Non-conventional Energy Resources
Prof. Prathap Haridoss
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture – 27
Geothermal Energy Technological aspects

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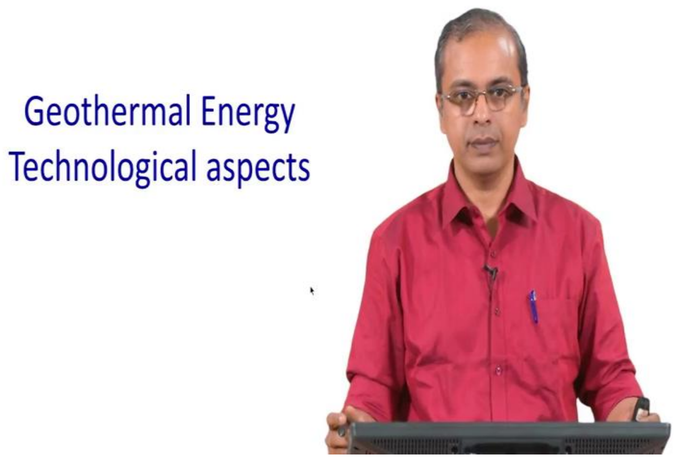

Hello, in today's class we will continue our discussion on geothermal energy. In particular today we will look at some aspects associated with the technology part of the process we understand that you know inside the earth there is a lot of heat and we are trying to extract it. So, a little bit more on the technological side of it some aspects associated with some challenges associated with the technological side of it is what we will try to focus our attention on.

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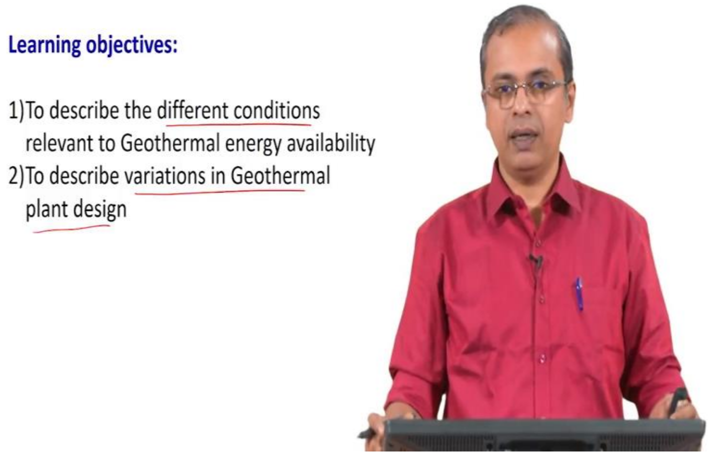

So, in this context our learning objectives for today's class are basically to describe the different conditions relevant to geothermal energy availability ok. So, it's not available in the same kind of quality or quantity I mean quantity it is not the issue the quality at different locations. So, if you actually go about trying to find it, you may find it with different levels of you know heat that's available there temperature that's available there even what is available there that is coming out may be naturally from under the ground. So, these are things that we have to look at.

Then we would also like to understand that in this context since what is available underground may be different, at different locations what are the variations in geothermal plant design ok. So, what are the typical kinds of variations that people have in relation to geothermal plant design. So, I think these are the two major ideas that we would like to focus our thoughts on and go through you know related information ok.

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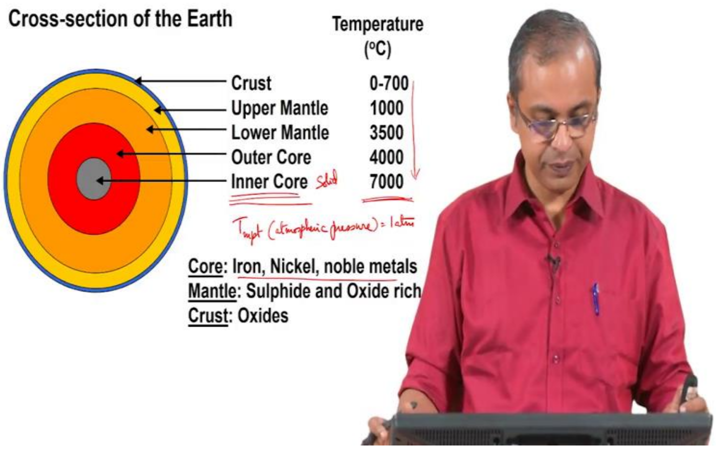

We saw this in the last class that we basically saw that as you go deeper and deeper in into the earth the temperature goes up and that’s basically the idea of this whole geothermal energy process. I also told you that these are all based on models the actual temperatures that you see here are all based on models and so you can see variation from you know a model to model. So, these are not hard and fast temperatures these are sort of estimates based on different models and as of now, we have no real way of actually measuring these.

In fact, even though you know the core is only 6400 kilometers below us you can actually learn a lot about planets that are far away from us, stars that are far away from much more effectively than you can learn about the core that is just directly below us because we cannot access it whereas, you can actually use astronomical instruments to access all of those. Incidentally even though the temperature is going up, one of the points that you must I mean find interesting perhaps to note is that the inner core which is where you are seeing the highest of the temperatures even though this may or may not be the exact number that we need to look at the temperature is, so, high there that in principle at about you know if we cross 5000 degrees C and you know if that kind of a temperature you cross essentially all metals will be in liquid state you will not you are not really going to have any solid metal at that point.

But if you actually go to the core the estimates indicate that in the core you actually have solid metal you don't have liquid metal and the reason is simply that whatever you see as the melting point which you see in the data that you see when you go and look up you know melting point of iron and melting point of copper or melting point of aluminum whatever the temperature that you see there is the temperature which is the melting point of that metal at atmospheric pressure ok. So, melting point T melting point that you typically see assumes that it is at atmospheric pressure.

So, that is equal to at one atmosphere and as you can you know as we sort of saw you could have to several million atmospheres if you go down based on you know how much of pressure is being collected there. So, therefore, the pressure is very high there and under those conditions even though you are well past the melting point the metal is forced to stay solid the atoms are pushed close enough that they stay in their solid state they don't break free and float away as liquid ok.

