Solar Energy Technology
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Lecture - 38
Passive Devices

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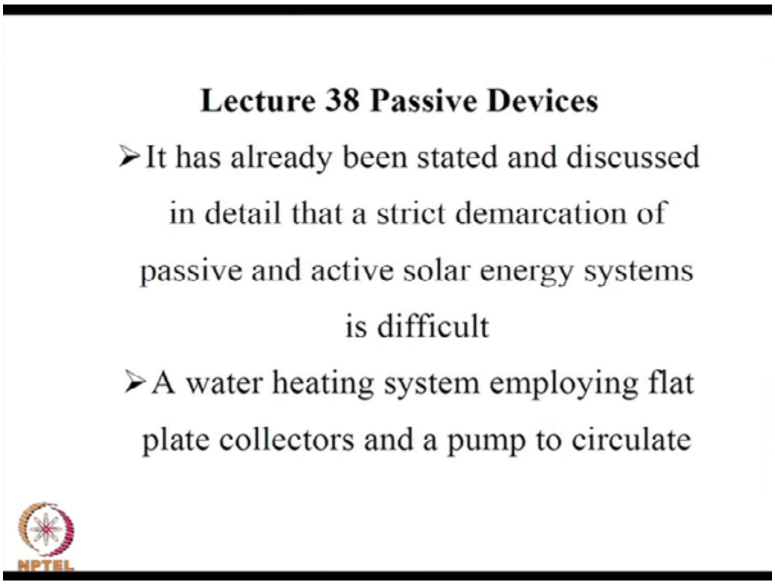

So far we dealt with active systems and then we shall have few examples of what are called passive devices. Of course, in the case of active systems that we have considered so far we dealt with of course, the analysis of the solar collectors both concentrating collectors as well as flat plate collectors and then f chart method, phi bar f chart method and the simulations, they are general enough for the flat plate collectors. For the concentrating collectors one can use the simulation methods, but there are no corresponding simple design methods.

However, if you want to go for concentrating collectors it becomes a specialty application for power generation for example or metallurgical furnaces instance and any other mechanical work producing, employing concentrating collectors that will highly depend upon the particular system. So, a general standard system is not easy to define or design. So, consequently we have not spent much time on systems active involving concentrating collectors.

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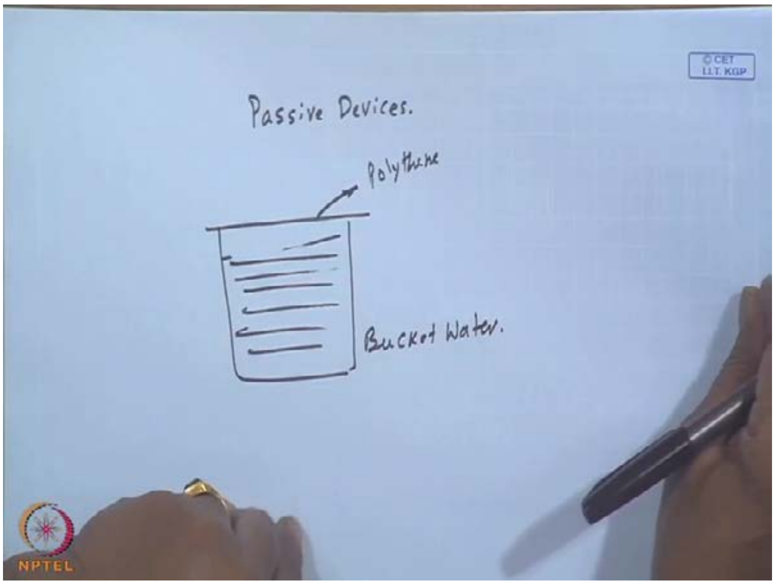

However, now we shall go to the passive devices. Unknowingly or unwittingly there are many applications which we are done passive for example, if you go to the village side, they take a bucket of water and simply put a sort of polythene sheet and keep it in the Sun for from eleven o clock to twelve o clock or something like that and it goes up by about 5 degrees. So, if the ambient temperature is around 20 it make go to 30 which is little more comfortable for taking a bath. So, this is simply a passive heating, simplest kind of passive heating that villages adapt.

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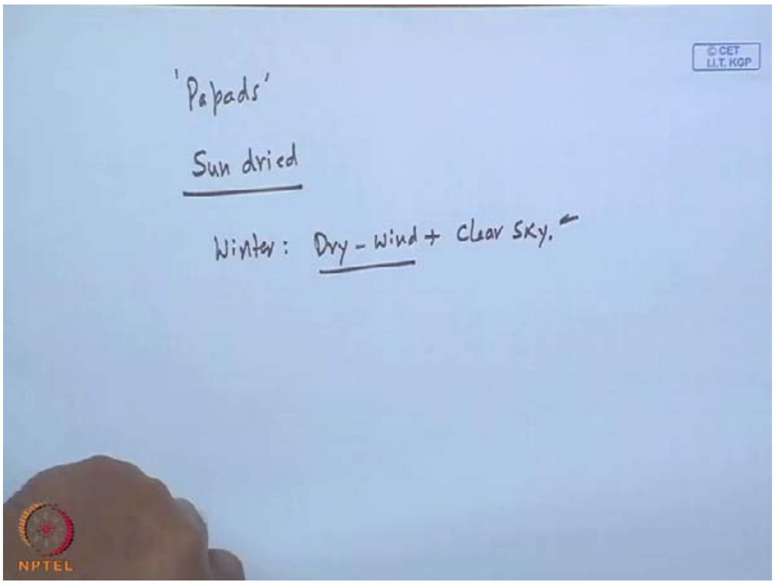

And if you look at the good old days say for example, your (( )) and n number of other what do you call (( )) food, eatable items, they are Sun dried. So, this is a passive solar application whether or not the solar energy technology as a course was studied by the elderly people, this is always used for Sun drying purposes and the season generally in the southern part of India is winter not because the Sun is so high or anything like it, it is dry, dry wind plus clear sky.

If you have a clear sky and southern latitudes, southern lower latitudes, the winter solar radiation is not at all that low and we had seen and the data I have given if you look at for Trivandrum the minimum was about 18 mega joules per meter square per a day and the maximum was about 21 mega joules per meter square a day for the months from January to December, almost the standard deviation is absent. So, you you can have a pretty clear skies and dry wind. So, when there is mass transfer control drying will be much better when it is a dry wind in addition to having a clear sky. So, these are and of course, drying of the cloths etcetera is a passive application of solar energy.

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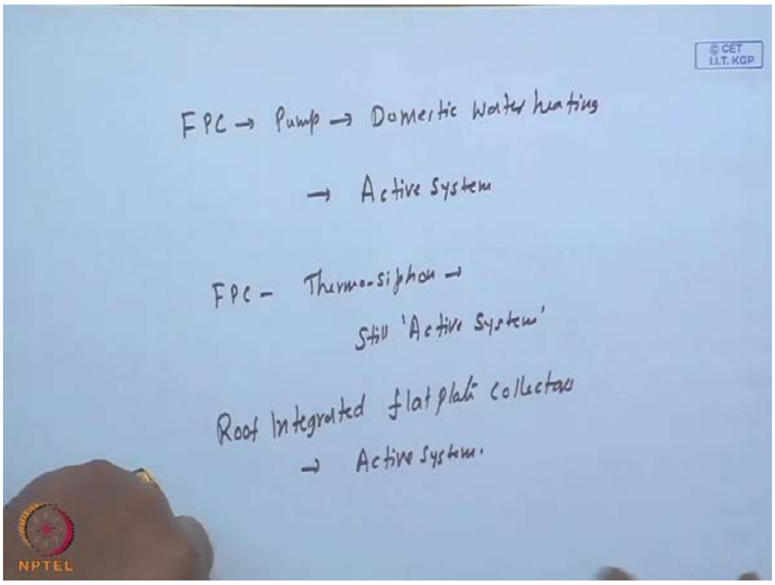

And coming little more serious side of this, we already pointed out that it is little difficult to have a strict demarcation between passive and active systems say for example employing flat plate collectors, use a pump for domestic water heating, most of the cases we consider them to be as active system. Similarly, use FPC, use thermo siphon and still active system because there is no auxiliary power there is no pump we do not call it a passive system, we will call it still an active system. Then for example, roof integrated flat plate collectors still an active system.

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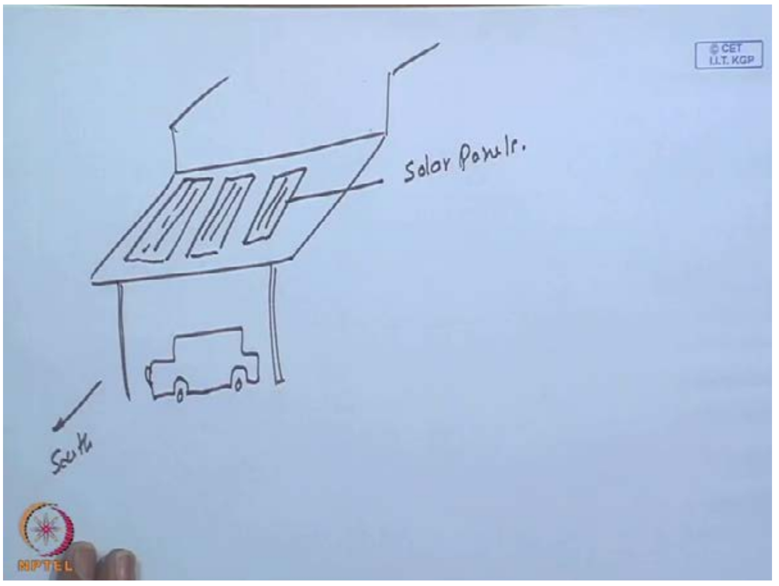

For example, if you are having a south facing something of a slant roof, this is south, this can have integrated solar panels, combine architectural beauty and the functionality and you have got this (( )) and this and glass, this could be a big building like this and you may have some pillars just to give you an idea and there will be a a car. These are the solar panels. This is a very commonly used practice and still we will call it a, what shall we say active system even though it is a part of the architecture.

