Chemical Process Utilities
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Lecture – 2
Energy Perspective to the Utilities

Welcome to the concept of energy perspective of process utilities. So, before we go into the detail of this energy perspective, let us look at a brief that we discussed in the previous lecture.

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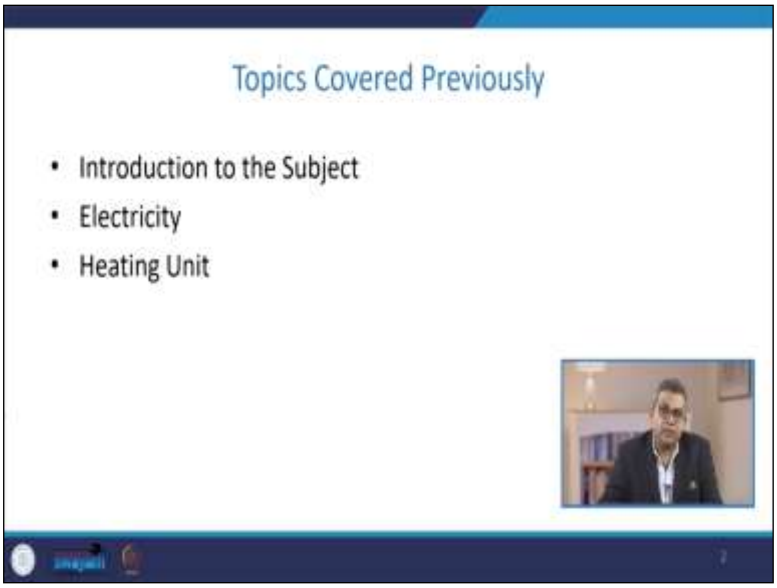

We had a brief introduction about the subject in which we emphasized that what is the concept of chemical process utility why it is so important. Then we discussed the electricity approach or electricity utility requirement with small examples, and then we studied the concept of heating units in which we analyzed how we can give major importance to a load of any heating unit.

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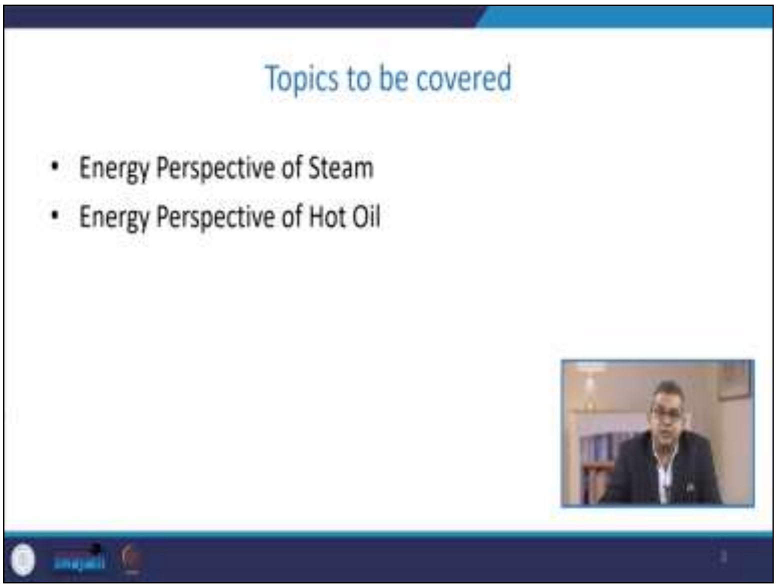

Now in this particular chapter, we are going to discuss the energy perspective of steam. Remember, this is an introductory aspect and energy perspective of hot oil.

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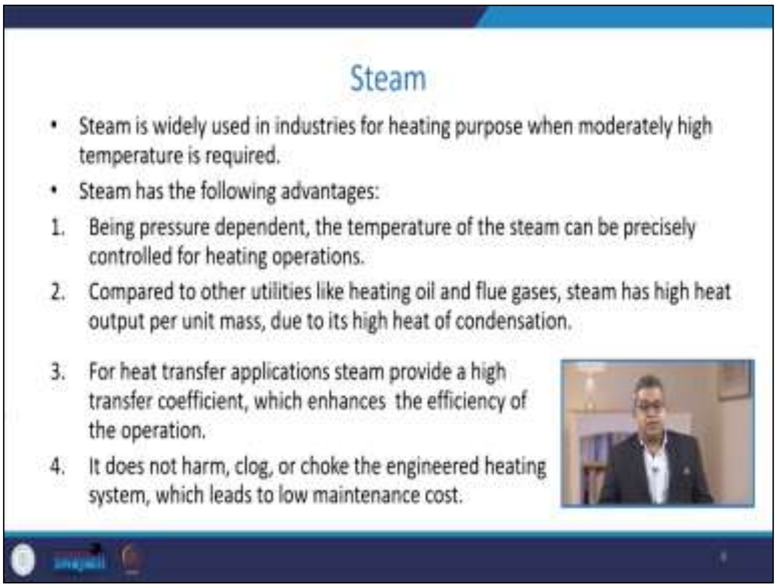