So, therefore, inner core is considered to be solid material and in fact, based on all the estimates based on the fact that earth has magnetic properties various other the density of the earth various other things the expectation is that these are the kinds of you know compositions of the center of the earth.

Incidentally I mean on along similar lines because of all this heat and pressure that is there it potentially this is something that you would this is a form of energy that you could extract in other locations to in other planets to if a similar situation were to exist of course, that would require some kind of a crust and then some you know hot material being beneath it. So, some places that may not be the case, so if you have a gassy planet and that is not the case then there may be no well defined surface on which this can be done. But this is an idea that is of interest even for space exploration because at various planets depending on where you are you could get energy directly from within the planet as opposed to say solar energy etcetera.

This may be relevant based on where the planet is located this is just an interesting aside . And in all those cases again based on the pressure the central part may be solid, the central inner core may be solid ok. So, for example, theory suggests that if you look at the center of say Saturn or center of Jupiter the temperature and pressure and composition are all just right that at the center of those planets it is very likely that you have a big diamond ok. So, the, you know we look for diamonds and it is such as scarce item here and on the planet on our planet and it is so expensive you may have a diamond sitting in the center of Saturn or Jupiter which is larger than our planet. So, that is possible we don't know that that is true, but the conditions are vector the high temperature the high pressure and the amount of carbon that is present create circumstances that are very similar to what is required to create diamonds.

So, this is just something that is of interest. So, different planets have different circumstances ah, but many of them have, have there is a chance that several of them have some energy in them certainly on earth we have this energy that we are trying to tap okay.

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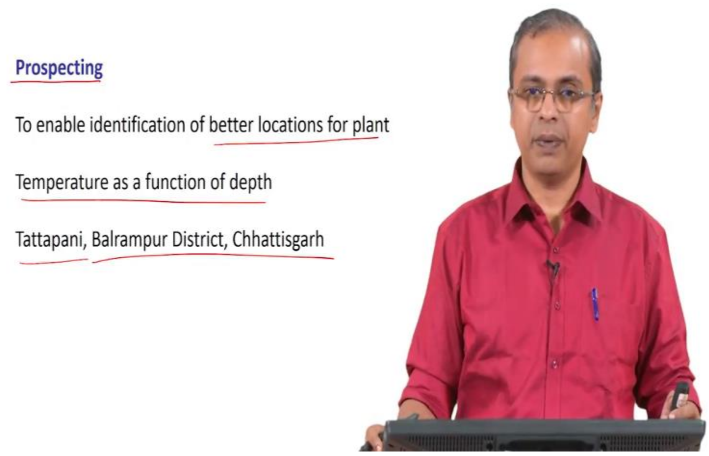

So one of the big activities associated with the you know locating and tapping of geothermal energy is this idea of prospecting ok. So, prospecting is simply exploring, exploring to find out what is available where, that's essentially what it is. So, people do prospecting for all kinds of different things I mean they may be prospecting for a particular ore, they may be prospecting for gold, they may be prospecting for diamonds etcetera.

So, even for geothermal energy that is basically the idea the there are people who study the you know geology of various locations of our planet and then, so they try to understand what are better locations for the plant. As we discussed potentially you could dig a hole at any place and based on the kind of temperature you get at some depth you can actually run a geothermal plant. So, in some sense the you know location is not totally critical you can actually do this at multiple locations and it is not impossible to do it that way, but there are better there are locations that have considered better locations and to identify those locations you have to do prospecting.

So, considerable amount of time is spent to locate various regions that people think might be of interest maybe because there is some you know hot water already coming out from under the ground which suggests that there is some hot spot below where you are able to access the heat at maybe a much shallower depth, you are able to access higher heat at a shallower depth.

So, therefore, there may be better locations and therefore, there is interest to you know explore those locations and see what you can obtain in those locations. So, to do that actually what they do is they try to make a chart of some sort where you have a map and then at in the map at various locations you indicate, what is the temperature at various depths? So, therefore, you will get some kind of an isothermal line you will get find out that at which depth you get the same temperature at various places.

So, if you are getting you know higher temperatures at lower depth then potentially there is a you know some hotter region below. So, that may be a region that is more interesting for us to explore from the perspective of geothermal energy.

So, for example, in India a place when they are trying to really set this up they have done this kind of geological exploration in several places in India. So, there is this Balrampur district in Chhattisgarh, a particular place called Tattapani in Balrampur district Chattisgarh which is where they are you know doing putting in an effort to set up a geothermal plant and so that is where we are likely to see some activity come up from the Indian perspective. But all of that again as I said it relates to this initial step of prospecting.

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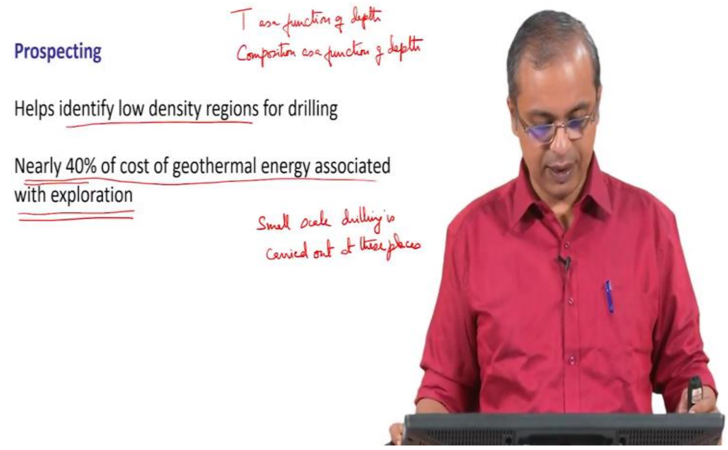

So, it also the prospecting also does multiple other things. I mean, so it is not just locating the region which is of interest you have to understand what is that region the they also you know drill course I mean drill through that location and pick up what kind of material is located at various locations in that region as you go down in depth.

