pebbles and then will be available as hot air at the exit which can be used for some application.

So, you can either use the hot air directly; you can directly use the hot air coming off this flat plate collector. Or you can use it to heat this container containing pebbles and then use that heat at a later point in time. So, these are different implementations of this idea of using a flat plate collector to gather heat to either heat water or to heat air. So, that’s our class on flat plate collectors and the only other point to keep in mind is that because it is flat and is picking up you know energy from the sun roughly of the order of which is coming down roughly in the order of 1 kilowatt per meter square; the typical heating that happens when you put it put it in the form of say a water heater; is that it will get you water from say room temperature kind of situation to say 60, 70, 80 degrees centigrade.

So, that’s pretty hot water and so typical household applications that’s more than adequate. So, you have like a equivalent of a 1 kilowatt heater if you just have a 1 meter square heating area and it will get you about 60, 70 or 80 degrees centigrade water. So, that's quite adequate as I said for household applications.

But if you want to do power generation; in which case typically you want to take the water convert it to steam and then use that to run some turbine; if that's the kind of application you are looking at, clearly reaching you know 70, 80 degree C is probably not good enough for you; ideally you want to get steam. You want steam and then that steam will be used to run turbines.

So, clearly we have to cross 100 degrees centigrade; so, we have to think of some ways to do that. If you had to use flat plate collectors, you would actually have to use a few of them in series and then you can you know take the hot water from one and then that would again get further heated up in the another flat plate collector and so on.

So, we can consider such options, but those are not efficient ways of doing it there are better ways to do it. And that is what would be referred to as concentrating the solar energy; so that is a separate topic and we will look at that in greater detail in our next class. But in this class, as I said we looked at flat plate collectors; how they can be used for heating water? How they can be used for heating air and what are its features? How it is put together? What are the major components involved? And also what are the you know strong points and limitations of this kind of a design?

Thank you.

KEYWORDS:

Tropic of Cancer; Solar Energy; Harnessing Solar Energy; Thermal Energy; Photovoltaic Energy; Intensity of Solar Energy; Flat Plate Collector; Solar Thermal Heaters; Heating Water; Heating Air; Heat Conduction; Copper plate; Absorbing Radiation; Reflecting Radiation; Glass Plate; Infrared; Visible; UV; Convection; Solar Unit Orientation

LECTURE:

Harnessing Solar energy to heat water and air with help of collectors. Their structure, geometry, orientation and design is illustrated and demonstrated in this lecture.