As we understand, steam is widely used in various industries for heating purposes when moderately high temperature is required. Now when we talk about the moderately high temperature again, it is attributed, and there are so many parameters associated with this particular high temperature moderately high-temperature concept. It also depends on the pressure aspect. It also depends on the various other allied units like steam traps, condensers etc., and the steam distribution network.

Because sometimes, the pressure may get dropped during the course of steam transportation or steam distribution. So, the question arises: What are the advantages associated with steam. See steam has plus points, as well as there are certain negative points, and above all, there are certain limitations associated with this steam. So, let us take some of the advantages of steam because we are discussing this team.

Now being the pressure-dependent, the temperature of this team can be precisely controlled for heating operation your regular thermodynamics law always prevails in this condition. So, sometimes this is a beneficial condition, and sometimes it is a disadvantageous condition. We will discuss this aspect during the study of steam in detail. Then compared to other utilities like heating oil, few gases steam has a high heat output per unit mass because of the latent heat aspect of water.

Now, this is due to its high heat of condensation. Another thing is that the other advantage is that steam provides a high transfer coefficient for heat transfer application, which enhances the efficiency of the operation. So, again this is the pure heat transfer phenomenon. Above all, it does not harm, clog, or choke the engineered heating system, leading to low maintenance costs.

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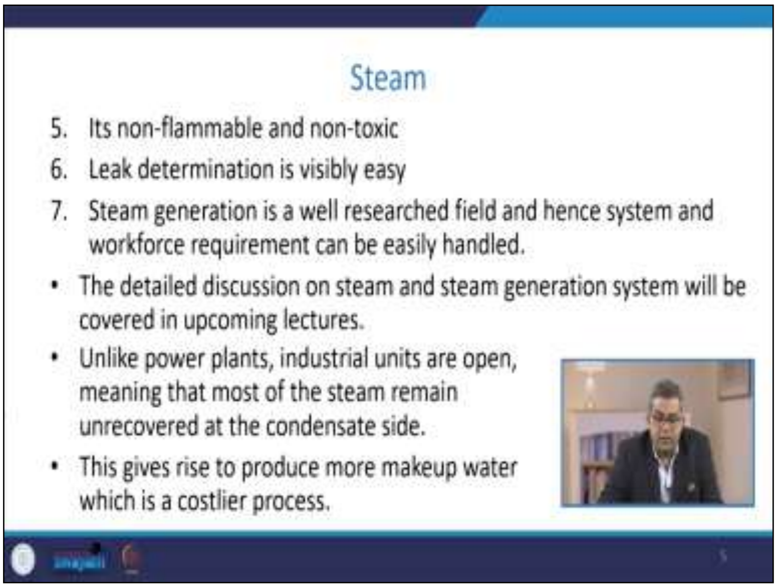

Other advantages include its non-flammable non-toxic because your basic raw material for generating steam is water, which is invariably a non-toxic substance. Now you can easily determine or visualize if any system leaks because the vapors may come out from that particular segment. So, you can easily determine where it is leaking, where is the problem which function is malfunctioning.

Steam generation is a well-researched field, and system and workforce requirements can be easily handled. We always talk about the steam table etc., during our initial days. So, it is a very research everybody knows what is an integral part of steam how we can control what is the latent heat what is the pressure and temperature etc.

So, steam is well researched and well studied. As I told you, we will have a detailed discussion of steam generation, steam control, steam distribution, condensation, steam traps, safety devices etc., in the upcoming lectures. Unlike power plants, industrial units are open, meaning that most of the steam remains unrecovered and the condensate sides.

This gives rise to producing more makeup water which is again a costlier process. Now, this particular segment means a lot. See, before we go into detail, what are the integral parts you require for the steam generation you require some source of heat for the steam generation you require a decade supply of water, but you cannot use water as such because sometimes water may have some hardness sometimes may have certain ions sometimes may have different type of impurities debris etc.

So, before using this water as a steam-producing steam producer or in a boiler segment, you need to purify it. Purification or conditioning maybe with the help of deionization, demineralization screening etc. So, it costs because all these unit operations are costly affairs. So, once you utilize the steam being generated from the boiler to a particular point, the steam may get condensed to give the water when the steam is over.