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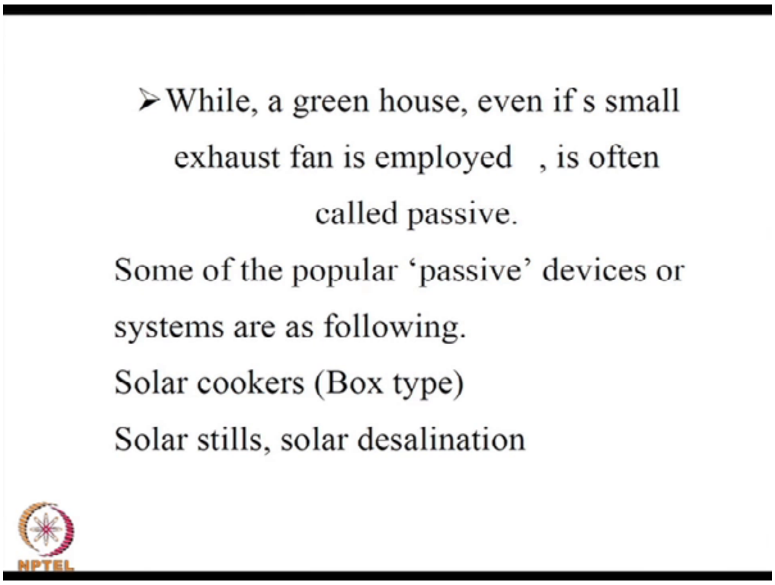

So, this we had said.

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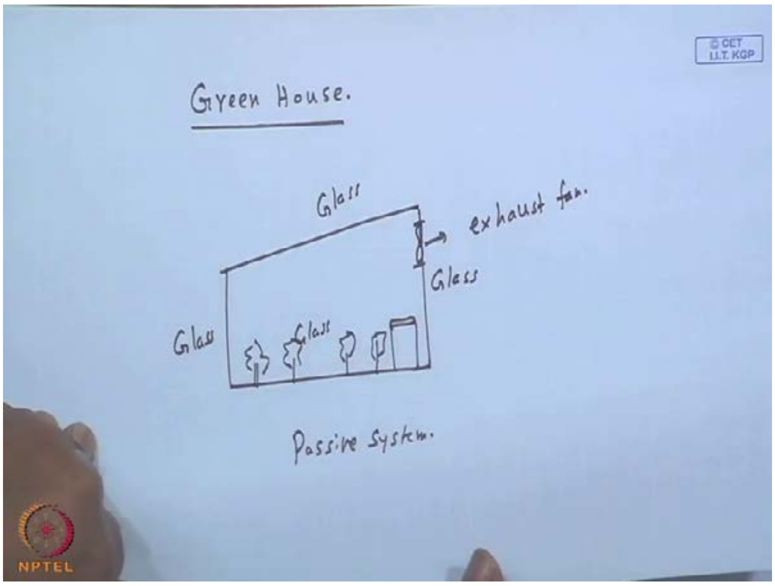

Now, we call, commonly refer green house. You may just have a building, may be slightly roof slanted, this is glass, this could be glass and everything, I mean this is glass again, backside also is glass, top also is glass and you may use it to preserve winter plants or a drum of water and you may have a small exhaust fan to remove the humid hot air. Still, this is a passive system. These applications will come in so though I am arbitrarily telling, it is very commonly heard a green house effect, we hear it in terms of the cloudy days and the pollution and heating up of the local climate. In addition you deliberately have a green house which a little later I will tell you specific applications of this type of a green house. And there are quite a few popular passive devices and everybody would be interested when you face a interview for a job or whatever.

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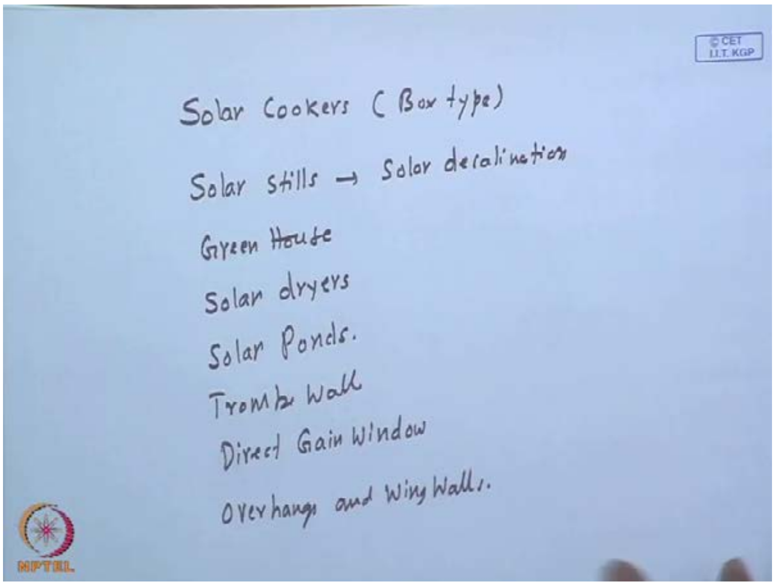

And for example, solar cookers which we will say a box type, you can have even a very active system, then solar stills, this is basically solar desalination, you may have n number of ways of doing, including a reverse osmosis process. Green house, this need not be used only in the derogatory term that this is a green house effect and the climate has become hotter. Solar dryers, they can be active, they can be passive and then solar ponds, trombe wall and a direct gain window.

These sound highly technical names, but when once we explain these are simple devices, any window facing south can be a direct gain window or even east or west, it will work in the afternoons or in the mornings entering along the Sun to enter and the window glass being transparent to solar radiation and non transparent to the re radiated infrared long wave radiation, the energy is trapped in the room. So, that is a direct gain window. Then these are overhangs and wing walls. So, this I will just explain little bit before we go in detail.

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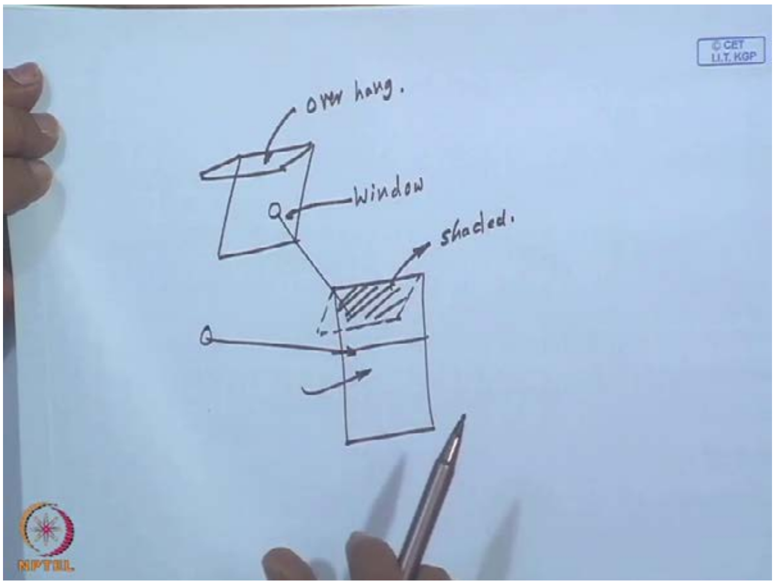

For example, you must have seen almost all the windows will have a projection. This is the window, this is the overhang. So, this will, if I look at it directly will shade a part of the window depending upon the time of the day. So, what will, this will provide is I think commonly we may be having an idea that this is to prevent rain entering through the window, that could be true, but this has got a very functional thing. In winter the Sun is pretty low in the northern hemisphere.

So, it will allow the Sun's rays which are at a pretty low level through the window and in summer the sun is pretty high up and it will cast a big shadow over here. So, it will not let the solar radiation enter as much in summer months and it will let in the solar radiation enter in the winter months meeting the requirement of in general not heating in summer and providing some heat in winter. And if you look at certain high altitude locations like in Srinagar the designs are very much different from what you will find in southern part of the India.

