Chemical Process Utilities
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Lecture – 10
Solar Energy-II

Welcome to the concluding part of solar energy. So, previously, if you recall, we discussed the introduction to solar energy in which we discussed the parabolic trough collectors PTC.

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We got the anatomy of linear Fresnel reflector LFR. In this particular lecture, we will discuss the concept of a central solar tower, which is more common nowadays.

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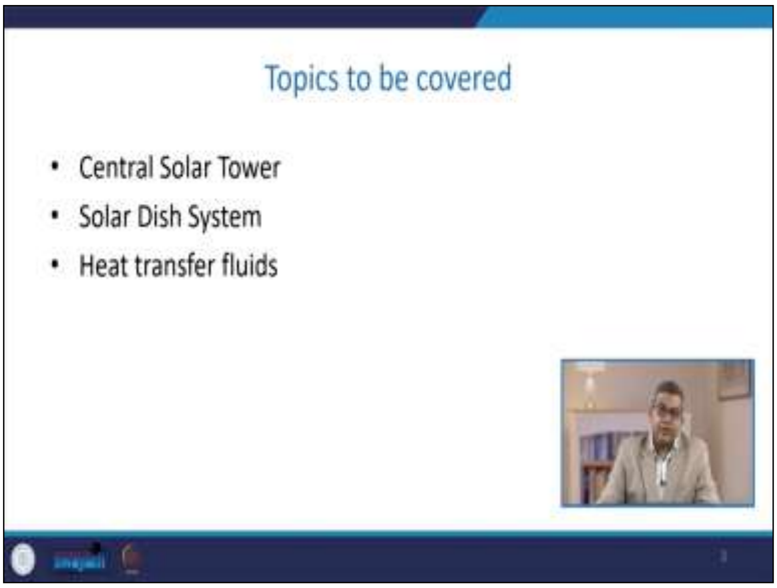

And solar dish system, and we will introduce the concept of heat transfer fluids. Let us talk about central tower technology. Central tower technology is quite simple. Especially when we compare it with the PST is well suited for large-scale grid-connected power plants and has larger economic benefits.

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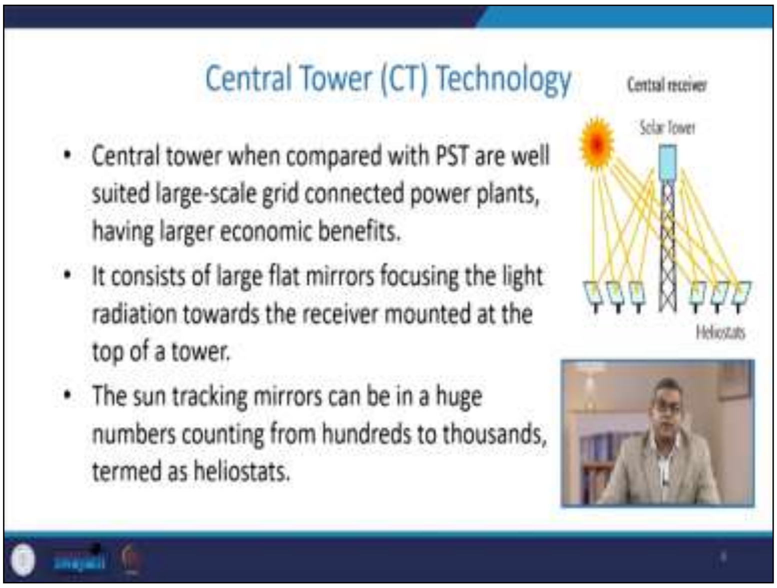

It consists of large flat mirrors like this here, you are having these large flat mirrors connected with the heliostats. These mirrors focus the light the radiation towards the receiver. This is a central receiver mounted at the top of a tower. These sun-tracking mirrors can be in a huge number counting from 100 to 1000, termed heliostats.

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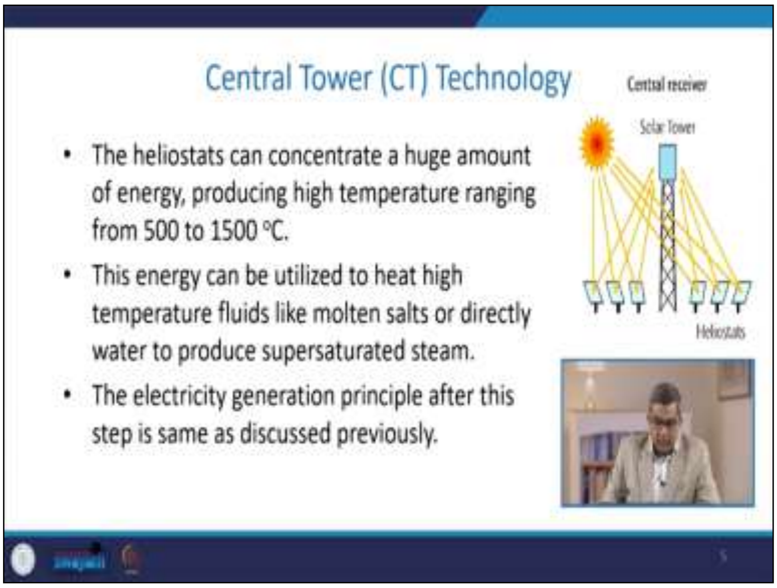

These heliostats can concentrate a large amount of energy-producing a high temperature ranging from say 500 degrees Celsius to 1500 degrees Celsius and sometimes even more.