Now again, two main losses may be attributed. One is the loss of energy during the condensation with respect to the latent heat, and the second is the loss of water. Remember, while generating the steam, you have contributed a lot of capital expenditure with respect to the water conditioning. So, this condensed water again can be utilized in the same steam cycle.

So, you need to give proper attention to all these aspects. Otherwise, you may require consuming or producing more makeup water, which will be a costlier affair, contributing to your product cost. So while considering because see in chemical engineering, we have a wide spectrum of industries.

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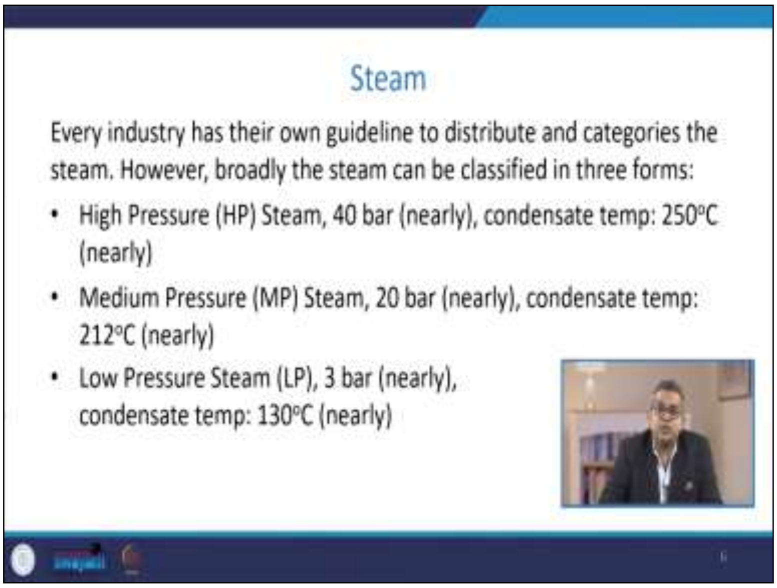

So, every industry has its own guidelines to categorize steam. Now broadly, we can classify it into three different forms. One is the high-pressure steam which is nearly 40 bar condensate temperature, usually 250 degrees Celsius. Then medium pressure steam is 20 bar, the condensate temperature is nearly 212 degrees Celsius, the low-pressure steam is 3 bar, and the condensate temperature is 130 degrees Celsius nearly.

Again, we can classify steam in different microscopic levels, but these are the broadly broad classification. Based on this classification, you can design your own steam generation system that shows how much requirement is there on the site. You may design your own distribution network even if you can adopt a centralized boiler system to produce steam or discrete type of water steam generation system at place of work.

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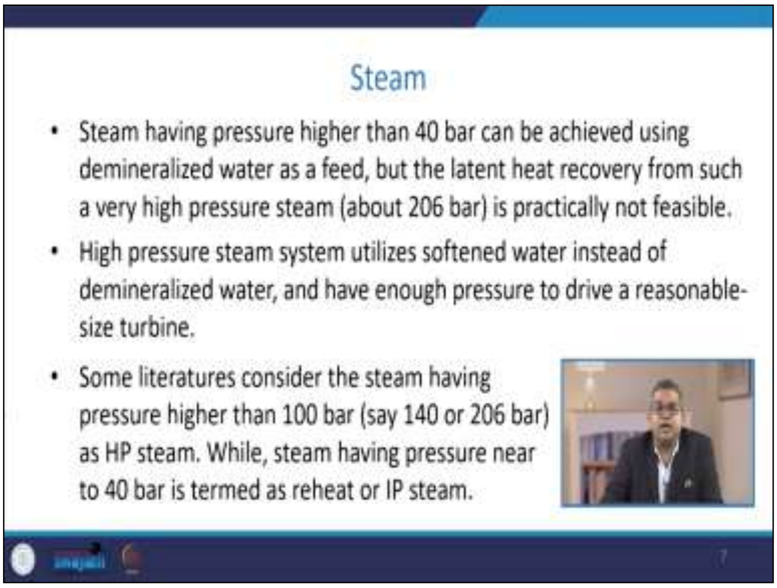

Now again, come back to the classification that steam having a pressure higher than 40 bar can be achieved using the demineralized water as a feed, but the latent heat recovery from such a type of system is very high-pressure steam is practically not feasible. So, while designing the distribution network or usable network, you have to look into this particular aspect that every time you say the heat recovery is a very catchy term.

But you have to look at the engineering aspect of whether it is economical or not. High-pressure steam systems now utilize soft water instead of demilized water and have enough pressure to drive a reasonable turbine. Now some literature may consider steam having a pressure higher than 100 bar, say 140 to 206 bar, as high-pressure steam, while steam having a pressure near 40 bar is termed as reheat or IP steam etc.

