Energy Conservation and Waste Heat Recovery
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Lecture – 02
Introduction to waste heat recovery (Contd.)

Hello, this is the second lecture on the web course on energy conservation and waste heat recovery. In the first lecture, I have tried to make it clear that waste heat recovery is a very important concept; a subset of the principles of energy conservation. It has got 2 main benefits. Firstly, it reduces the usage of fossil fuel and secondly, it saves the environment from further degradation, there are some more advantages which we will come to know while we will proceed in this course.

In the current lecture, we will try to understand what exactly is waste heat recovery, comparing it with energy principles or with energy flow without waste heat recovery and then we will see why there is waste heat in the industry what are the different advantages of waste heat recovery, how a waste heat recovery system can be designed; that means, what are the factors we have to keep in mind while designing a waste heat recovery system, etcetera.

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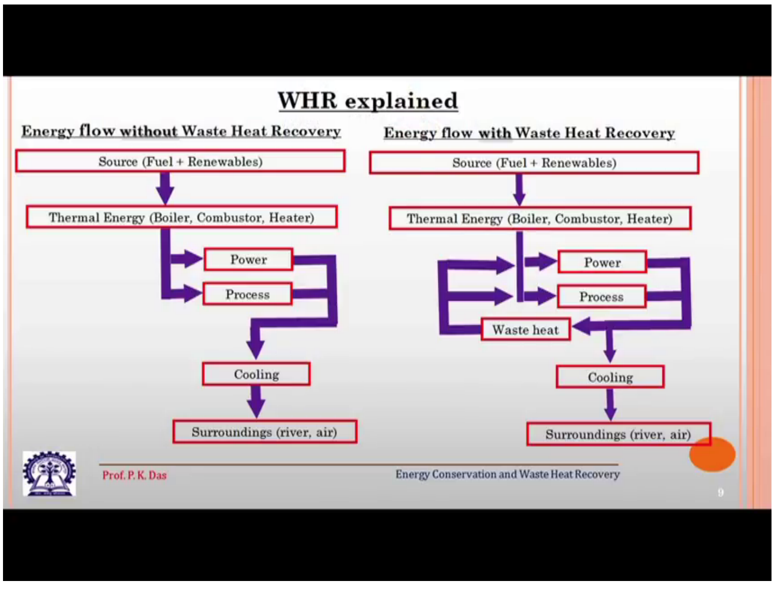

So, let us proceed this slide reads as waste heat recovery explained on the left hand side of this slide we have got energy flow without waste heat recovery. So, how is it we have got some source either it could be some fuel or renewables or in some case, it could be energy from the grid and then from there for producing the energy there could be the thermal route; that means, from the fuel we can have thermal energy for getting the thermal energy the equipment which we use a boiler combustor there could be fluid heating also if we use the fuel.

So, there could be heater from there in general we can get 2 output, one is power and another that thermal energy required from process. So, power and process and then in all these process; that means, from the fuel, we are producing thermal energy and from there we are getting mechanical power or process heating in all these processes, we will have certain amount of heat which can be which can be termed in general as waste heat. So, that waste heat that will be going to cooling or there would be some sort of a cooling option and ultimately it will be dumped to the surroundings which could be which could be some water body or air.

So, this is the normal flow of energy schematically shown where there is no waste heat recovery. Next, let us say, we have adopted waste heat recovery. So, again we will get the energy from the fuel and renewables. So, from there we will have the thermal energy and again, we will have as a output power and heating for the process during all these process waste heat will be generated, but now we have got waste heat recovery system or devices for waste heat recovery. So, in general, again we can return some amount of energy back to power; that means, we can generate some amount of power from waste heat and; obviously, we can also generate some sort of process sitting from the waste heat. So, it goes back to power and process and then ultimately certain amount of energy has to be dumped to the environment through cooling.

But, if you see here whatever energy we have drawn from the source in the second case; that means, where we have got the provision for waste heat recovery we are drawing lesser amount of energy from the source here whatever energy we have dumped to the environment in the second case with our waste heat recovery principle we are dumping lesser amount of heat to the surroundings. So, these shows the difference between a system without waste heat recovery and a system with waste heat recovery and 2 things we can see that here we are drawing lesser amount of energy and we are dumping lesser amount of energy to the surroundings.

So, as I have told, again I will stress upon the same point that we have reduced our cost of energy the depleting source of energy, we are stressing lesser demand on it and then environment we are producing a lesser degradation of energy because we are dumping lesser amount of energy to the environment, but that is not without any kind of penalty or any kind of pain. So, we have to have a waste heat recovery system; obviously, this will need certain amount of certain amount of investment certain changes in our process plan more space. So, all these things could be some sort of consequence of having waste heat recovery principle or waste heat recovery methods.