This energy we can utilize to heat high-temperature fluids like molten salts or directly water to produce supersaturated steam. This electricity generation principle after this step is the same as we have already discussed in that you produce the superheated steam. Then this steam is passed through the steam turbine generators to produce the electricity.

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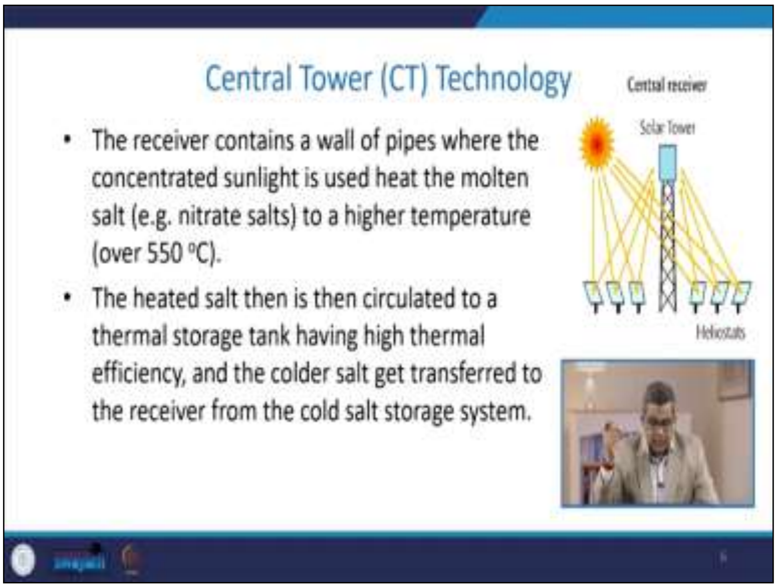

The receiver contains a wall of pipes where the concentrated sunlight is used to heat the molten salt, sometimes nitrate salts, to a higher temperature like 550 degrees Celsius or sometimes more. This heated salt is then circulated to a thermal storage tank with high thermal efficiency, and the colder salt gets transferred to the receiver from the cold salt storage system.

The energy is then used to produce steam, which converts this thermal energy to electrical energy. We have studied these various cycles, and the foremost cycle in this particular aspect is the Rankine cycle. When the heating process stops at night and cloudy days, the molten salt was stopped to pump through.

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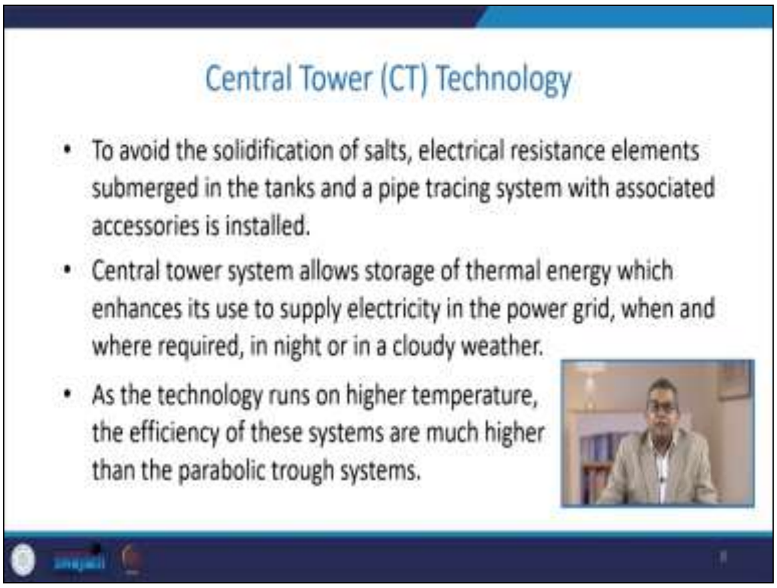

To avoid the solidification of salt electrical resistance element may be submerged in the tank, and a pipe tracing system with associated accessories may be installed. Question arises what the reason for solidification is. So, the solidification of salt can occur due to the melting point limitation. So as molten salt, for example, let us take the example of nitrate salt having a melting point of nearly 350 degrees Celsius.