So, I told you that there is a broad classification scheme for steam types.

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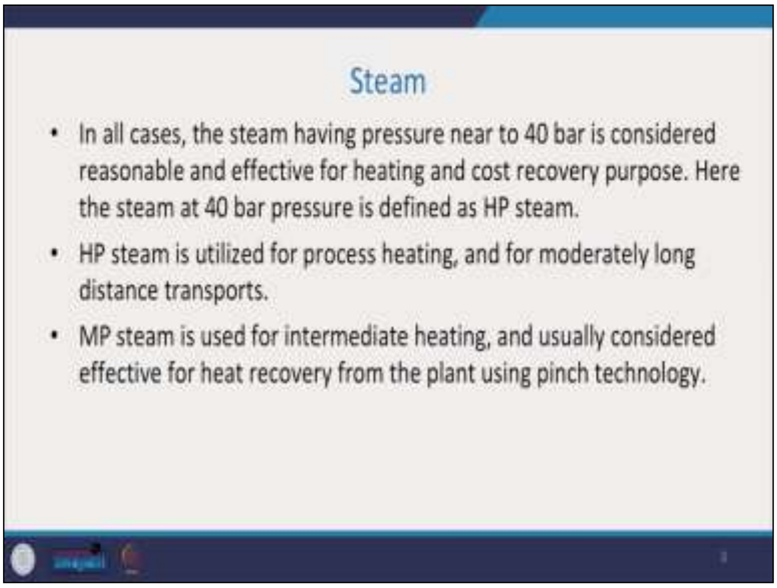

So, in all cases, the steam having pressure near, say, 40 bar is considered reasonable and effective for heating and a cost recovery purpose. Now here, the steam at, say, 40 bar pressure is defined as high-pressure steam. This high-pressure steam is utilized for process heating and for moderately long-distance transportation. Remember when we talk about the long-distance transportation system, you have to look at the pressure drop this may incur because of the condensation for a variety of reasons.

Medium pressure steam is used for intermediate heating and is usually considered effective for heat recovery from the plant using pinch technology. We will discuss this aspect later on.

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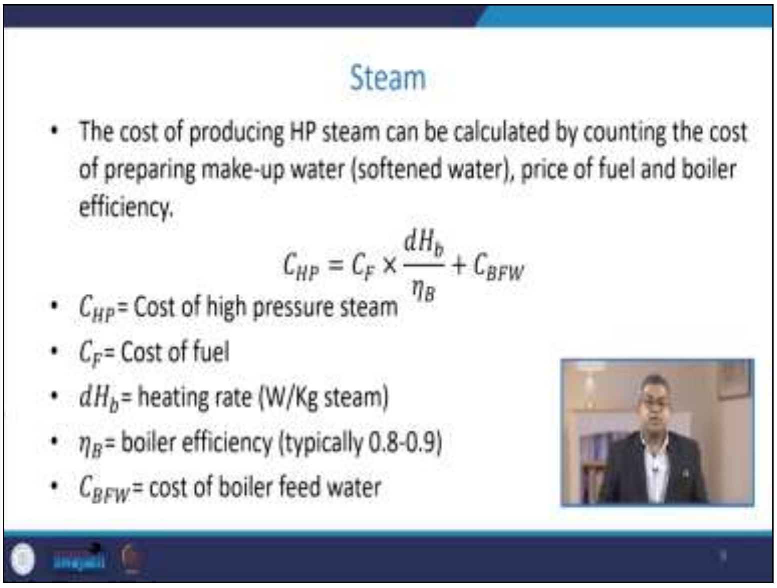

The cost of producing high-pressure steam can be calculated by counting the cost of up water, water softening, price of fuel, and boiler efficiency. The rule of thumb is that you cannot make a system 100% efficient. So, this is this simply simple mathematical formula it gives you an idea of what should be the cost of high-pressure steam. So, the cost of high pressure is steam; this is equal to the cost of fuel heating rate than the boiler efficiency.

$$C_{HP} = C_F \times \frac{dH_b}{\eta_B} + C_{BFW}$$

- C_{HP}= cost of high pressure steam
- C_F= cost of fuel
- dH_b= heating rate (W/Kg steam)
- η_B= boiler efficiency (typically 0.8-0.9)
- C_{BFW}= cost of boiler feed water

So, boiler efficiency is again a very very you can say important affair then cost of boiler feed water I told you that boiler feed water again it is a very costly affair to condition the water as per the desired level. Now, if condensate is returned to the boiler feedwater, then the cost of steam should be claimed for the condensate. Now let us take that say, for 100 recoveries, the cost of boiling feed water can be compensated with the credit from the condensate hence can be neglected during the further calculation.