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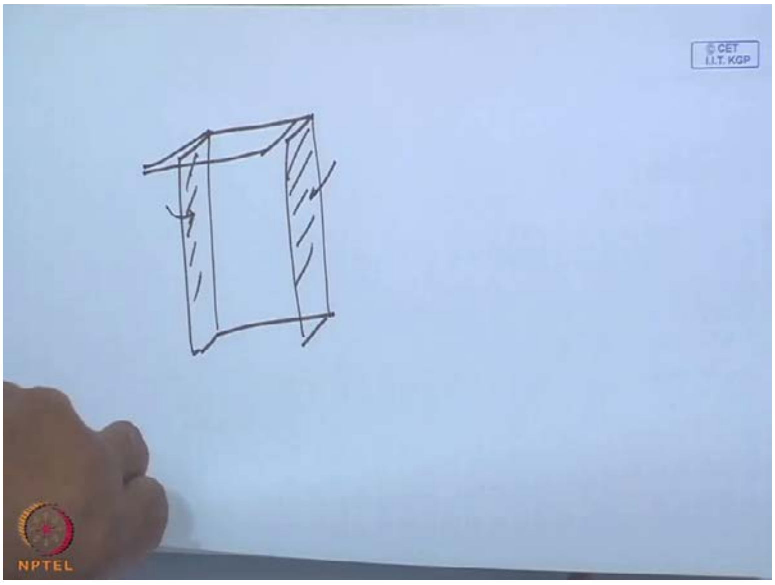

And wing walls are also the same except that they are to the side of a window or an opening. If you look at some of the large buildings including for example, IIT, Kharagpur main building you have this projections, wing walls over the main building and mechanical department, in number of other places and you would wonder whether it is only for architecture, but then these wing walls will prevent a lot of radiation entering in the morning if it is in the east and in the afternoon if this is in the west.

So, in conjunction with a overhang effectively it looks like a box type of window which will be completely shaded whether you desire or not desire depends upon the season, climate and your objective and how else to do it. And if you want to have both the effects of let us say heating and cooling, heating in winter and cooling in summer then you may have a movable overhang which will change either the angle or retract into the building or come forward from the building. A algorithms have been devised for that purpose also.

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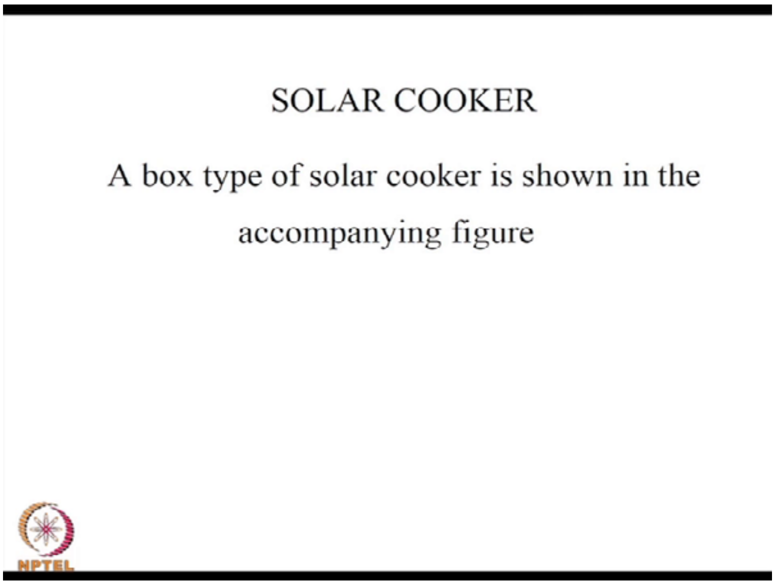

So, first we will consider the solar cooker.

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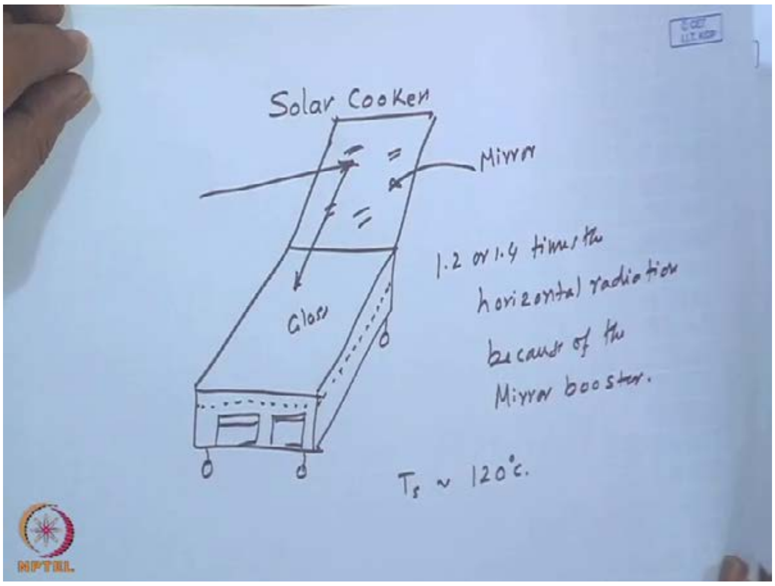

A box type cooker is shown in this figure. So, you have a little box and you have got a cover for this. This may be glass, mirror sorry and this is glass. There could be even two and then you have got your utensils placed three or four of them as the case may be. Now, the angle of this roof or the lid is such that the reflected radiation from the sun will fall onto this, so that there may be a factor of 1.2 or 1.4 times horizontal radiation because of the booster.

If you recall in our flat plate collector technology you can increase this solar radiation falling on the flat plate collector with a mirror booster; that is exactly what we are doing here. And this may have little wheels, if you want to move from one place to the other. So, you can adjust this angle depending upon the time of the Sun and you can orient it towards the Sun of course, somebody has to be monitoring it and it can be stagnant temperature T s could be around 120 degree C which is sufficient to break the hydrogen bonds in rice and vegetables and dals.

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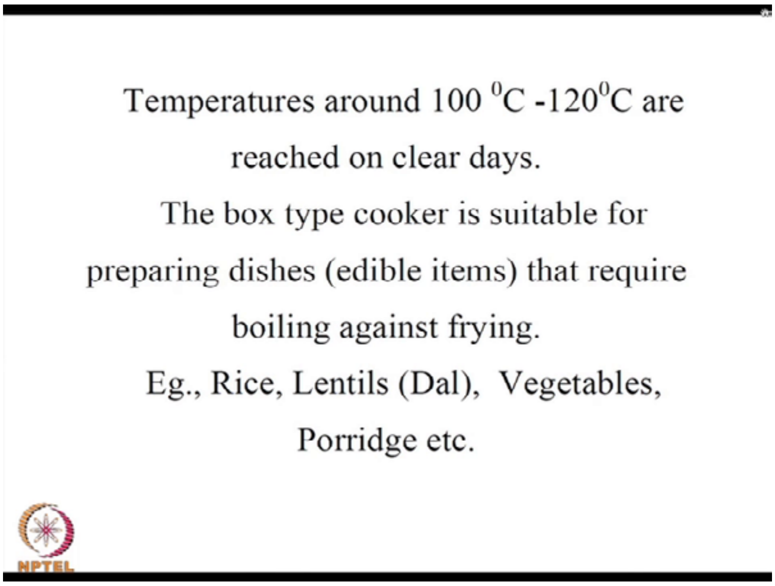

So, consequently anything that can be boiled and cooked can be done in this particular solar cooker which is a simple static passive device, could be typically about 0.5 meters by 0.5 meters which will hold about four containers and cooking of maybe half a kg of rice and lentils or dal, vegetables and even porridge.

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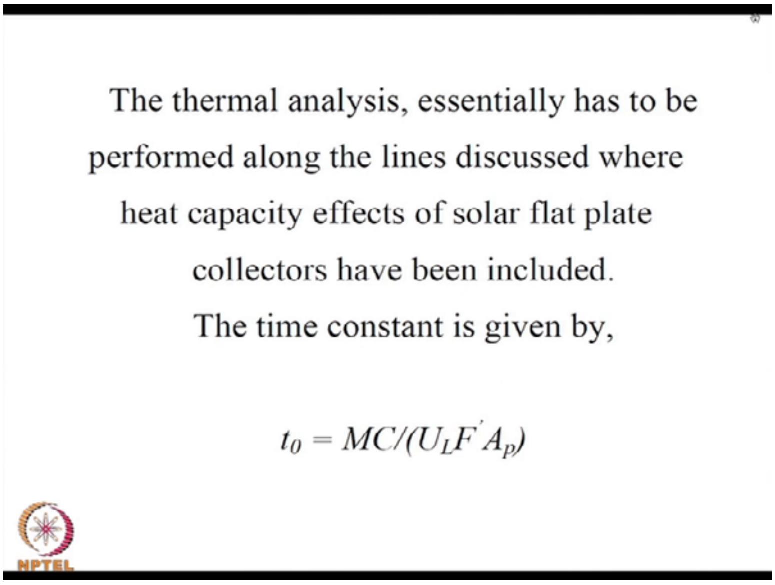

So, this is useful, you cannot do a deep fry, but definitely you can make cooking.

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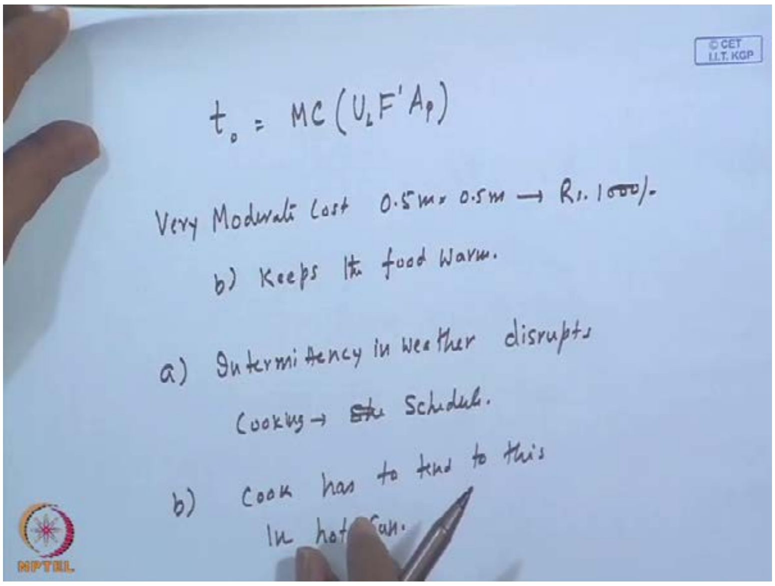

So, the time constant for this is given by if mass M, specific heat C, times overall loss coefficient U L and a sort of collector efficiency factor by the area of the aperture. M and C the mass and specific heat of the pot and U L the overall heat loss coefficient, F dash the collector efficiency factor and A p is the exposed area of the cooker. So, there are advantages of this cooker, the cost is generally very moderate about this 0.5 meters by 0.5 meters.