Hence when the temperature decreases, it starts solidifying. This can cause the choking of pipelines on thermal storage, and it may create further complications. So, this solidification phenomenon is extremely important. The central tower system allows the storage of thermal energy, which enhances its use to supply electricity in various power grids, distribution networks, etc., when and when required at night or in cloudy weather.

As the technology runs at a higher temperature, these systems' efficiency is much higher than the parabolic trough system. Advantageously this system sometimes requires flat land hence can be used in some sort of hilly reasons because a lot of opportunities and menus are available in those hilly regions.

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On the contrary, each mirror needs an individual dual access control while the PTC system can share it to a large mirror array. This increases the operational problem related to the calibration and adjustment of mirrors on a large spectrum or a large scale.

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There are some existing solar tower plants, and this includes a 2.75 megawatt of solar tower power plant ACME has installed in Bikaner Rajasthan. The turbine pressure and the temperature are 60 bar at 440 degrees Celsius. The world's largest heliostat with an area of 150 square meters has been installed at Gurgaon to set up one megawatt or thermal power and is sometimes referred to as 1M WTH CSP central tower plant facility in India.

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This power plant's main objective is to develop the optimized design of the heliostate field volumetric air receiver and thermal storage and three major components of concentrated solar power that is CSP the center is receiver plant. Another objective is to develop or development of local sources for all the key components of the plant with a focus on lowering costs which will make the technology competitive with other forms of energy.

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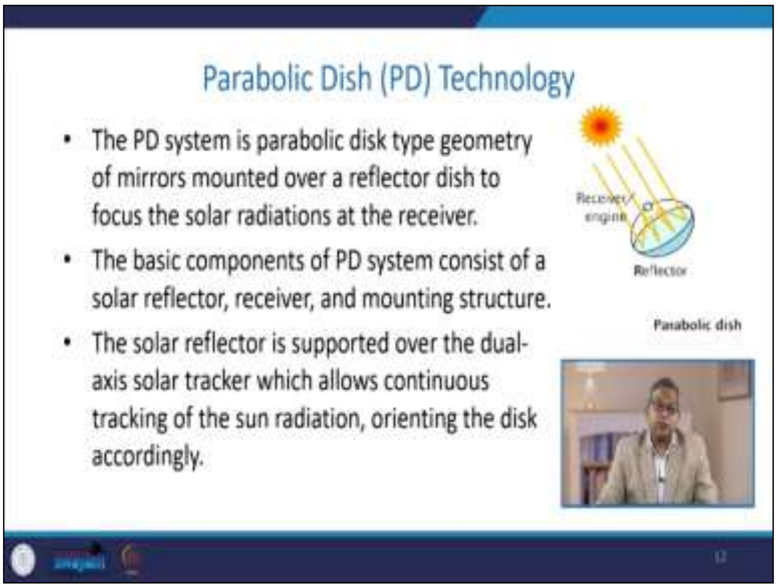

Another thing is that we would like to discuss the parabolic dish or PD technology. The parabolic dish system is parabolic disk-type geometry of mirrors mounted over a reflector dish to focus the solar radiation at the receiver. Here you see that the receiver engine and all these things are addressed to the receiver engine. The basic component of the parabolic dish system consists of a solar reflector and a receiver and mounting structure.

This solar reflector is supported over the dual-axis solar tracking system, which allows the continuous tracking of the sun radiation orienting the disc accordingly. The focused sun rays from the reflector are then concentrated towards the central receiver fixed at the focus of the parabolic dish. So focusing is important. This receiver is attached with a heat engine containing thin tubes filled with various gases.

These gases can be helium, hydrogen, nitrogen, or air, depending on the, or it is based on according to the engine properties.

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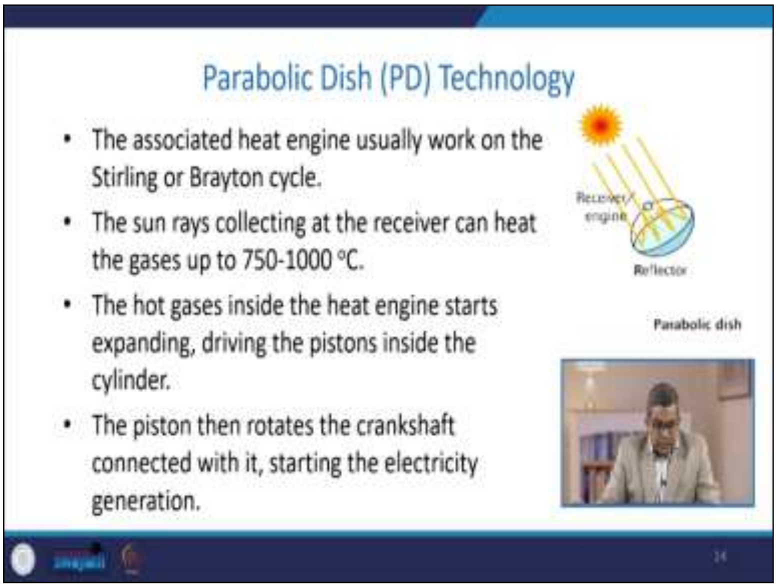

The associated heat engine it usually works on Sterling or Brighton cycle. The sun rays collecting at the receiver here you can see these can heat the gas up to 750 to 1000 degrees Celsius. The hot gases inside the heat engine have the tendency to expand, driving the piston inside the cylinder. The piston then rotates the crankshaft connecting with it and starting the generation of electricity.