So, the cost of medium pressure and low-pressure steam can be calculated by discounting the earnings from the shaft work produced by the steam work.

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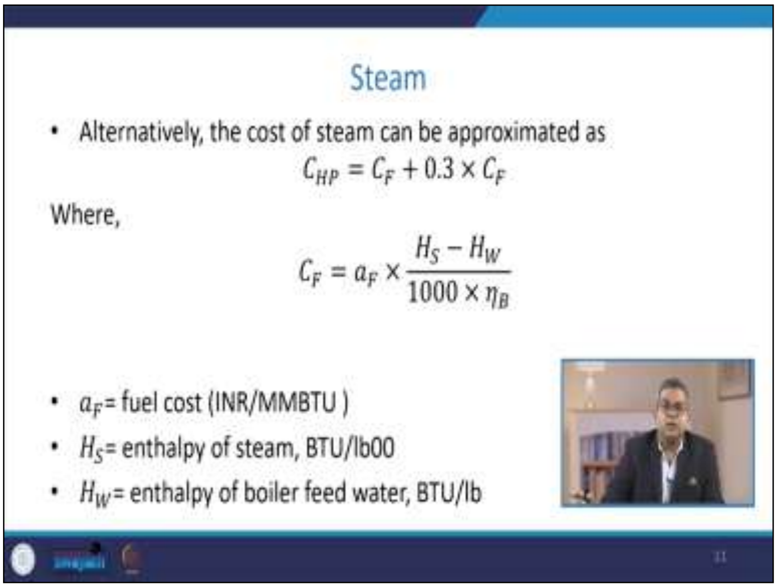

Now alternatively the cost of steam can be approximated as

$$C_{HP} = C_F + 0.3 \times C_F$$

Where,

$$C_F = a_F \times \frac{H_S - H_W}{1000 \times \eta_B}$$

- a_F= fuel cost (INR/MMBTU)
- H_S= enthalpy of steam, BTU/lb00
- H_W= enthalpy of boiler feed water, BTU/lb

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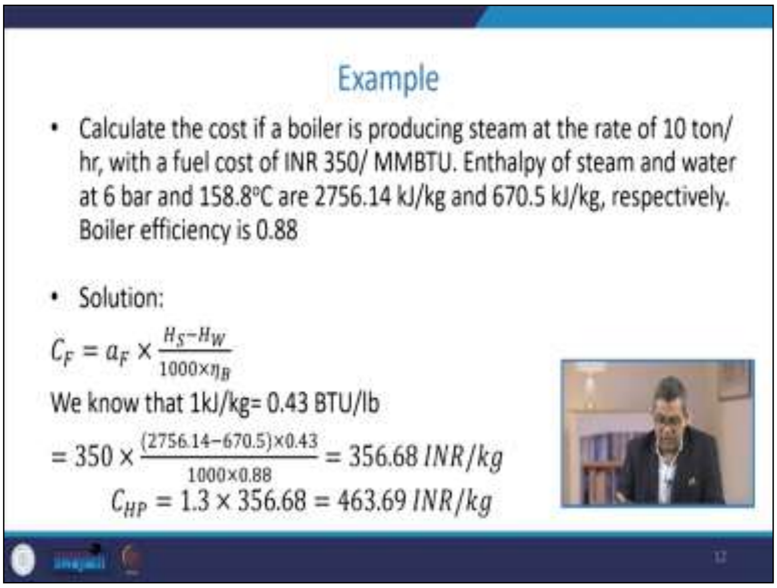

Now see, we have given a couple of mathematical relations. So, let us take an example. Now you need to calculate the cost if a boiler is producing steam at the rate of 10 tons per hour with the fuel cost of say 130 rupees per MMBTU enthalpy of steam and water at 6 bar and 158.8 degree Celsius there it is 2756.14 joules per kilogram and 678.5-kilo joule per kilogram respectively, and you may take the boiler efficiency as 0.8.