So, it's a temperature, so they are locating you know finding out temperature as a function of depth and composition as a function of depth. So, composition means not necessarily chemical composition we are looking at you know what kind of rocks are there what kind of I mean is it sandy, is it full of rocks and if so, what is the thickness of the rock layer, how much of sandy area you have to go through, what kind of clay is there in that region, what kind of soil is there how deep it goes. So, those kinds of information this is very this may not seem immediately relevant, but it is actually very useful in identifying low density regions.

So, even within the same area, so supposing you have located a particular region where it seems like there is some hotspot below even in that region you can check out multiple neighboring locations to see if there is one region where the drilling seems to be going much more easily right. So, that enables setting up of the plant in a much more easy manner and therefore, this is very important initial activity and incidentally I mean here this is done. So, extensively to in order to locate these plants nearly 40 percent of the cost of geothermal energy is a associated with this exploration process. So, and that is because they set up you know sort of you know small scale plants are set up, small scale drilling is done.

So, small scale drilling is done small scale meaning the plant is actually almost like a mock plant they will set up they will actually have to drill , I mean a hole into the ground to some reasonable depth, to understand everything, to understand the temperature as a function of depth, to understand what you know geological features are there as a function of depth, you can also see if you know there has been some relatively recent melting and solidifying in those regions that gives you an idea if you know that has been a relatively active location so to speak and then get this information together. So, you have to drill these holes and these are being done at various locations and each of them costs a fair bit of money. So, nearly 40 percent of the cost of geothermal energy is associated with exploration.

So, lot of you know work is done on this remote sensing to get a better sense of what features are available at larger you know, larger area of land so that they can identify these locations much better and therefore, in fact, the general thinking in the in the field of geothermal energy is that it is much more important to invest in technologies that help you in this exploration process, that will help you do this exploration much more effectively, much more efficiently, in a much more time bound manner so that you can get all this information without whole lot of delay and without a whole lot of expenditure of money money and resources.

So, if you can cut this down you know if you can cut down this exploration cost significantly the cost of the plant itself comes down because this exploration cost is all getting you know tied into the plant eventually when the plant comes you have to recover this exploration cost from whatever it is that the plant produces.

And at if you take that into account 40 percent is very high 40 percent of the cost being the exploration is a very high. And that is mainly because you have to actually make those tools drilling holes at various locations it is not something that you cannot easily just get this information by taking photographs etcetera you have to drill and that is the reason why this seems to be expensive. So but prospecting is a very important activity in this context.

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Incidentally, so plants have been set up around the world in this in this context and as I said in India in Chattisgarh they are working on setting one of these up. The largest such plant is in California it’s about the 1500 megawatt plant has multiple I think multiple drills are there at that location and you have 1500 megawatts have been generated there.

Number of other countries have been involved in this process. You can see here in Philippines if you take the 10 largest plants that are around internationally then you have three of them being in the Philippines. So, there it seems to be quite an important form of energy capture that is you know being pursued actively. So, in Philippines we have three of them in the US and in Indonesia there are two each two of these large plants are there including this one in California and in Mexico Italy and Iceland you have one each. So, clearly this is you know worldwide phenomenon lot of nations are looking at it, we are we have not actively pursued it to the extent that these plants are already set up and generating electricity and so on, but we are also considering looking at it and we are you know in the process of setting up a plant.

So, the again the nice driving force for this is that I mean you don’t really need any there is no pollution coming out of it is kind of a clean form of energy and potentially infinitely renewable. I mean it is going to last for such a long time that you don’t have to worry about it running out of it so to speak. So, this is the sort of the global scenario in this context.

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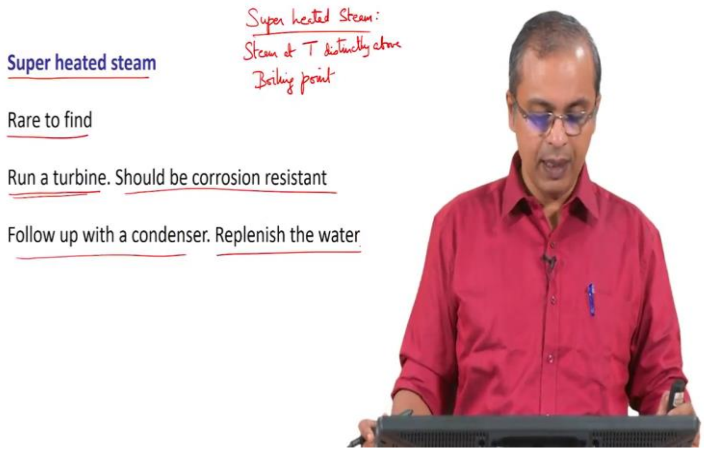

Now, let’s say we have done some prospecting ok. So, you have done some prospecting and you locate a particular region where there is very high temperature and in fact, when once you drill you find actually there is a lot of hot material coming out from there typically steam. So, that is what is coming up. So, based on the location and the temperature essentially based on the temperature you have multiple possibilities of what you can get from that location right.

So, either you can get a big because if the temperature is pretty high then you may end up getting what is called superheated steam ok. So, water boils off and then you get steam and that point as just about boils off and just you just about created create steam that is called a saturated steam. So, that can condense relatively easily because you have just past the boiling point if you heat it distinctly above that boiling point that steam is heated distinctly above the boiling point then it is called superheated steam ok. So, a superheated steam is that you know steam at a temperature distinctly above the boiling point okay. So, that is superheated steam right.

So, typically superheated steam and so the advantage of superheated steam is it’s not going to immediately condense in generate water ok. So, this is may not seem like much, but we will discuss that in a moment to understand what is the big significance of it if we say you know it’s not going to condense all of a sudden so to speak. First of all in the grand scheme of the fine that people have as they go about prospecting this is relatively rare to find relatively, it is there it is there in some locations, but it is relatively rare to find superheated steams directly coming out from underground, but if the if you do find it in a location it's a big positive because; that means, you can directly start putting a plant there and start operating it and you can directly use it to run a turbine ok.