So, it is a very simple and very common phenomenon. This process has a similar type of principle to what we are observing in the internal combustion engine. As the combustion process occurs outside the piston-cylinder geometry, the parabolic dish system can also be referred to as an external combustion engine.

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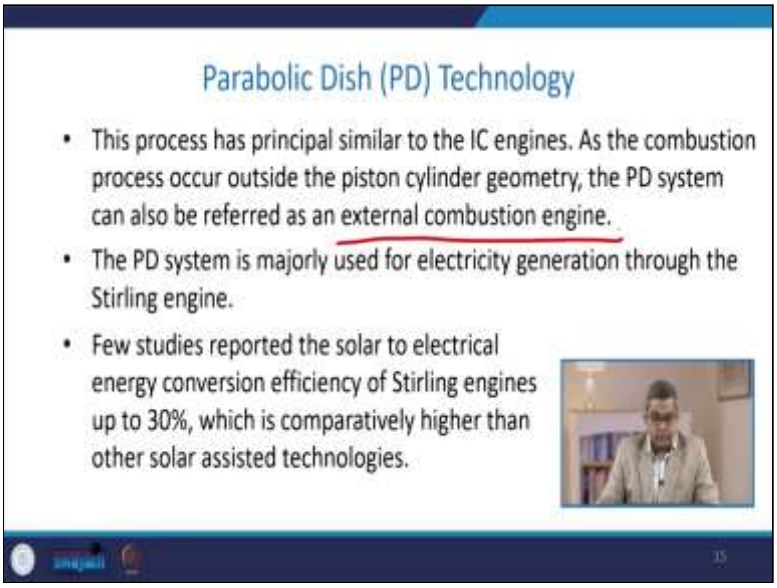

The parabolic dish system is measuredly used for electricity generation through the sterling engine. People have carried out various studies in this particular approach. A few studies reported that the solar to electrical energy conversion efficiency of sterling engines can go up to 30%, which is, you can say, comparatively higher than other solar-assisted technologies.

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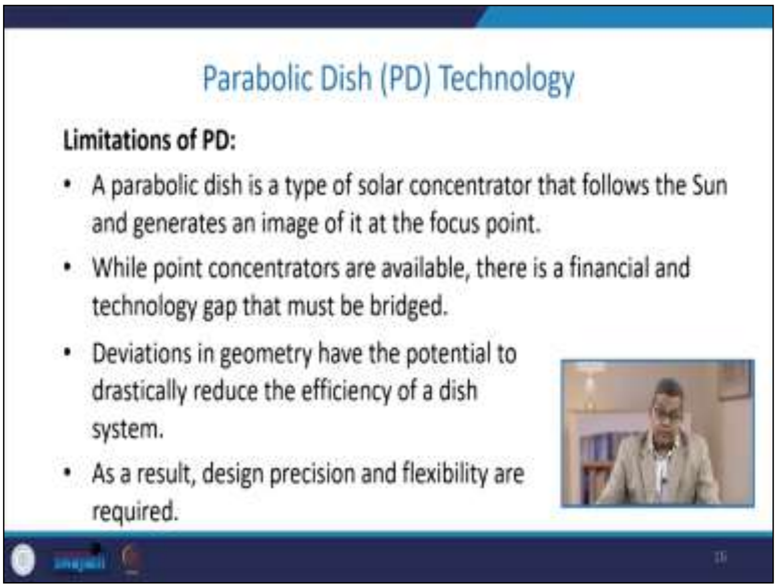

But once this parabolic dish offers various advantages, there are so many limitations of parabolic dish that are also attributed to the system. a parabolic dish is a type of solar concentrator that follows the sun and generates an image of it at the focal point. While point concentrators are available, a financial and technological gap must be bridged. This may be attributed to the deviation in geometry, and the deviation in geometry have the potential to drastically reduce the efficiency of this system.

So, in view of this the design precision and flexibility or utmost precision is extremely important and it is required there are existing PD systems in India.