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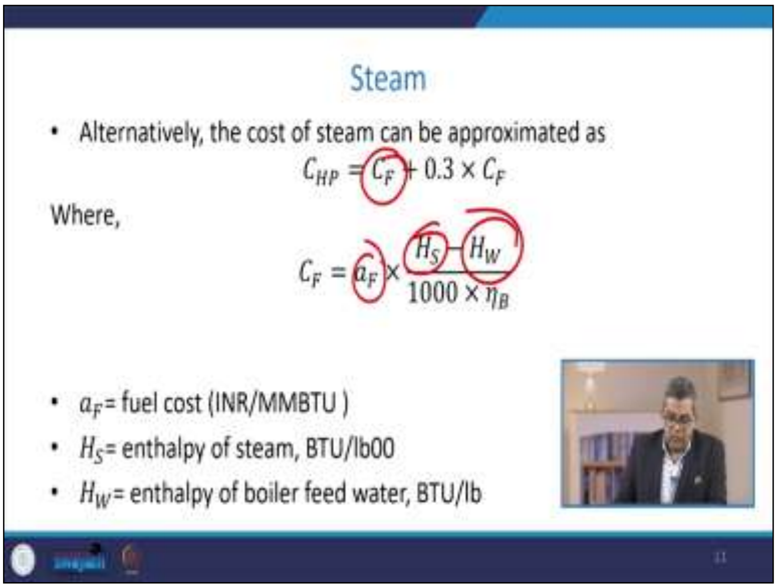

So, go back to this particular formula C F is equal to a f into H s minus H w upon 1000 into the boiler efficiency. Now we know that one kilo joule per kilogram is equal to 0.43 BTU per pound.

$C_F = a_F \times \frac{H_S - H_W}{1000 \times \eta_B}$

We know that 1kJ/kg= 0.43 BTU/lb

$$= 350 \times \frac{(2756.14 - 670.5) \times 0.43}{1000 \times 0.88} = 356.68\ INR/kg$$

$$C_{HP} = 1.3 \times 356.68 = 463.69\ INR/kg$$

We can calculate the annual cost by considering the generation of 8000 hours per year.

Total steam generated = 8000 (h/yr) X 10 ton /h = 80,000 ton/yr =

80,000 X 907.18 kg/yr

Total cost per year = 80,000 X 907.18 X 463.69 = 3.36 X 10^{10} INR/yr

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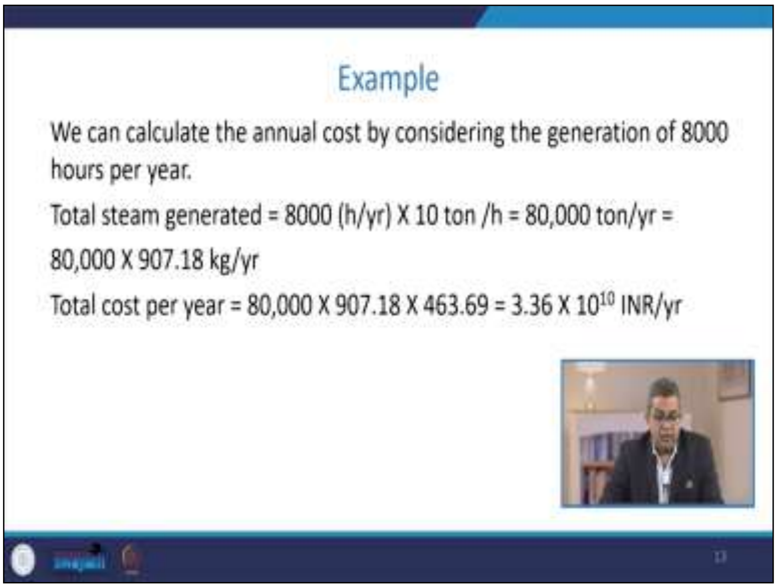

So, we can calculate the annual cost by considering the generation of 8000 hours per year. Now roughly this is the rough estimate of eight thousand i had that boiler works and usually thousand hours per year. So, the total steam generated is eight thousand hours per year multiplied by 10, 10 usually require is 8000 tons per year and if we multiplied by 907.18 kilogram per year.

So, the total cost of per year would be 80000 907.18 into 463.69 it comes out to be 3.36 into 10 to the power 10 rupees per year.

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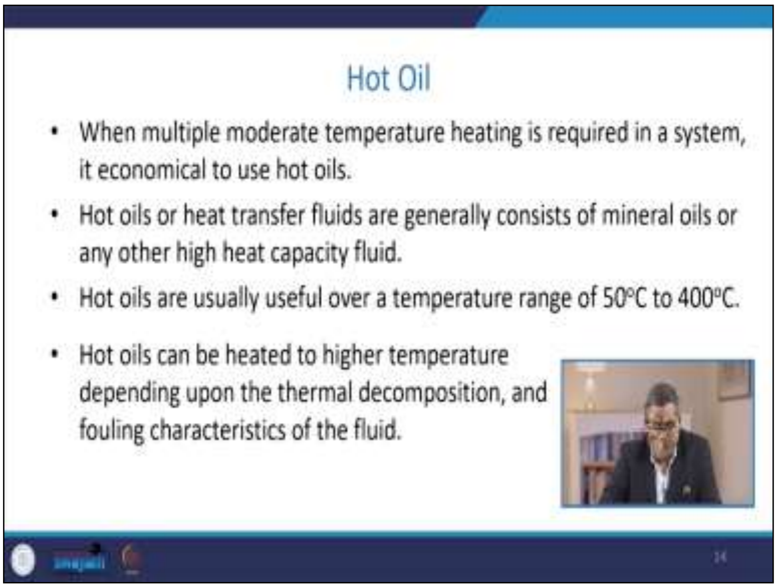

Now let us take another example of hot oil. Hot oil is a very good heat transfer media. So, when multiple moderate temperature heating is required in a particular system, it is economical to have hot oil in the process. As I told you, heat transfer fluid generally consists of mineral oil or any other high capacity high heat capacity fluid.