So, you can run a turbine directly using it we will just see some schematics of this in just a moment, but basically the steam can be taken to turn the turbine. The one issue that you have to be cautious about is that even in thermal power plants they are creating superheated steam and then sending it in to run a turbine. So, that in that sense conceptually once the steam is generated the processes is the same we send it to run a turbine. Now, the only difference between say thermal power plant situation and this geothermal situation is the fact that when you do this super heating and you generate this steam and you send it in the thermal power plant you started with clean water ok. So, the water is clean it is something that you had control on and therefore, the steam that you get is also clean and that is used to run the turbines.

Now, in the case of the geothermal plant what is coming from underground may not necessarily be 100 percent steam you may have some other gases in it, you may have even some radioactive material in it etcetera, so which may be coming out. So, therefore, what goes into the turbine especially under these conditions when you are sending it directly into the turbine is potentially something that can damage the turbine ok.

So, therefore, you have to be cautious about it and you have to take appropriate precautions with respect to the turbine materials to be ensure that it is more corrosion resistant then maybe you would normally set it up to, set it up to be. So, they put coatings on turbines you know you can put different kinds of coatings on turbines just to ensure that there is greater resistance to corrosion greater resistance to any abrasion etcetera. So, that kind of precaution needs to be taken.

So, but in any case if it is superheated steam it can be run to it can be sent to run a turbine and also the we will look at this we can follow it up with a condenser that we will see in a moment and basically we also need to if it is coming straight from the ground if the superheated steam is coming straight from the ground we don't want to exhaust that superheated steam. So, whatever happens at the end of the process the water that is generated is pulled back into the ground at that that location to ensure that the cycle stays operational ok. So, this is the general idea that people would like to do with respect to superheated steam. So, if you look at a you know sort of a schematic we will see a schematic here.

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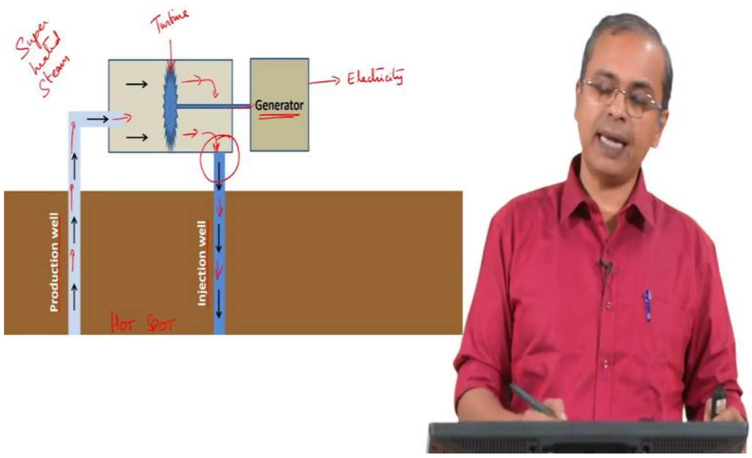

So, we have some where further deep down we have hot spots or some hot spot is there where we have very high temperatures and you are able to get steam. So, normally what they will do is having found such a location they actually drill two wells. So, one is called a production well which is what you see here. So, this is the well from which they tap the steam . So, the steam comes up the way you see here and then goes into this turbine because it is already superheated steam.

So, this is for superheated steam superheated steam it enters and there is just a schematic of some turbine that I have put here. So, let’s say this is the turbine and this turbine then rotates you get this generator. So, this turbine goes and then the steam goes past the turbine gets the turbine to rotate and then the turbine is then connected to a generator here. So, the generator generates electricity and then you have an electricity out.

So, this is the basic idea that we have. Now, after you cross the turbine the steam would have cooled or at least completed it’s task and then at that point we can send it back this is what we say referred to as by saying that we can we should replenish the well, the point being that you know you have taken something out from under the ground and if you exhaust it off the you may no longer be able to easily get the steam from that location. So, you send the condensed water back into the ground. So, this way you can keep it running indefinitely as long as there is heat down there. So, there is typically an injection, but through which you complete the loop. So, you send this material back in and this is called the injection well. So, now, when you complete this when you go past the turbine right, so the steam hasn't completed it is work it has done rotated the turbine and you are about to exit the generator I mean the turbine, turbine chamber.

So, at that point you may still have it as steam. So, what should you do? I mean if you if you directly put steam back in here it may not be as effective in terms of going back down into the injection well and you may you it may still have some energy or you are you have actually not fully captured the energy if you are just sending it back as steam, just you know steam which was superheated significantly it is now, steam that is either you know just about saturated or just marginally superheated.

So, you are not fully captured all the energy that is available in this process, if you just do what is being demonstrated by this schematic. So in fact, whenever we find superheated steam they do one more step which is which is which happens in this region at the exit from the turbine area where we say that we don't take what is coming and we exit we do not directly send it into the injection where we do one more step before we send it to the injection well and that is what you will see here.

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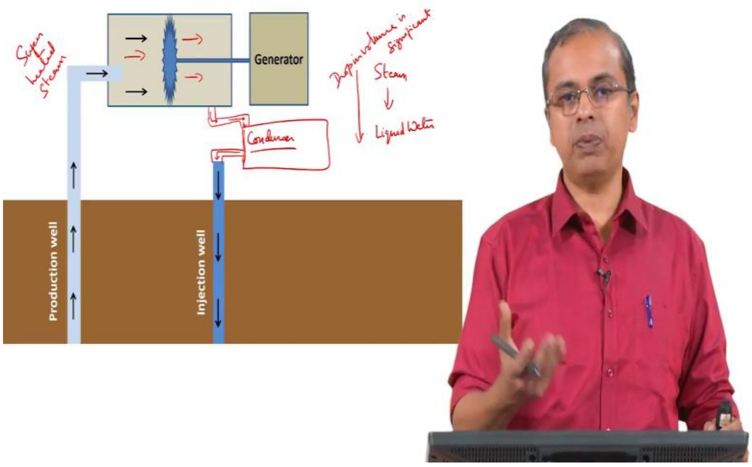

So, what we do is we put in a condenser. So, what comes out is actually sent into a condenser ok. So, here it is allowed to cool down further till it becomes liquid water ok. So, it becomes liquid water and then it is sent into this injection well ok. So, this is what is done. So, this may not seem like much. So, you would say, so what I mean you have you anyway across to the turbine.