There may be subsidies from the government at different places particularly in certain states in India, this may not cost more than Rs 1000 even without subsidy and consequently your payback period will be quite small and b, keeps the food warm even after it is cooked. So, assuming there is no intermittency and there is a continuous thing, somebody can keep it in the Sun and even if you do not worry so much about the booster mirror coming into the picture, the horizontal radiation itself if it is high, it can cook the food and keep it warm until you come back after I think your job or whatever and but the disadvantages are intermittency in the weather disrupts cooking and schedule.

In other words unfortunately the consequence could be little serious, if it is half cooked you would not know what to do with it, then you may have to bring it back to your gas stove or electric stove and then try to minimize the damage. So, the cook, yes the cook has to tend to this in hot Sun when it is working nicely and if you want to adjust even if it is once in 5 minutes you cannot take a chance.

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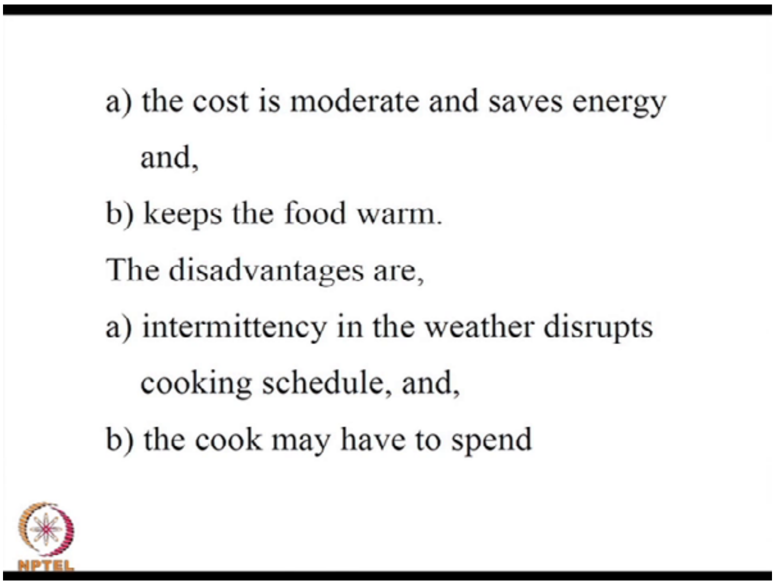

Possibly, he spends little time, has to spend some time outside in moving it to the position where there is no shadow and changing the tilt of the mirror booster, so that the reflected radiation will fall on the solar cooker.

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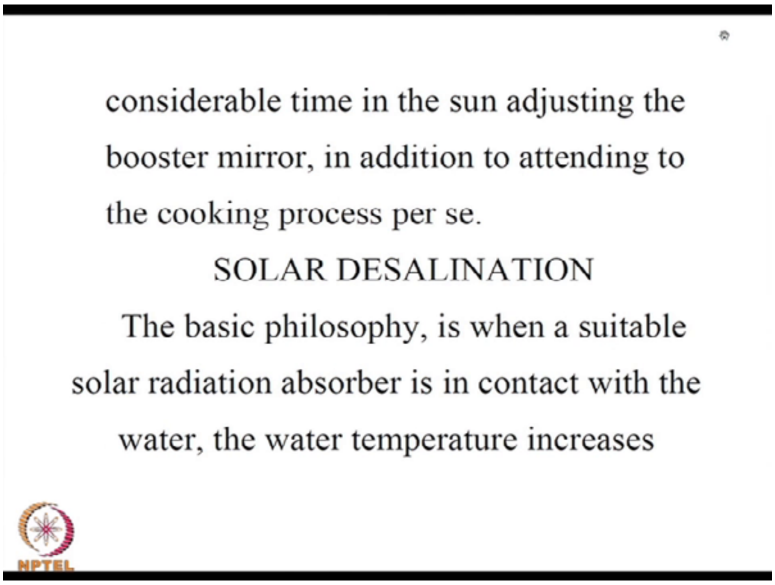

So of course, there may be some cooking process itself that needs to be attended to like you may like to stir the dal or the vegetables once in a while, so you have to go out. So, but nevertheless this is good for at least quite a good season where the time schedule is not all that stringent. One can go, if not by one o clock if it is cooked by two o clock, three o clock it may be used in the evening meal or whatever then you, one can easily use this at least something like 200 to 250 days in the Indian context of the climate.

Then next popular thing is why you can make a calculation very easily and if you cook it and if it is going to cost about 1000 rupees or so for a 0.5 by 0.5 meter which will hold four to five utensils very easily, they can be black painted.

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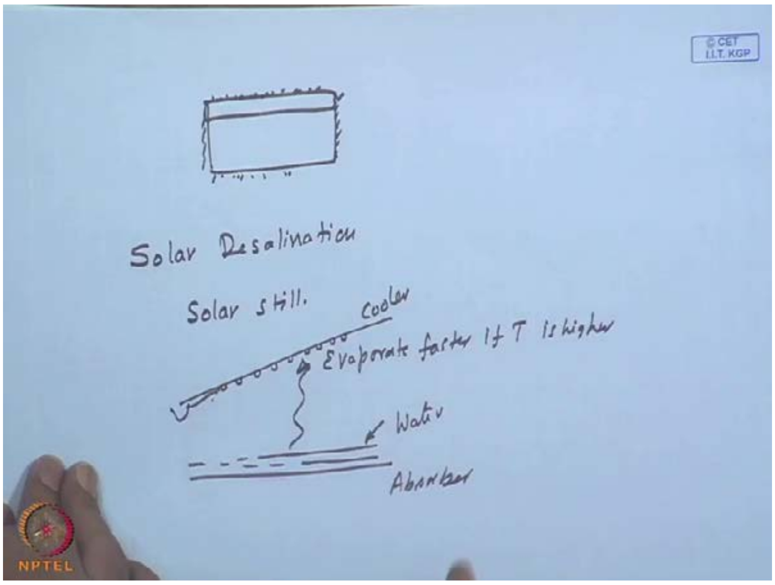

So, you can have any aluminum dish, it can have a cover, the whole thing is black painted. So, this will absorb in addition to being having conduction from the bottom of the solar cooker. It can be insulated at the bottom if you want even to have little more high efficiency and even the sides. Then next quite attractive is solar desalination. Sometimes, this is the general term and you may call it a solar still for the particular device.

So, when suitable solar radiation absorber, you have got a absorber in contact with water, this will evaporate faster if T is higher. There is a difference between boiling and evaporation. Evaporation is a continuous phenomena, it can take place at any temperature, mass transfer controlled. So, you have an absorber and a water layer which heated to 45 degrees 50 degrees C it will evaporate much more than what it would had been at 30 or 20 C.

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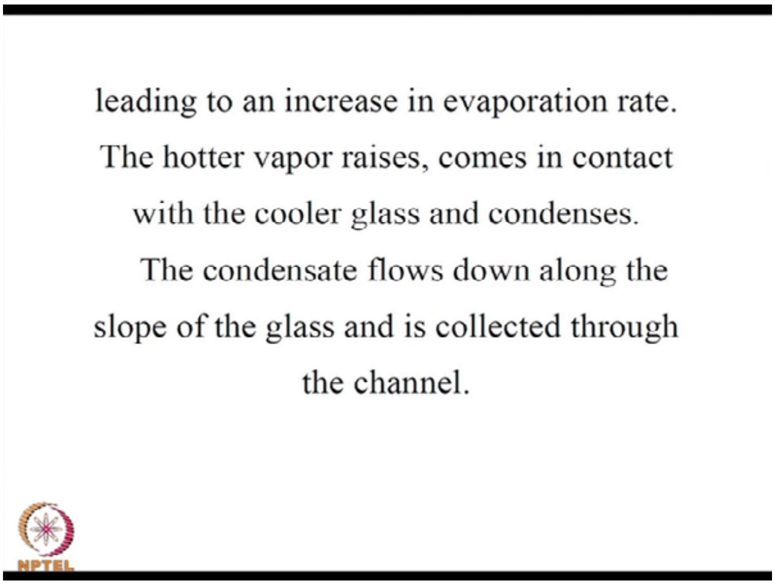

So, that lead to an increase in evaporation rate. The hotter vapor raises and if it is coming in contact with a cooler surface, then it will condense on this and then it could be corrected over a channel at the bottom.