So, nowadays we are having a very because of technological advancement, we have a very big basket of this hot oil. So, we have ample choices. In the subsequent lectures, we will discuss the prerequisite for any mineral oil to be used as a heat transfer media or heat transfer fluid is. So, hot oils are usually work within the temperature range of 50-degree Celsius to 400-degree Celsius.

You may ask why we are not using steam because the steam is water is available in abundance. See, if we go beyond 250 degrees Celsius with the steam system, then it creates a lot of problems and a lot of working or capital we need for this type of steam generation, and that is why hot aisle offers a very good economical choice. Now, these hot oils can be heated to a higher temperature depending upon the thermal decomposition and following characteristics of a fluid.

So, these oils have their limitations concerning the composition with respect to their formula, molecular weight, etc. Sometimes they may get decomposed to give some low heat products and it may be a very dangerous affair if we are not using the suitable heat transfer media.

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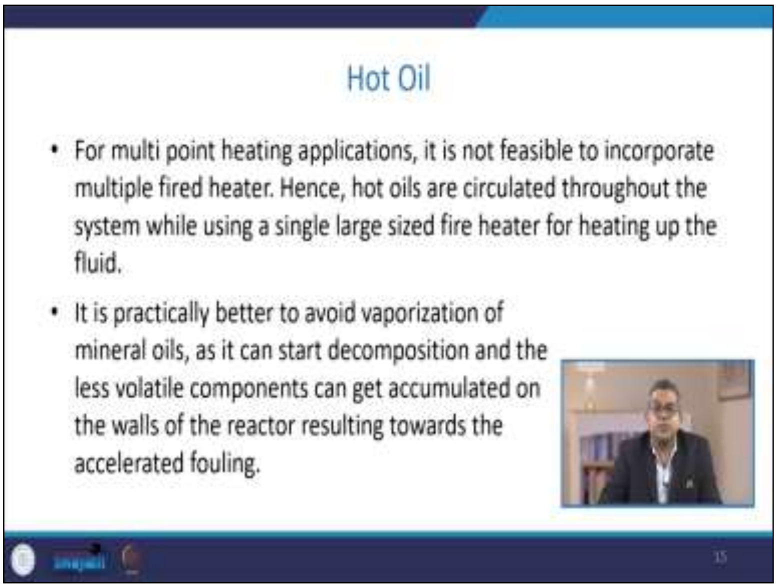

For multipoint heating applications, it is not feasible to incorporate the multiple-fired heater; it is sometimes uneconomical. Therefore, these hot aisles are circulated throughout the system while using the single large sized fire heater to heat the fluid, keeping in view all the limitations of these hotels. Now it is practically better to avoid the vaporization of mineral oil.

So, there are certain limiting factors with respect to that temperature and pressure. So, if we are violating those conditions, it can start decomposition and less volatile component as I discussed they can accumulate on the walls of a reactor resulting the accelerated falling and sometimes it may create a problem or sometimes it can pose a safety hazard.

These hot oils can be heated to a higher temperature at a low-pressure limit. Now, this feature leads to the selection of tubes with a lower thickness, which reduces the cost of the instrument and reduces the cost of operation or working cost.

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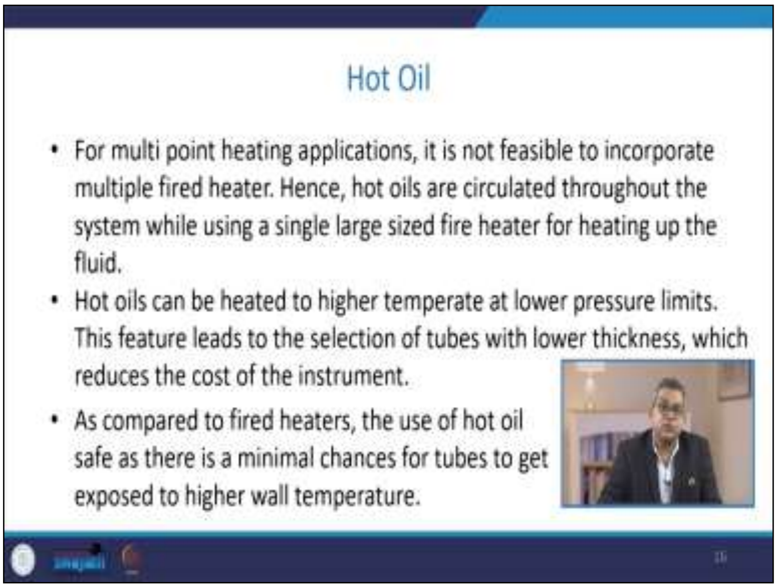