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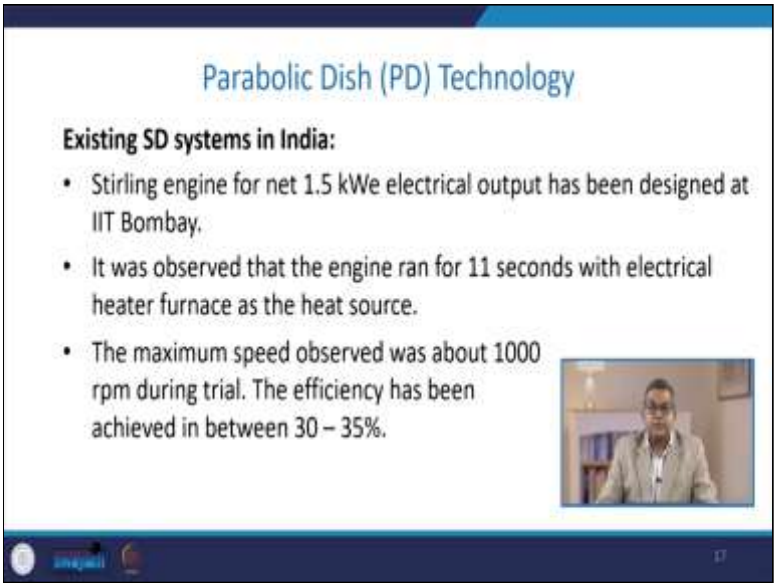

External engine for net 1.5-kilowatt electricity output has been designed at the Indian Institute of Technology, Bombay. It was observed that the engine ran for 11 seconds with an electrical heater furnace as the heat source. The maximum speed observed was about 1000 rpm during the trial run and have achieved an efficiency between 30 to 35%.

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Another solar studying engine has been developed by ONGC in collaboration with Infinia Company, USA, and installed at nice and I see for the performance evaluation test under the Indian climatic condition. This system has 2x axis tracking, and that is, it tracks the sun according to the time of the day and also according to the time of the year. As a result it always faces toward the sun and concentrates all the direct solar radiation falling on that particular aperture.

The sterling engine at the receiver point of the dish concentrator is a helium gas engine with the free piston.

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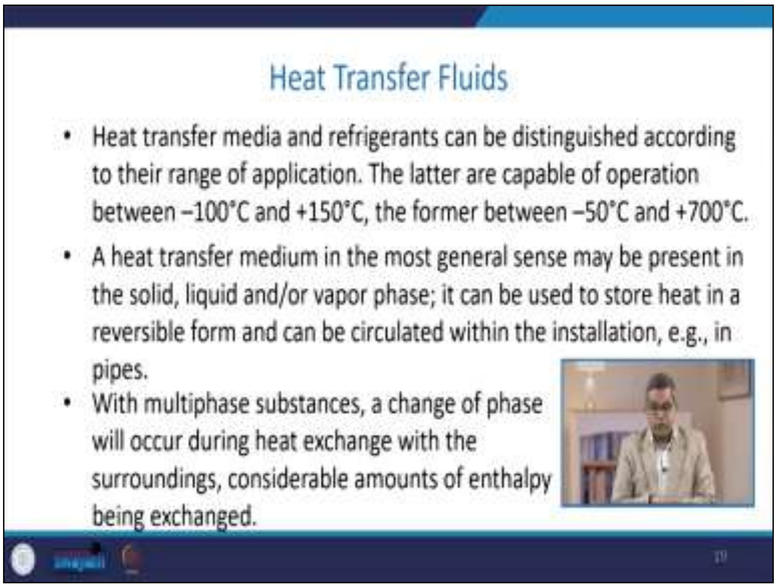

We have discussed a lot about solar energy and you see that whenever we are talking about solar energy, the integral component of this solar energy is the heat transfer fluid. As we previously discussed, heat transfer fluid offers a very good spectrum in all chemical engineering applications and especially when we look for heat transfer media, all these heat transfer fluids came into existence.

One of the widely applicable heat transfer media or fluids is water apart from the air. Water offers a wide spectrum with respect to abundance with respect to the ease in use with respect to the, neutrality etc but it has several limitations that you cannot go beyond a certain level. So, we have to look for the various other heat transfer media or a flute, considering the variety in the chemical engineering approach.

And simultaneously, the refrigerant also plays a vital role and is also clubbed with the heat transfer media. So, these can be distinguished because we have n number of processes simultaneously we have n number of heat transfer media. when we say that we have n number of heat transfer media, we need to have some distinguishment.

So, one distinguishment can be based on their range of applications. Say these heat transfer media or the refrigerant are capable of operating from saying minus 100 degrees Celsius to say up to 250 degrees Celsius and sometimes minus 50 degrees Celsius to say up to 700 degrees Celsius. heat transfer media or a medium in the most general sense may be present in the solid, maybe in the liquid in or in the form of a vapour phase like we used the gaseous heat transfer media in the parabolic dish type a system.