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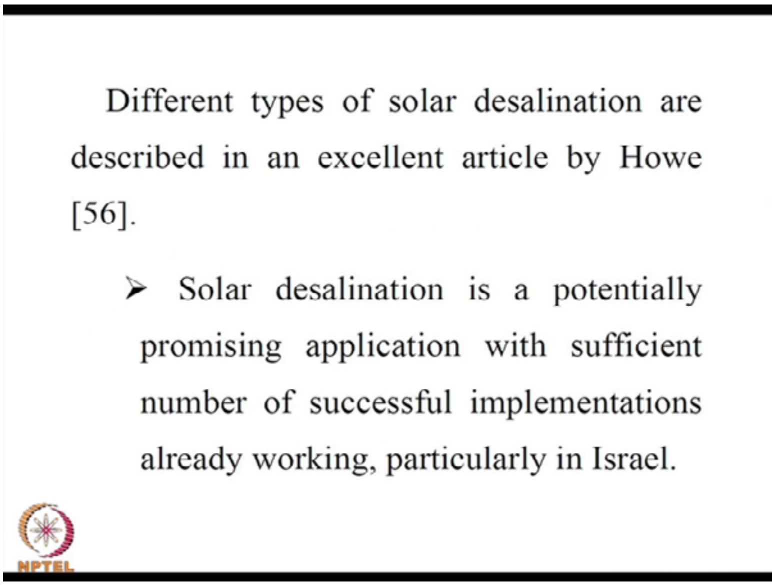

So, this is all the principle which I can give. Of course, you can see the article by Howe, in that reference number 56 at different types of solar desalination is described and is potentially promising application with sufficient number of successful implementations particularly in the country Israel, there are many solar desalination units or to even to feed to their citrus gardens, citrus fruit gardens.

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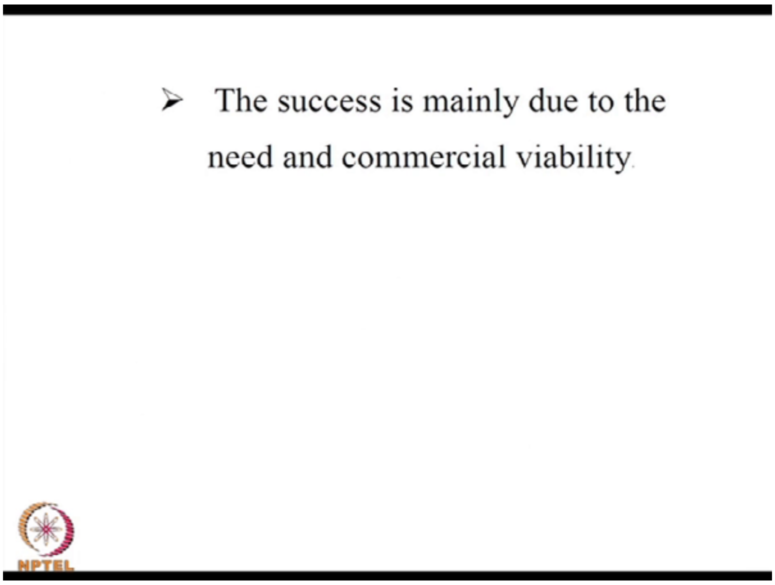

The success is mainly due to need and commercial viability because it does not cost as much as an active flat plate collector system. And if you do not have drinking water and if you want to have some potable water, if there is availability of some brackish water or salt stranded, salt full water you can obtain drinking portable water by this means.

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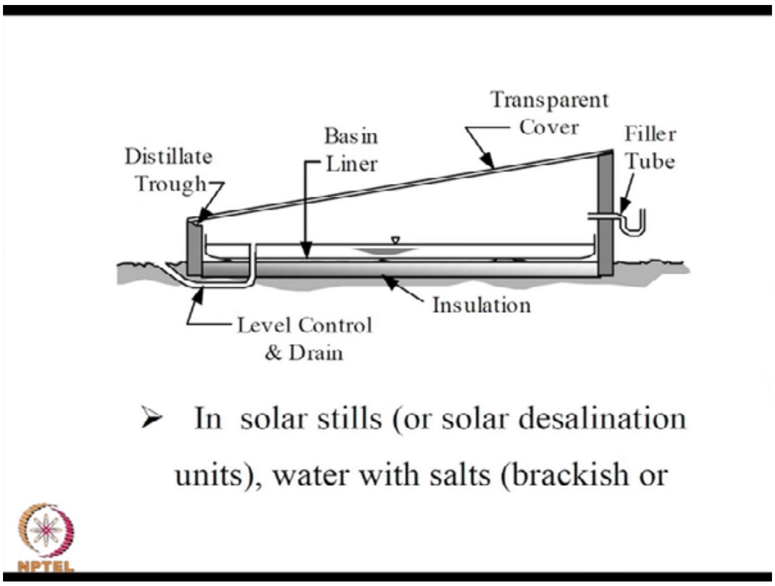

So, here is the picture which you can see.

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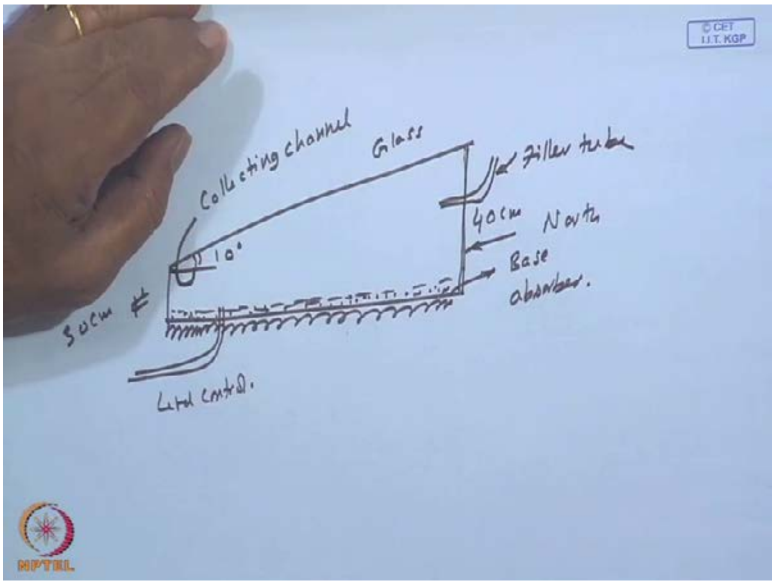

You can have the bottom with an insulation and this is a glass. The slope is typically 10 degrees and this may be about a foot or what should we say 30 centimeters. This may be 40, depends upon if it is 1 meter you can calculate depending on the slope and you may have a filler tube over here and then you have a collecting channel. Here you have a layer of water may be 2 inches because if it is too much the heat capacity will be large and consequently to heat that much larger quantity of water it takes more time.

So, at the same time we do not want to have dry patches and this is the collecting channel which you have set and well if you want to have a control for the level, you can have a drain level control. So, if you put more water it gets out beyond that thickness and this is base absorber. So, this brackish water or water with salts you can see the picture. As I have already described there is a filler tube, there is a top glass, every side east, west, north, south; they are transparent.

Regarding the north this one if you say it is your north, there are different arguments. It can be transparent, some people argue let the diffused radiation come through this and hence little more radiation. Others will say that will also cause a loss, instead of that make it black and non transparent and that will absorb and the absorbed radiation will in general heat the surface and heat the water. So, whatever is the argument, probably there was no (( )) difference in the performance weather you put a transparent glass over here on the northern side or a black painted opaque surface.

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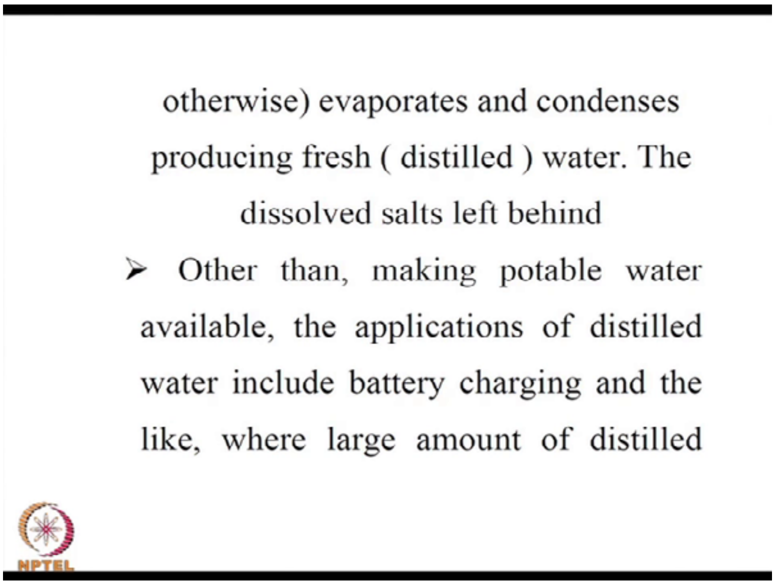

So, there are a good number of other commercial applications also out of which one is of course, your potable water and battery charge.

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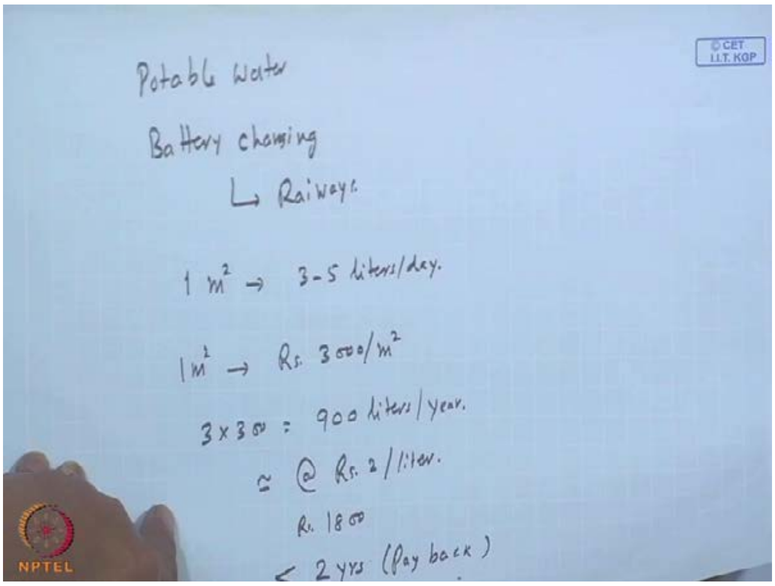

This requires huge amount of distilled water. Why I say huge amount is if you look at your railways, each compartment has got a very, very large capacity battery, they need to be charged almost wherever reach the destination. So, they need a lot of distilled water. So, railway workshops could be one, battery charging is a thing, do not at the personal level, but definitely this is one single source where lot of battery charging goes on. Of course, now the maintenance free batteries are in the market and if they also go to the railways, I am not sure then this demand may come down.