Compared to the fired heater, the use of hot oil says they are relatively safe as there is a minimal chance for the tube to get exposed to high wall temperature. So, these are some of the advantages associated with this one.

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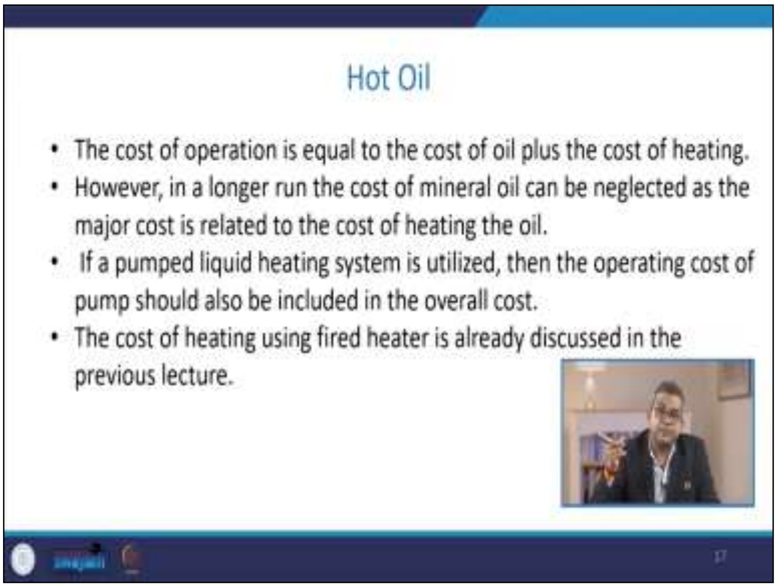

Apart from this, the cost of operation is usually equal to the cost of oil plus the cost of heating. So, in this way, sometimes, if you do not have any kind of a chance of a leakage or any other thing, you can minimize the cost. In the long run, the cost of mineral oil can be neglected as the major cost is related to heating the oil. But simultaneously, you cannot overlook the fact that this mineral oil is being repeatedly used, and sometimes if any kind of unsaturation is there, it may get polymerized.

So, it would be best if you found out how many cyclic operations you can carry out with some simple single set of mineral oil. Now, if a pumped liquid heating system is utilized, then the operating cost of the pump should also be included in the overall cost. So, ultimately it contributes to the cost of utility. So, the cost of heating using a fired heater is discussed in the previous lecture.

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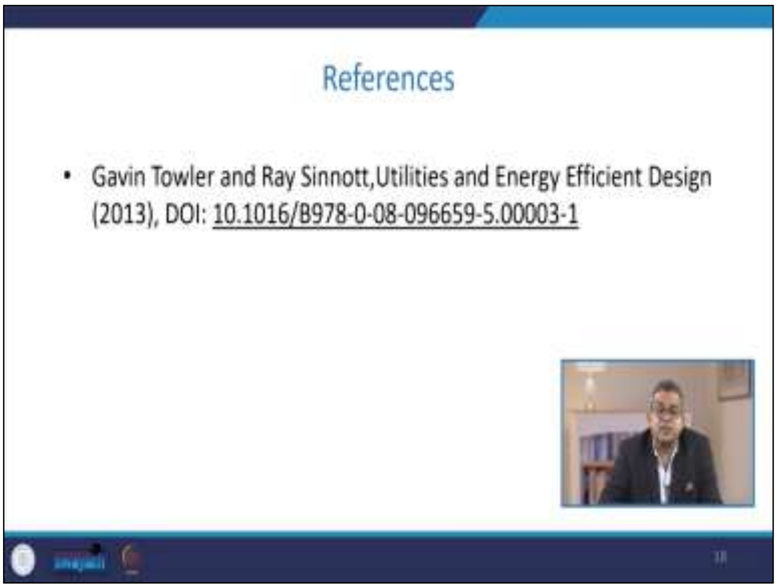

So, by this we are coming to the end of this particular lecture, and again, if you are looking for some more detailed knowledge about this particular segment, you can have a lookup this reference, thank you very much.