So, it can be used to store the heat in a reversible form it can be circulated within this installation, sometimes pipes sometimes some other storage media like this. So the phenomenon is quite simple it absorbs heat, discharges heat, and again go back to its previous condition. When we talk about multi-phase substances, a phase change will occur during the heat exchange with the surroundings and a considerable amount of enthalpy is exchanged.

So, when we studied the different types of CSP technologies. So, it can be observed that the most common and influential component in these systems are heat transfer fluid, as evident when discussed. So, many processes and you can sometimes see the liquid sometimes the gases form are being used. So, these heat transfer fluid circulates throughout the tube to transfer the thermal energy and therefore is required to in the much higher amount.

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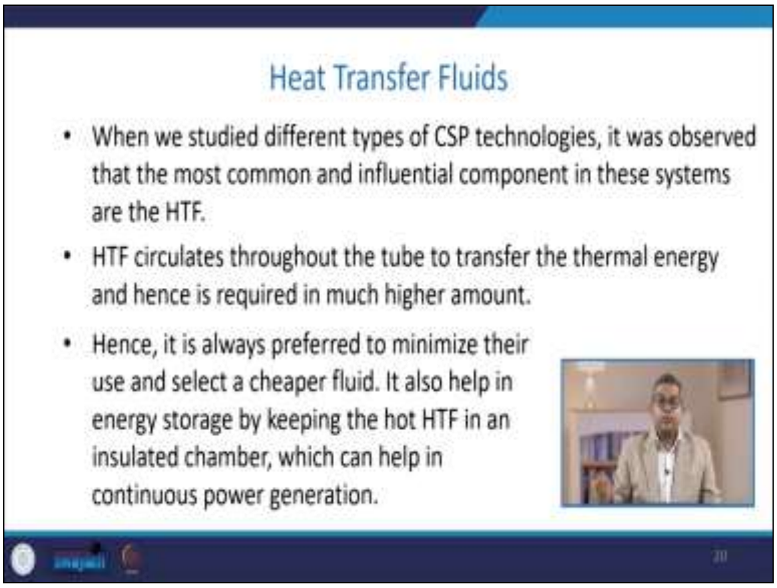

So, it is always preferred to minimize their uses and select the cheaper flute we are we may have a debatable thing on this cheaper fluid sometimes the cheaper fluid may have a corrosive effect. While adopting this economic approach, one must look at different parameters, which kind of a fluid would be used? It should be non-corrosive, and nonreactive, which can recirculate easily and discharge the heat to the port quickly as possible.

So, all these things must be addressed. So, it also helps these heat transfer fluids it helps in energy storage by keeping the hot heat transfer fluid in an insulated chamber which can help in the continuous power generation. There is a broad spectrum of selection criteria. The question arises that we are having a wide galaxy of heat transfer fluid then how we can select the appropriate heat transfer fluid.

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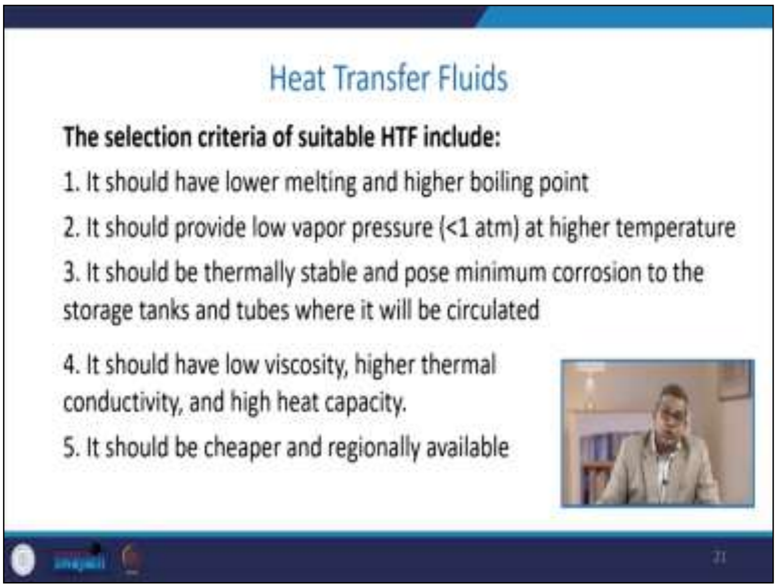

One criterion is that it should have a lower melting and a higher boiling point. It should provide low vapor pressure maybe sometimes less than one atmosphere at a higher temperature it should be thermally stable and pose minimum corrosion to the storage tank and tubes where it is it will be circulated it should have a low viscosity and higher thermal conductivity and higher heat capacity.