So, already crossed the turbine what is the big deal in putting it into a condenser and then sending it into the injection well there is a big difference. The moment you put it in a condenser you have taken steam and made it water, liquid water ok. So, when you do this the drop in volume the drop in volume is significant. So, steam is going to have significantly higher volume than this the same amount of steam when it is converted into liquid water.

So, there is a huge drop in volume when it goes from steam to water. So, now, this drop in volume means what. So, you had supposing you have a chamber in that chamber you have steam ok. So, you have let’s say some one meter cube chamber 1 meter by 1 meter by 1 meter, 1 meter cube chamber that is filled with superheated steam. Now, suddenly you cool this you cool this and then this whole superheated seemed suddenly condenses into some you know handful of let’s say I will just give some example maybe 100 ml of water it is what it is let’s say 100 ml or 200 ml of water ok. So, now, suddenly there is a huge drop in volume which means significant amount of vacuum is being generated inside that chamber ok.

So, when you do this condensation you are generating vacuum because whatever was there you suddenly reduce the volume the container still has the same volume, but the interior you know material that was inside that the vapor that was inside that has suddenly condensed to a very small volume.

So, you have generated a significant drop in pressure which is essentially you are creating a sort of vacuum. If you create a vacuum then you pull the gases pull the steam that is coming up here even much more effectively ok. So, and in that process you actually make the turbine work even better ok. So, by just the condensation process, by creating vacuum on the exit side you will make the whole turbine system work much better. So, you actually get even more energy you are able to extract even more energy out of the turbine and as well as from the from the you know superheated steam that arrived at the turbine and through the turbine.

So, you end up creating much more energy or extracting much more energy. So, therefore, a condenser is actually very important part that is there that is added to this system of this geothermal energy process when you have a superheated steam and it significantly helps improve the you know operation of that plant and therefore, this is always done ok.

So, we never typically in this kind of a situation when you have superheated steam we are not exhausting this I mean we are not venting the steam out into the atmosphere instant we send it through a send it back to the same location from which we took it out by using an injection well and on top of it we also use a condenser to create liquid water and then only then we inject it back into the air well. So, so this is what you will typically see.

Now, this condenser may have some other you know may be may have a water I mean low some water involved in the condensing process cold water may be available locally which is used for condensing process. So, typically condensers you will see some vapors coming off of it, but that is from water that is other than what is being used for this that is coming through, the steam coming from the steam ok.

So, this is the kind of layout that is used if after prospecting you find the location where you have superheated steam. And of the possibilities that you can have when you do this prospecting or when you do this you know surveying for this geothermal energy this is your best case scenario where you found steam and you were directly able to use it. So, then the plant complexity is much simpler and it is much more capable of extracting this heat for you, but this is not what you always find ok.

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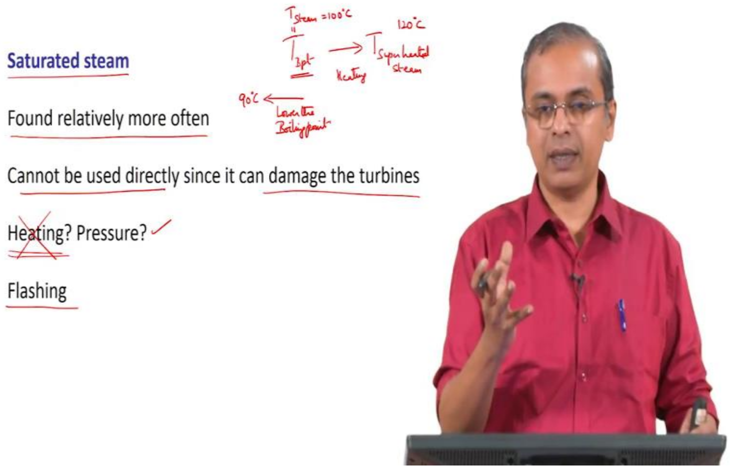

Often what you find is saturated steam. So, saturated steam means it is just past the boiling point I mean. So, you boil boil the water you are just past the boiling point you have created steam , but you are sitting at a temperature that is very close to the boiling point and at that point if you do anything that cools the steam even marginally you are going to get droplets of water ok. So, if you would take even the tiniest bit of heat out of it you can get droplets of water. So, many places this is what is being formed relatively speaking, significantly more often much more often then you find superheated steam you are likely to find saturated steam.

Now, there is an issue with this. I mean in some sense conceptually it is the same you can still send the same steam into a turbine and make it operate and. So, in that sense you should not consider it dramatically different than using superheated steam, but we cannot use it directly because the condensation that happens creates droplets of water and those droplet us of water can damage the turbine over a progressive period of time .

In all these cases, in all these technologies many of these parts are expensive parts and we don't want them damaged, turbines are kind of expensive to make and they are expected to last considerable number of years. So, you don't want the turbines to be damaged, but when you have droplet us of water you know physically going through the process they can damage the turbines they can lead to corrosion many issues can arise. So, what what can we do? So, the possibilities are different, different possibilities, we can think of we can actually try heating the water. So, you have reached steam. So, in the in the in a thermal power plant you are basically taking water at say room temperature and then using coal and heating it up two 100 degree C and then you heat it to get steam with, then you heat it to get superheated steam and then you send it into the turbine right, so that much of energy you are getting from coal.

Here you already have steam ok. So, it’s just saturate it is saturated steam. So, it is already there in that you know you already taken it 100 degrees C got it past the boiling point and it is in steam. So, with relatively less amount of coal for example, if you had to use coal with relatively less amount of coal you can get it to become a superheated steam. So, that’s a simple. So, you are not you are not, you want be 100 percent clean in that sense because you are going to use some some fuel maybe coal may be oils something to do this final bit of heating to get it to become superheated and then you could use this you can use the same turbine that you used before etcetera. So, that is one possibility.