So, the output from 1 square meter of the solar still is about 3 to 5 liters a day. So, if 1 square meter is, if this may be costing around let us say Rs 3000 per meter square, so even if the rate of 3 and 3 into 300 that will be about 900 liters per year. In the rainy season you really do not buy because you can as well collect the rain water which is as good as the distilled water at least after the first 5 minutes of the shower. So, at the rate of 3000 rupees per meter square if it is 900 liters per year this roughly and a liter at Rs 2. So, that will be 1800 rupees, so less than 2 years. This may be a bulk rate for the liter, but if you buy for your battery charging the last I remember is at least 6 rupees per liter I paid that may be about 10 years back.

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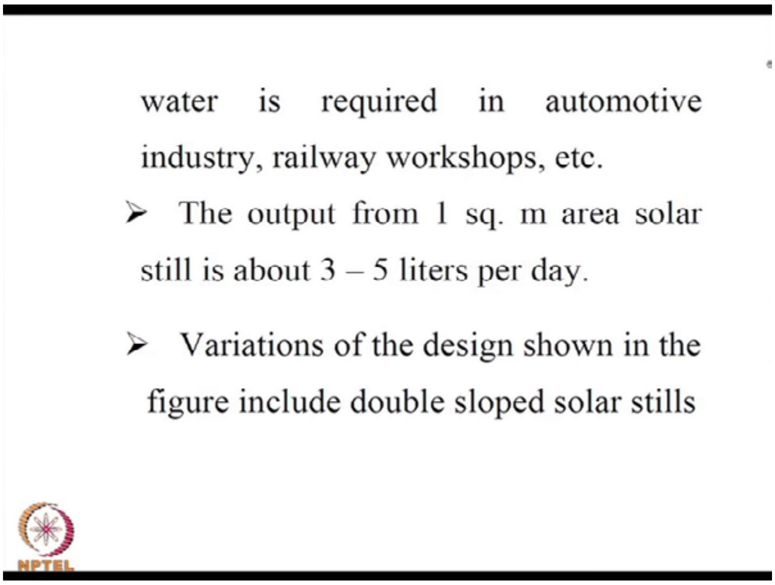

So, if you compare with the commercial requirement of the distilled water, solar desalination units, they compare very favorably from their convex point of view also.

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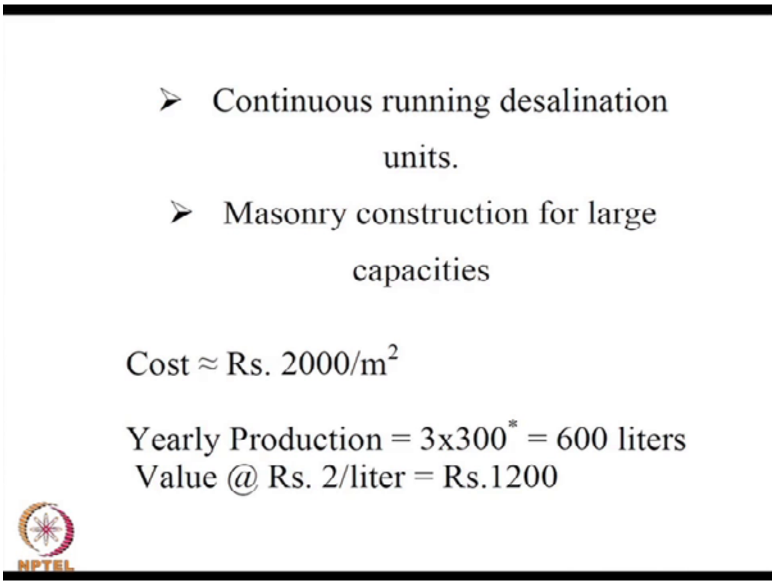

So, one can think of variations.

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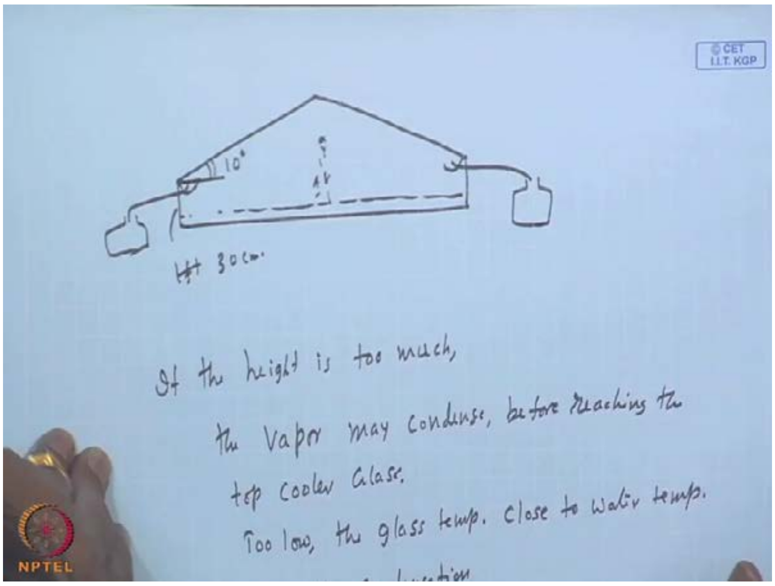

So for example, instead of a single slope, one can have double slope, there by one side wall you are avoiding. So, there could be two running channels from which you put it in a bottle. So, this will save half of this particular thing. Now, the questions you may say that this is about as I said that 1 foot, 30 centimeters and this is a slope of approximately 10 degrees. Why? Why not more? Why not less? The reason is if the height is too much, the vapor may condense before reaching top cooler glass. So, it will go up, condense and it will drop back, it will not go there.

So, it should not be very high and if it is too low the glass temperature, it will be close to the water temperature. So, no condensation, no condensation may take place. So, you should give a chance for that to be cooler, but at the same time not too far away for our vapor not to reach it and condense on the way. So, this is what is going to happen.

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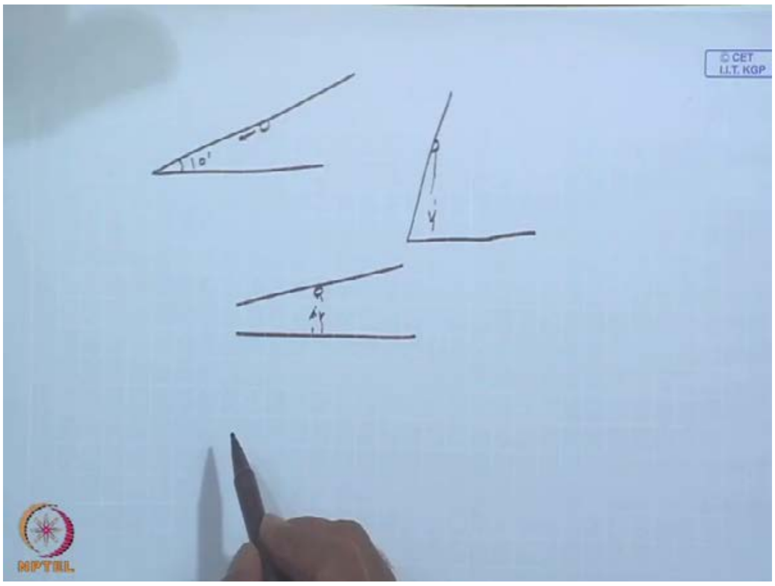

And then this angle if you find a drop, it tries to come this side because of gravity, some component in the vertical direction and it tries to stick to this because of surface tension. And if you have a too large, it may come down straight and not flow along the surface and if it is almost horizontal definitely it will condense and it will fall back. So, if you are almost I mean something like this, it will condense and then come back. So, this 10 degree is based upon the surface tension of the water and the experience has been found to be this, quite acceptable.

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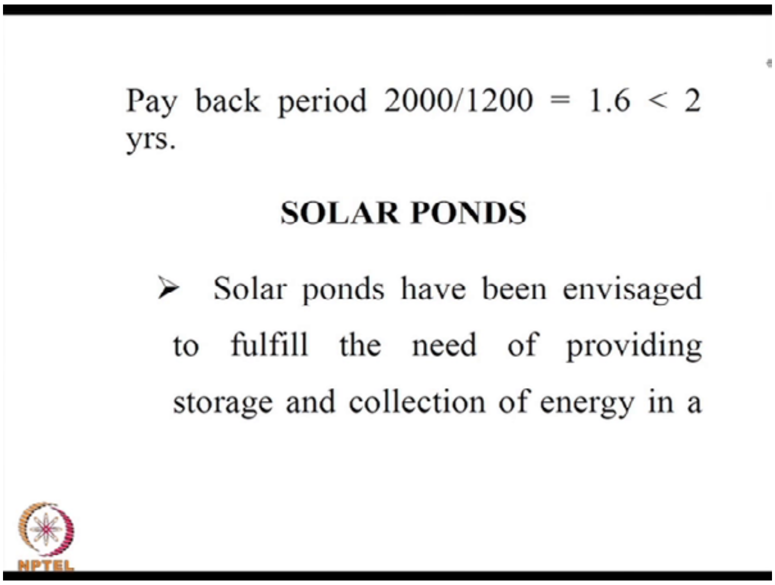

So, this is what I have done it, so less than 2 years. Now, if you look at active solar energy systems employing let us say flat plate collectors.