It is the foremost requirement for higher thermal conductivity and a high level of heat capacity, and it should be cheaper and regionally available. So, when you are using it must not pose any kind of availability issues. These heat transfer fluids broadly can be classified into six different categories as we discussed that air and water are most abundantly available in the heat transfer fluid.

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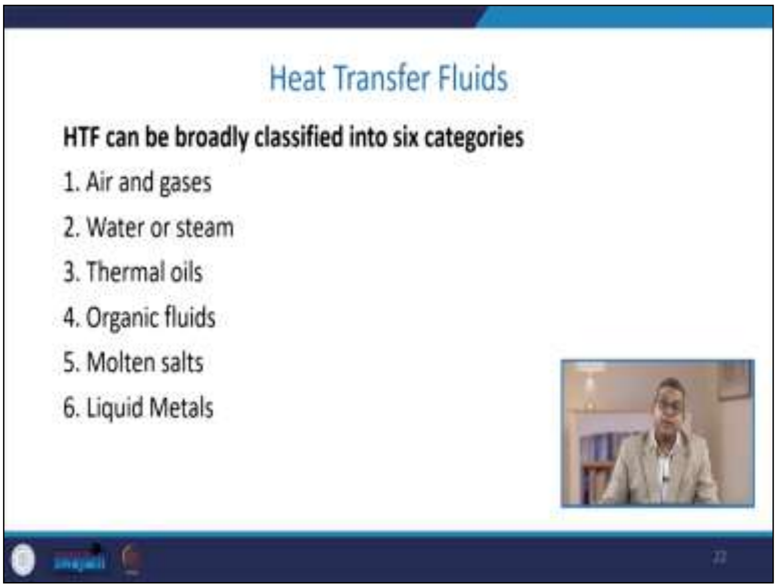

So, one category is air and gas. Second, maybe the water or steam then we have various thermal oils sometimes, the synthetic organic fluids or various organic fluids can be ac as a heat transfer fluid. Molten salts are a very good candidate of heat transfer fluid liquid metals are having wide range of heat transfer temperature differences. The molten salts are industrially wildly accepted as a heat high-temperature heat transfer fluid.

Providing high heat capacities is highly thermal conductive in nature and possesses low vapor pressure and less corrosive properties.

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Another important heat transfer fluid is the liquid metals capable of providing similar operational characteristics, which we discussed for the molten salts. Other competitive and cheaper alternatives include some organic and thermal oils and organic, sometimes synthetic organic segments. In the CSP section, we have already discussed various things related to these heat transfer fluids. Usually, the higher efficiency is obtained at higher temperature operation.

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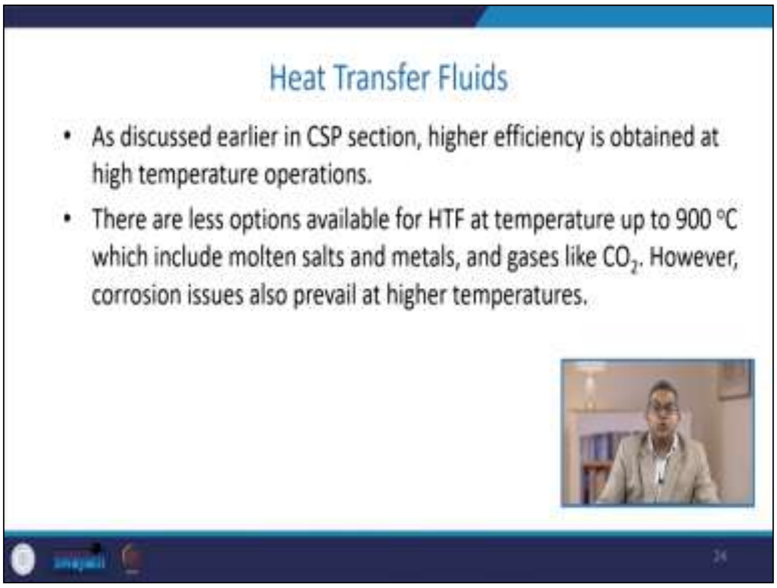

You can say the less options available for heat transfer fluid at a temperature up to 900 degree Celsius, which includes molten salt metal gases sometimes like carbon dioxide, etc. But when we go for a higher temperature the issue pertaining to the corrosion it also prevails. So, all these things while designing, selecting, and developing any kind of system must be addressed.

So, let us discuss one by one, that is air and other gases are the first category. Air is not you can say, widely commercially acceptable but highly studied heat transfer fluid because it is available in abundance. It is available virtually free of cost. This air can be heated up to 700 degree Celsius at atmospheric pressure, further used to produce superheated steam.

As I told you, it can be considered the cheapest because it is available in abundance and sufficiently available heat transfer fluid.