But generally that is not done because of course, this whole idea is to run this in a very clean manner and by including this burning of this coal you are not really you are sort of destroying that good aspect of this technology. And more than that there is also the economic aspect of it these plants are as I said you know they are not located just about anywhere some prospecting is done and it is located at some maybe even in some remote location which is where the hot spot happens to be.

So, to run this plant if you are going to adopt this strategy of you know heating it then you have to keep transporting fuel to this remote location. So, and these are not small plants these are typically you are trying to set up a plant which runs you know significant power capacity is there, so corresponding to that a significant amount of steam will have to be used and therefore, corresponding to that a significant amount of fuel will be required. So, if you have a remote location and you have to keep transporting this on a day a regular basis and these plants are you know set up to run for several decades if not more than this is a big process you are setting up which is not at all a convenient process. So, therefore, this is not taken into this is typically not done. So, heating is not pursued in this context.

The other option you have is that anytime any liquid. Let's say you say you know just that just the way we spoke about melting point I told you that you know if you have a melting point for a metal you increase the pressure you can, you can go to even higher temperature the metal will still not melt it will stay in solid state because you have put pressure to force those molecules to stay together or atoms to stay together. And therefore, it is unable to melt and the idea of melting is there they have drifted away from the crystal structure and they are moving around, but because of pressure now they are staying together.

So, at high pressure the metal does not melt as easily as it melt sets a one atmosphere pressure. The exact opposite would be true if you started going the other way around. If you start decreasing the pressure then the melting point, the boiling point, etcetera will actually decrease because you have now, you know made it easier for the molecules to separate out right. So, therefore, if you manipulate the pressure instead of the temperature you can create a situation where what comes as saturated steam suddenly has a boiling point that has decreased and because it's boiling point has decreased it is now, supersaturated it is or superheated it is superheated right.

So, this idea of super heating is related to the boiling point that's the point we have to remember that it is related to the boiling point. If you know what the boiling point is if you heat the steam past the boiling point say 10-20 degrees past the boiling point then you have superheated the steam, but, so you can do that by either. So, you have T boiling point. So, you have to go higher than this, so to superheat. So, we have to go to higher temperature to superheat it.

So, now, if you can do that by heating , if you do do that by heating the temperature of the steam is going up and therefore, it becomes superheated steam alternately you can do it by reducing the boiling point or let's say lower the boiling point . So, if this is if this is the T of the, T of the steam. If the steam temperature is at the boiling point at this at under 1 atmosphere if you drop the pressure below 1 atmosphere the boiling point is decreasing and therefore, even at the same temperature.

So, let's say this is supposed to be 100 degree C, let's say this 100 degree C. So, I will say that the temperature of the steam is the boiling point is equal to 100 degree C let me just say that as an example. So, you can heat the temperature to let's say 120 degree C in which case the steam is superheated or we can lower at the boiling point to say 90 degree C, 90 degree C. Let's just an example.

So, if you drop it to 90 degree C if the boiling point drops to 90 degree C then with respect to 90 degree C a 100 degree C steam is superheated right. So, it is only a relative and this boiling point is a variable. So, even though when we read in you know literature that the boiling point of something is a particular value of boiling point of water is 100 degree C.

We keep reading it that way, and we think that that is the only point boil temperature at which water will boil that is correct that is the temperature at which water will boil under 1 atmosphere pressure, that 1 atmosphere pressure is something it will be there in your textbook, but I don't think you would have paid attention to it if you think about it carefully you will find it will go and look up this information it will always say boiling point of something at this pressure it will say that. We somehow don't the pressure part of it does not register to us because we went only looking for the boiling point.

And the pressure is always assumed to be a one atmosphere because most of the time our operation is at one atmosphere. So, boiling point of water is 100 degree C at one atmosphere. You drop the pressure significantly you can decrease the boiling point if you increase the pressure you can increase the boiling point. So, this is, so the boiling point is variable and depends on the pressure and so if you decrease the pressure you can decrease the boiling point and then the same the I mean the steam at the same temperature is now, superheated relative to what it's boiling point. So, that is what is done and this ideaa of you know lowering the boiling point by adjusting the pressure. It is called flashing.

So, what happens is steam comes out before it enters the turbine it will enter a chamber where it is allow to expand. If it is allow to expand then it's boiling point comes down and therefore, it becomes superheated and once it becomes superheated because the pressure has decreased pressure has suddenly decreased and therefore, it becomes superheated and at that point you can send it into the turbine.

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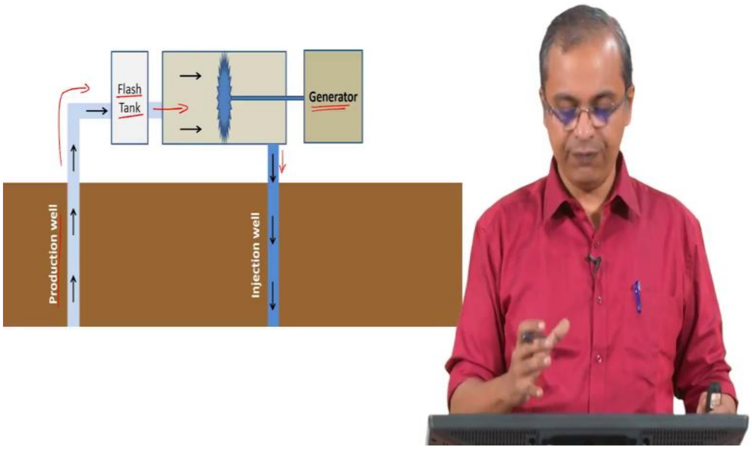

So, this is basically what we do. So, from the production well it’s the same process you pull up the steam and you send it into this tank called the flash tank. So, here flashing is done and this, this concept is called flashing where you suddenly decrease the pressure and because it is decreased suddenly you have superheated steam and then that superheated steam is sent into the turbine. And then that rotates the turbine then you get the generator to operate and then after that you can send it back into the injection.