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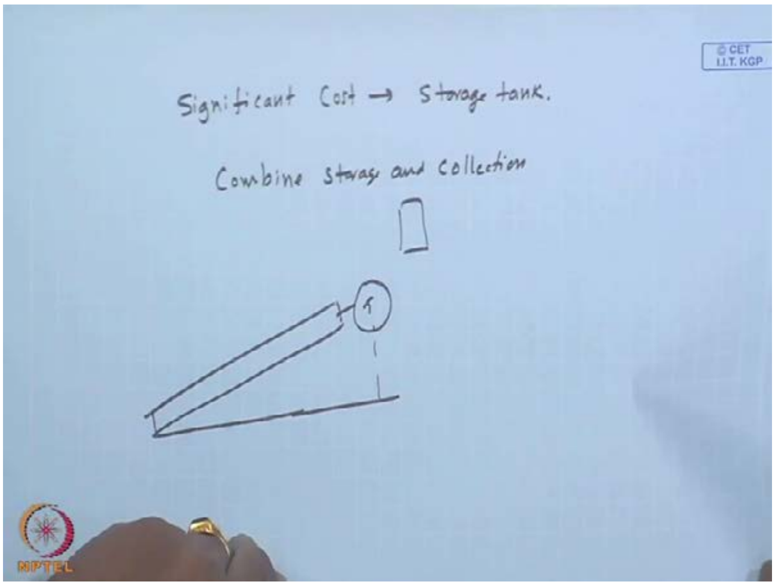

Significant cost goes to storage tank. There are ideas; can we combine storage and collection? Of course, some designs which say that storage and the collection are combined with a tank joined with this, this really not combine the storage and the collection, only the tank is kept near the collector instead of somewhere vertical, something like this. So, this I would not consider it as a combined storage and the collection. But of course, the other disadvantage also is the your heat capacity of the collection absorption system increases so much consequently the one has to think about the operational convenience also.

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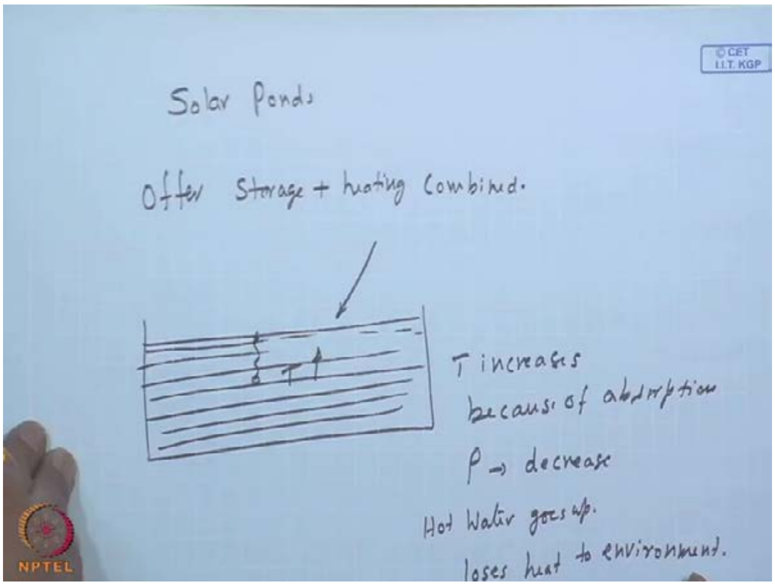

But the solar ponds offer storage plus heating combined. If you take any ordinary pond which I am representing just like this, there is a water, some level, it could be a river, it could be a pond, small tank, so there is the solar radiation, some of it will be absorbed. So, the temperature increases because of absorption. So, rho decreases. So, the water goes up, hot water goes up and looses heat to the environment. So, what is normally happening in a lake is or that the layer of water absorbs the solar radiation, the temperature increases, as the temperature increases the density decreases and it goes up interacts with the surroundings and loses its heat and it is a continuous process.

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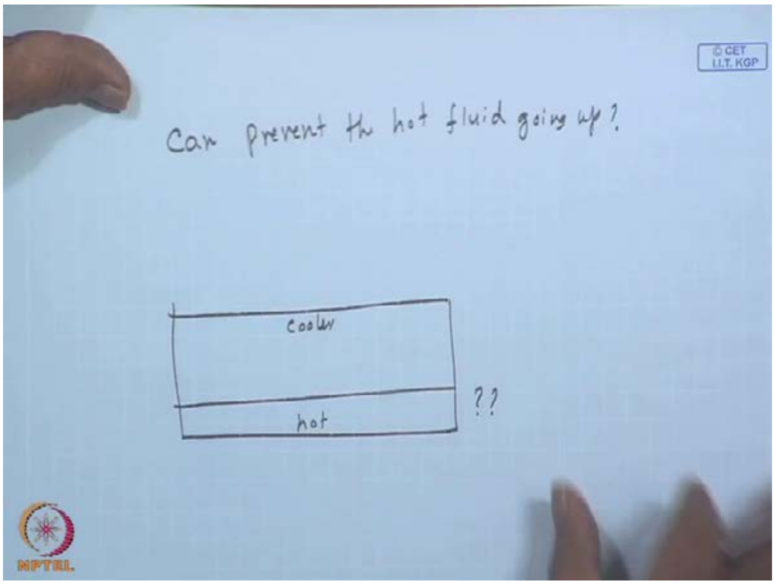

Now, somehow if we can prevent a hot fluid going up, if we can do that you have a situation over here. Hot, cooler, how to do this?

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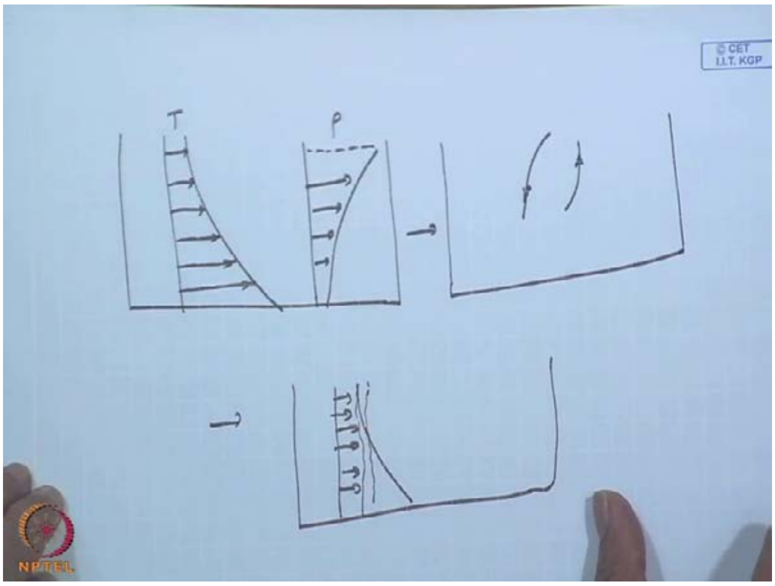

So, if we imagine initially that you have got a temperature profile like this. Somehow, I maintained it, somehow I got it then the corresponding density will be like this. This leads to cooler denser fluid coming down and hotter lighter fluid going up leading to a more or less, this initial temperature will become something like this. In fact it does not decrease it will only become this much and this is a continuously that is what is happening in the natural (( )).

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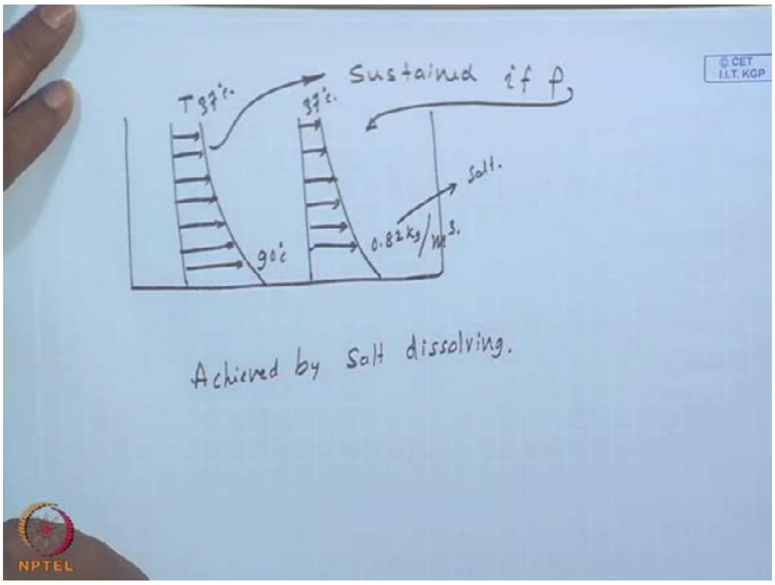

Instead if you have the temperature distribution like this hotter at the bottom and lighter cooler at the top and this will be sustained if if the density is like this. So, I want a higher density fluid at the lower level even though the temperature is higher, so achieved by salt dissolution, dissolving. So, this will be at at let us say 90 degree C and I add a 0.82 k g per meter cube. So, this layer will have a 0.82 k g of salt per meter cube at 90 degrees, makes the density higher than what it is at let us say 37 degree C sorry this is 37 degree C.