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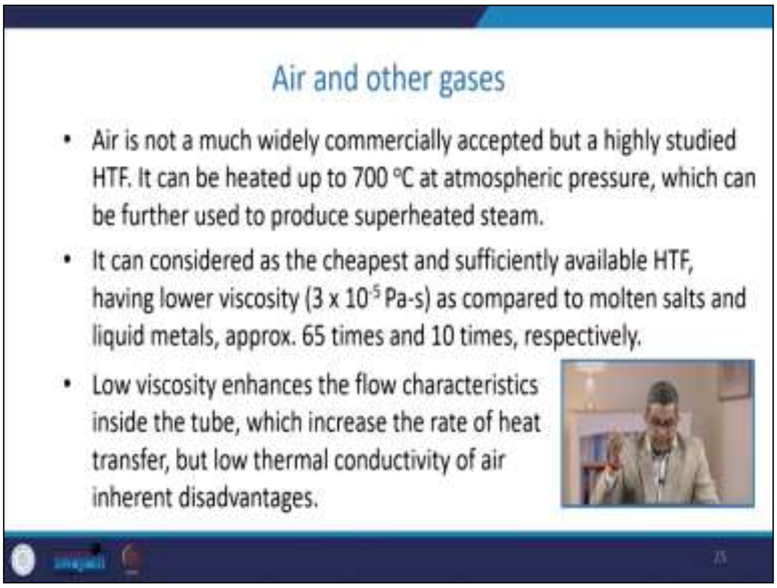

This has a lower viscosity that is 3 into 10 to the power minus 5 Pascal sec compared to the molten salt and liquid metal and approximately 65 and 10 times compared to the molten salt and liquid metal, respectively. This low viscosity enhances the flow characteristics inside the tube, which increases the rate of heat transfer but is economical in one way.

But because of the low thermal conductivity of air, this is an inherent disadvantage. So, the major disadvantage associated with the air is that it possesses very low thermal conductivity. The corrosion characteristic for air also depends on the type of impurities present in the steel using piping. So, sometimes metal like chromium and aluminium can help reduce corrosion by forming a protective oxide layer over the steel surface.

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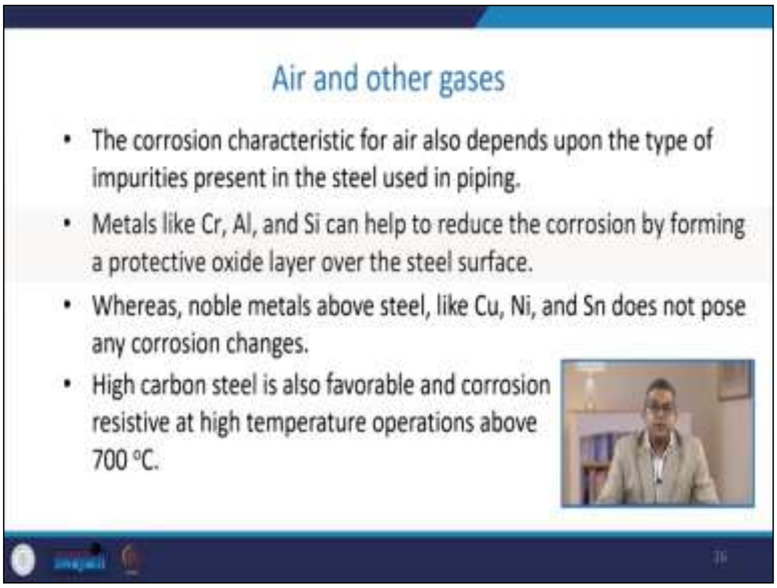

Certain noble metals above steel, like copper and nickel, do not pose any corrosion changes. High carbon steel is also favorable and corrosion resistive at temperature operations of nearly at 700 degrees Celsius. Apart from air, helium and supercritical carbon dioxide have also been studied as heat transfer fluid. Helium is already in use for high-temperature nuclear reactors, and it can be affordably obtained from natural gas processing.

Helium can also be used in high-temperature CSP just like air, but it poses a very low heat capacity and thermal conductivity. There are several limitations that need to be addressed to overcome these limitations. One can or an entire operation can be operated at high velocity and high pressure. On the other hand, Supercritical carbon dioxide can achieve better efficiency at lower temperature CSP compared to steam and helium.

So, as it requires a high-pressure operation uses is limited to CSP like power towers. Supercritical carbon dioxide or CO 2 as a heat transfer fluid is a topic of high research interest nowadays people are working on over it. Several research works are also going on in this field and it can be considered as a future heat transfer fluid at least for the power towers based on CSP.

In this particular lecture, we had discussed about the different heat transfer fluids. We had a discussion about the classification of these heat transfer fluids. Briefly about that, what are the desirables of these heat transfer fluids what should be the selection criteria of these heat transfer media? if you wish to have a further study we have enlisted four different references, you can have a look of all those references if needed, thank you very much.