And again you know it depends if you have if it is still you know it is still in steam condition you can again put a condenser and again drop it to vacuum conditions to get the liquid water to form, and then you can send that liquid water down the injection well. So, this is the manner in which you would handle a situation where you have you have you have saturated steam coming into the becoming available to you coming from the location where you have done this prospecting okay.

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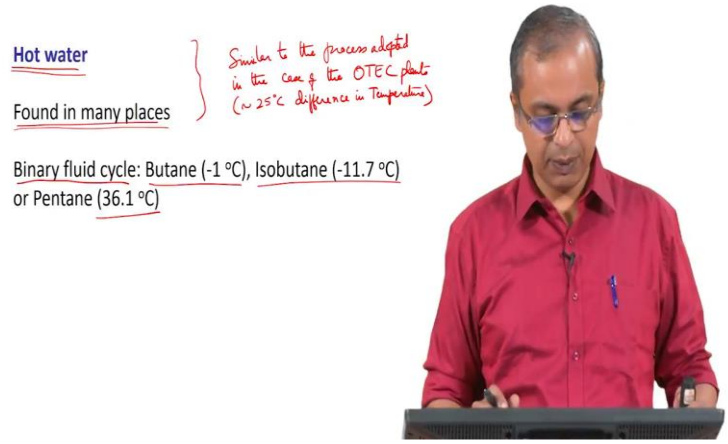

The third possibility is hot water. So, we saw superheated steam, we saw saturated steam. Now, we are looking at hot water. So, this is the third possibility that we have which is hot water. This is actually found in many many places. So, when you do the prospecting this is what you are most likely to find most commonly you end up finding this hot water in which case the process that is used as I mentioned is similar . So, we saw in the OTEC plant discussion that we had a couple of classes ago that there you are only looking at a difference of about 25 degrees centigrade, you are looking at water coming from the bottom of the ocean which is sitting at about 3, 4 or 5 degrees centigrade and you are looking at water on the top of the top surface of the ocean which is sitting at about 25-30 degree centigrade.

So, the difference in temperature is only about 25 degree centigrade maybe even less 15 to 25 degrees centigrade is the difference that you are looking at with that itself we are running a generator right. So, with that it is we are running a generator. So, when you get hot water when you do geothermal prospecting and get hot water then clearly you can use the same concept you can use the same concept that you are using in a OTEC plant.

So, typically to do that you need to do something called a binary fluid cycle and the different again the idea is the same if you have some you know vapor going through the turbine you can get it to rotate and so you look at liquids which have low boiling points. So, you can take butane which is minus 1 degree centigrade boiling point. isobutane is minus 11.7 degrees centigrade boiling point pentane which is 36.1 degree C boiling point.

So, you can use these as liquids as opposed to using water which is 100 degree C boiling point. So, so to use water and then get steam from it and then run the turbine you would have to be past 100 degree centigrade temperature, but if you have got hot water, that hot water may be reasonably hot it may be you know 80 degree centigrade, 90 degree centigrade or something like that and therefore, you may actually have considerable amount of heat available in it, it is just that it is not yet past the boiling point it is not in scheme. So, you use some other fluid and you exchange heat with this water and using that process you run the turbine.

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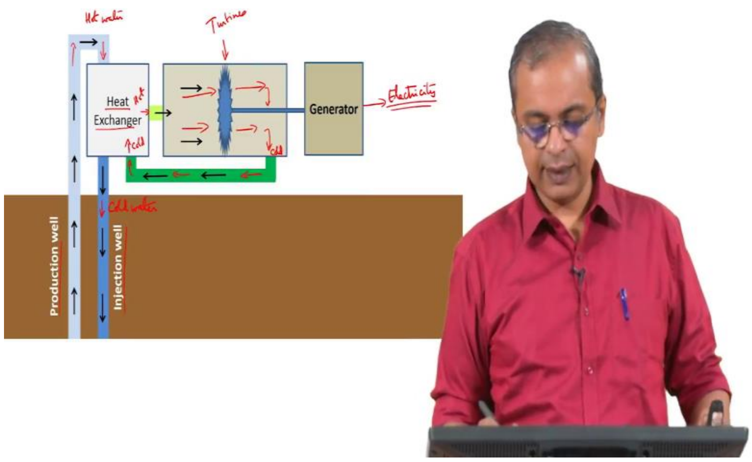

So, for example, it would look something like this. Again you would have a production well. So, from this you pick up the hot water and it goes into a heat exchanger. So, this is very important. So, we have a heat exchanger that is out here. So, in this heat exchanger this water enters hot.

So, you come here with hot water and what is coming out here is cold water okay. So, cold water is exiting from the condenser from the heat exchanger and goes down. So, there is another fluid which is running between, so this is the fluid that is running from the well from the production well to the injection well through the heat exchanger. So, your water does not see the turbine it only sees the heat exchanger it goes in goes enters the heat exchanger hands off heat and goes down cold. Then you take the take another fluid which could be any of these that we spoke about butane isobutane pentane etc you find a fluid which is low boiling point and has the you know correct range of temperatures with which we can operate it in this situation and that fluid enters here cold picks up heat and then exits out here hot ok.

So, it enters in cold exits out hot vapor form it will and exit out that hot you know a gaseous form of that liquid of that you know a pentane or butane or whatever you have taken fluid is now going to run the turbine. So, you complete running the turbine and then you exit the fluid will exit out and it is now, cold again and goes this way ok. So, you have 2, 2 fluids here the fluid that is coming from the underground and that's this loop that we just saw which is how the heat exchanger is you know picking up that heat and handing it off to this second fluid, which is the binary and hence this is called this binary fluid cycle because there are two fluids involved here and the second fluid is what runs the generator runs the turbine actually. So, the turbines are here and then that runs the generator and from here you get the electricity okay.

So this is the basic idea of this process where you could be running using hot water ok. So, and that is the way in which this system is set to run.