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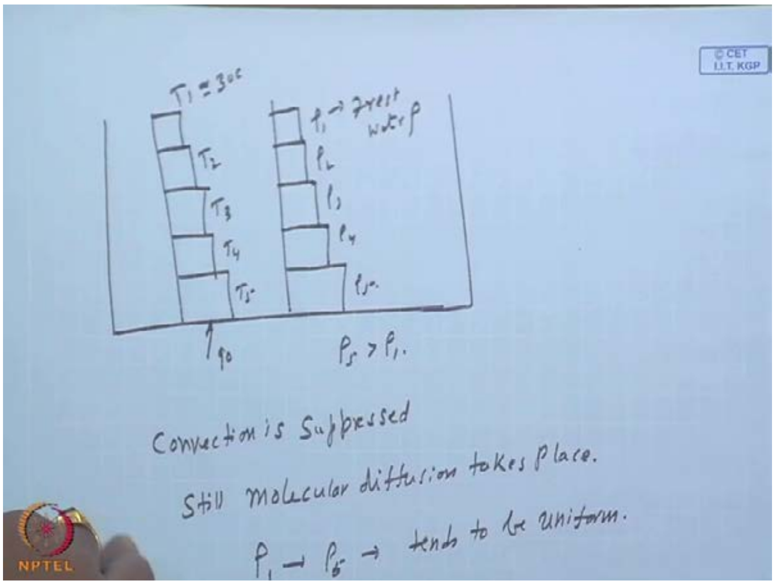

So, like that if I discretize it I will have a solar pond with temperatures continuously decreasing like this and the corresponding densities will be also decreasing. So, this is T 1, T 2, T 3, T 4, T 5, rho 1, rho 2, rho 3, rho 4, rho 5. So, if this is 30 C this may be the fresh water density and if this is 90, see this rho 5 is higher than rho 1, rho 4, rho 3, rho 2 etcetera. So, then this will stay at the bottom and we have this. Given, that somehow I built this my problem will be, now convection is suppressed, still molecular diffusion takes place. So, again rho 1 to rho 5 tends to be uniformed.

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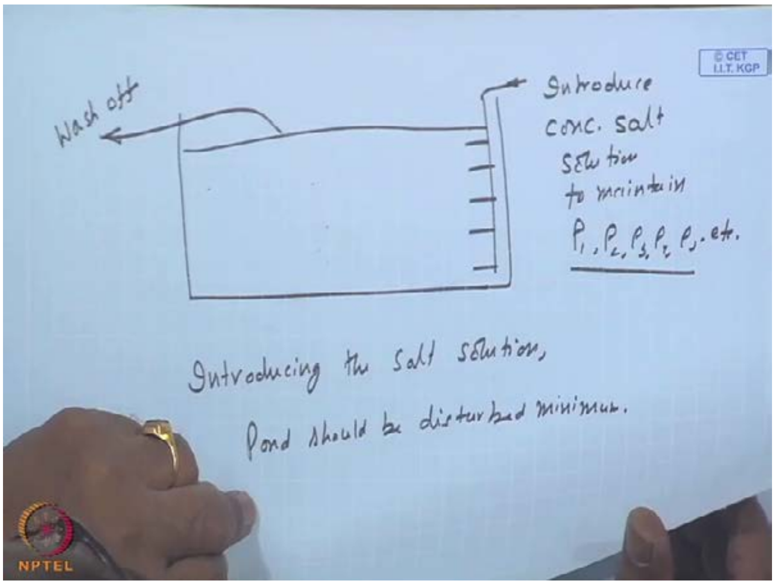

So, what we do for this is before that is happening. So, you have this and if you design carefully at different levels, so depending upon the diffusion rate and the density that you originally calculated are obtained as rho 1, rho 2, rho 3, rho 4, rho 5 and the tendency will be to settle at something like rho 3 or so. So, you will add the salt, the required salt concentrated solution or the required quantity to maintain rho 1 to rho 5 as rho 1 to rho 5 and top most thing which has become more salt ridden, wash off with fresh water. So, this is the method in which you built a solar pond, you introduce a layer of water with a certain concentration of the salt, you let it get heated then another layer then another layer then another layer.

And they are maintained by continuously introducing concentrated salt solution and the top layer being removed by replaced with fresh water. Only thing that one has to be cautious is while introducing the salt solution the pond should be disturbed minimum though conceptually I have put one pipe with number of pipes, you may have a something like a shower or a colander type of distribution from the bottom to just release the required quantity at the lowest possible velocity, so that there is no disturbance to the stratification of the solar pond. Now, so far so good, but this hot water is full of salt. So, directly we may not be able to use it for bathing or washing or any other purpose.

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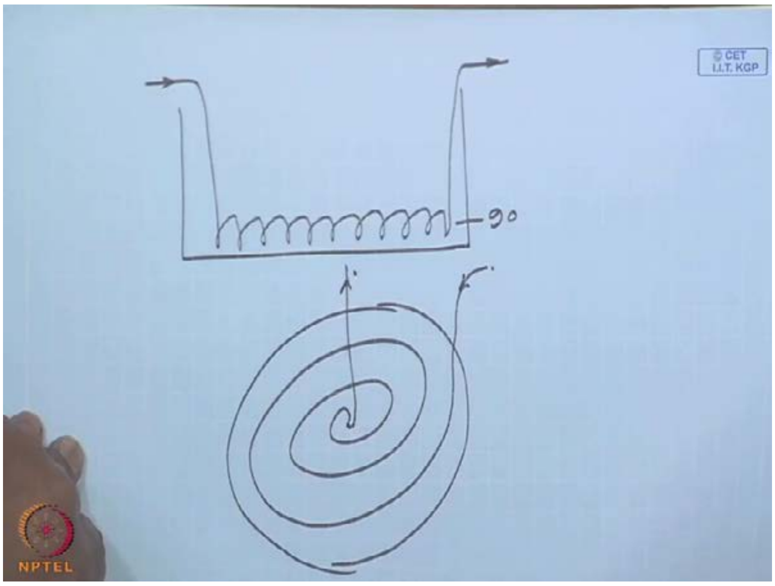

So, what people do is depending upon your requirement you may have a heat exchanger. A quite thing at the particular level this may be for 90, I may have it at a higher level if you want it 75 degrees, 70 or 60 or if you look at from the top view, if I tentatively take it as a circular solar pond I may have. So, we can have a spiral type of heat exchanger like a jalebi and at the bottom or at different levels and put in the cold water and the hot water comes out. And these are also once again quite successfully being operated in the country of Israel and the very large solar ponds have been constructed.

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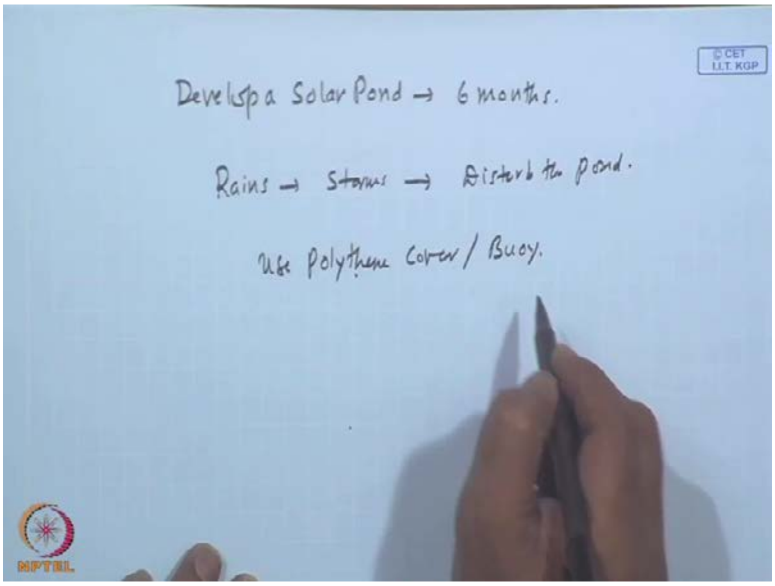

And of course, one difficulty is that you require nearly about 6 months to develop, develop a solar pond requires about 6 months. It has to be done slowly and you cannot disturb the stratification and then the danger of rains, storms, they will tend to disturb the pond. Of course, there are various methods. You may use a polythene cover or a buoy on top of the pond so that these disturbance, these disturbances will minimize the developed solar pond and it will not be too much stratification be discharged.

So, what you got is a large area, a large quantity of water that is stored and heated and you are drawing the energy and consequently this storage also it will be a long term storage as against 1 day or 2 stage storage, if you have a 100 meter diameter tank and even if it is about 30 centimeters deep hot water that will be good enough quantity and if you draw a 50 percent of that or 30 percent equivalent thermally then the temperature drop will be a may be only 2 degrees or 3 degrees which you can, that way sustain for easily 4 to 5 days of your requirement and hope meanwhile the sun shines as bright.

So, we will have a few more examples of application particularly over hangs and the wing walls and how to calculate the shadow and the solar radiation received incase when it is by the window that is shaded by an overhang in our next lecture.

Thank you until then.