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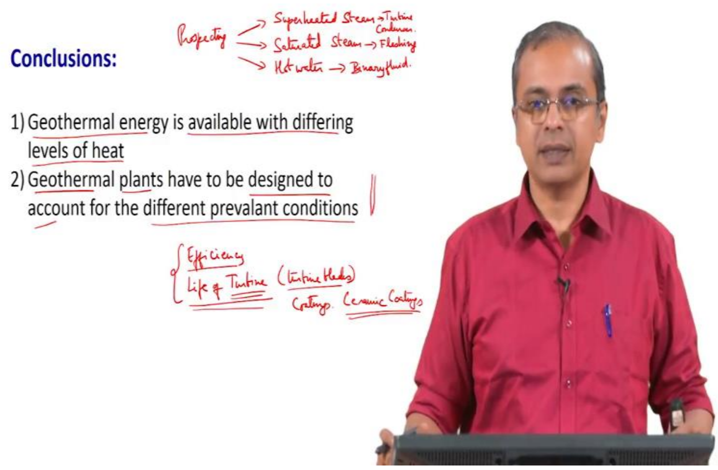

Now, if you look at it as I said you know the geothermal energy is available with differing levels of heat. So, we saw that you know based on the location you could actually have either super saturated steam, superheated steam you could have or you could have saturated steam or you can have hot water. So, these are the 3 that you would get based on your prospecting. So, you do prospecting and you could get one of these 3. And and therefore, this is a very from location to location you get this and then based on this you run a turbine with a condenser, you do flashing in this case, and in this case you use a binary fluid ok. So, so these are all the options that you have available to you and in that process you can generate the electricity from the turbine. And therefore, the geothermal plant has to be designed to account for the differing prevalent conditions.

So, whatever the condition is as I said you know you have 3 possibilities here which could be distinctly different in how their behavior is with respect to the turbine. And a lot of this as I said has got to do with you know in all these cases you are looking for efficiency and you are also looking of life, life of turbine blades turbine etcetera. So, life of turbine blades etcetera, the that efficiency and life are the two criteria that you are using when you decide what is the design that you need to use.

And it also tell you that given that this is geothermal and you don't really have significant control on what is coming out from underground significant variation is going to be there from site to site, both in terms of I mean this temperature is just one variation that we are talking of that decides there is a very important parameter because the design of this plant itself will be based on this variation of temperature that , clearly you know you have three totally different designs that have to be put in place.

So, you cannot just you know force fit one design to all locations of this plant. So, this, you have to do some initial design understanding of that location to decide what kind of a plant you have to use. But if you look at life of the turbine you have to keep in mind that what comes out is not going to be pure steam, you are likely to have other things that are coming out. So, your system should actually be capable of you know keeping track of track of that to ensure that you know whatever is coming out is not dealing with the turbine which is incapable of handling what is coming out and therefore, this turbine material is a know fair amount of material science is there with respect to turbine blades and lot of coatings are given often ceramic coatings.

So, ceramic coatings are often given for turbine blades primarily to ensure that you know the turbine blade doesn't directly get impacted by what is heating it, ok so and that dramatically increases the life of the turbine blade. So, sometimes you know Zirconia based coatings are used, etcetera and they are used to create this thermal barrier coatings they are called and that helps handle the temperature plus also the fact that it's a ceramic kind of coating usually make means it is much more resistant to attack from corrosion and so on, and so those coatings are very significant.

Even, even if you can you know the actual blade if it sees a temperature that is you know 5-10 degrees lower than the temperature of the gas that is hitting the turbine blade then that itself will greatly increase the life of the turbine. On top of it we you know if there are any particles that are coming by chance from underground etcetera which you don't have control on the ceramic material will take the impact from those fine particulate material that may be present and in that case that again helps protect the turbine blades.

So, the coating or the study of those coatings is a very significant activity because not only do they have to understand which material to use you would also figure out what is the best way to apply that material on top of the blade . So, that that you know coating is uniform and has some predictable properties, so that you can say safely say that you know for a certain range of operation of temperatures certain range of you know compositions the turbine blade will be safe .

So, even though we draw you know diagrams like this where you have just put in a turbine system here clearly, since this is not a you know typical thermal power plant where you have a lot of control on what liquid is being used, I mean what's the quality of water that is being used we cannot just like that put whatever is available in a typical thermal power plant cannot directly be used here. It's a good starting point and that is probably where people will start, but you have to account for all these things, you have to account for what is available locally in terms of what is coming out from underground and figure out if you need to put in additional coatings to make it run.

So, there are these conditions that we have to look at people actively look at it, but as I said the geothermal energy as an as an as an overall area of activity has all of those positives. The first thing is you are not depending on a particular find of oil of any nature. So, in a sense it puts almost all nations on even footing. So, many of the you know political aspects associated with energy are you know blunted when you look at energy of this nature when you look at say solar energy, wind energy and geothermal energy I they get blunted and if it is geothermal energy to some degree I mean clearly you don't even need access to the coast. So, OTEC for example, needs access to the coast. So, even within the , within a, within a nation like India only the coastal areas can you know immediately attempt to benefit from the OTEC kind of activity.

Even there you have all this you know flowing water and you have difficulty in controlling the pipes and the lifetime of the pipes. Whereas, here it is it's primarily a hole in the ground and so to some degree it puts everybody on an even footing you can actually do this at various places, although as I said based on prospecting they tend to pick specific locations in preference to other locations ok.

So, those are our conclusions for today's class. Geothermal energy is available with differing levels of heat at different locations and plants have to be designed to account for the various different prevalent conditions, conditions prevalent primarily looking at efficiency and lifetime of turbine. And with those cont you know aspects taken into account this is a technology that is very clean and can be used at multiple locations.

So, we will halt this discussion with this today and we will pick it up in our next class.

Thank you.

KEYWORDS:

Prospecting; Temperature as function of Depth; Exploration; Superheated Steam; Production Well; Injection Well; Saturated Steam; Superheat; Flashing; Flash Tank; Hot Water; Binary Fluid Cycle; Heat Exchanger.

LECTURE:

Geothermal energy is available with differing levels of heat based on prosepecting. The three levels of water forms based on the location are either super saturated steam, superheated steam and hot water. The technologies involved in these processes are described and illustrated. The advantages of Geothermal Energy in contrast with OTEC based energy is listed.