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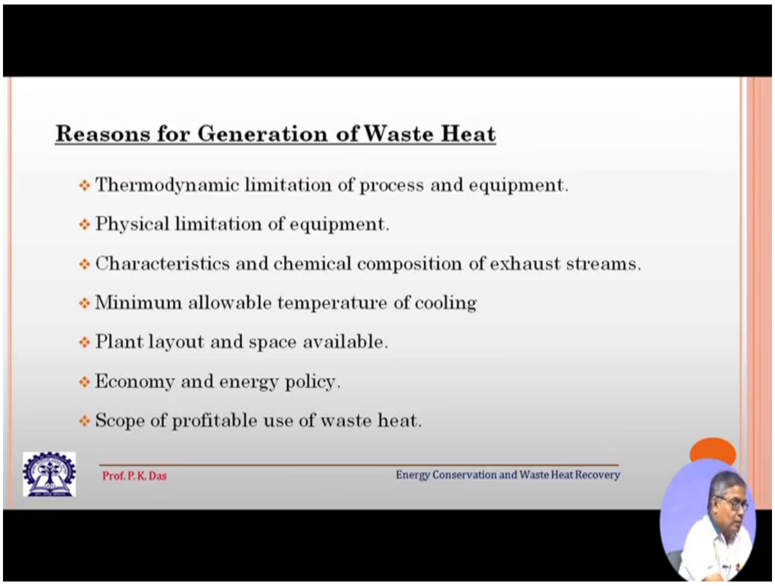

But the gain; what we get by this that is quite commendable because we are saving the energy and also we are saving the environment; now let us come to the generation of reasons for generation of waste heat why in an industry there will be generation of or industrial practice why there will be generation of waste heat the first thing is the thermodynamic limitation of process and equipment now let us let us explain it with the help of a diagram.

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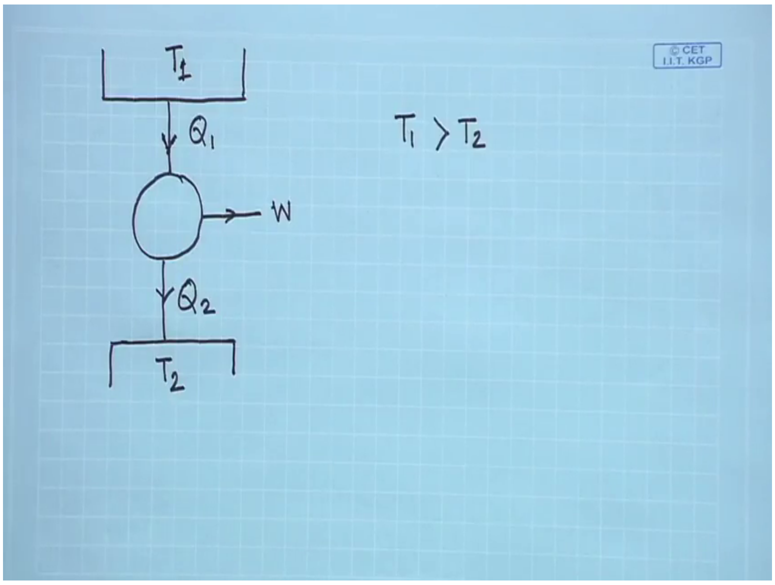

Let us say we are familiar with the with the power cycle which is which is schematically drawn like this; this is called heat engine cycle. So, heat engine cycle thermal energy is getting converted into mechanical work or useful work.

So, what we are doing there is a source we are taking heat from that source; source is at T 1 and we are taking Q 1 amount of heat, then we are producing some work out of it and then dumping or rejecting the rest amount of thermal energy which is Q 2 to another sink which is at a temperature T 2 where T 1 is greater than T 2 so; that means, we are having some device which can be called a heat engine which basically representing a thermal cycle power cycle and in this cycle, we have to take some certain amount of heat from a high temperature source only part of heat, this is very important; only part of heat, we can convert into work and the rest to be dump to the environment.

So, this is according to the law of thermodynamics and there cannot be any violation of heat; how much heat we have to dumped to the environment that is of course, a question and we have already known it from the thermodynamics we will have another chance of recapitulating it after a few lectures, but certain amount of heat we have to dump it to the environment. So, Q 2 is a nonzero positive quantity. So, what I have told that there is thermodynamic limitation of process and equipment.

So, this shows the thermodynamic limitation of the process thermodynamic limitation of a power plant cycle and then there are limitation of equipment also what is the limitation of the equipment that we know that certain thermodynamic process if we can do a single process, if we can do in an equipment, we will have better efficiency of the cycle like say, we want to have a reversible process suppose some gas or vapor is expanding we like to have some sort of reversible process.

So, reversible process demands that there will not be any losses like friction etcetera due to viscosity and there will not be any kind of heat transfer none of these can be guaranteed by any equipment design whatever superior may the design be whatever superior may the design be we cannot guarantee this and then there is then the limitation of the equipment and that limitation is thermodynamic limitation. So, 2 limitation; we are getting one is thermodynamic limitation of the power cycle because certain amount of thermal energy is to be deposited to the environment and there is thermodynamic limitation of an equipment in that certain processes cannot be ideal there will be losses which will amount to irreversibility which we will discuss later on.

So, when the this kind of thermodynamic limitation is there the direct implication is that we are generating heat waste heat which needs to be dumped to the environment then next I like to point out the physical limitation of equipment. So, what is physical limitation of equipment?

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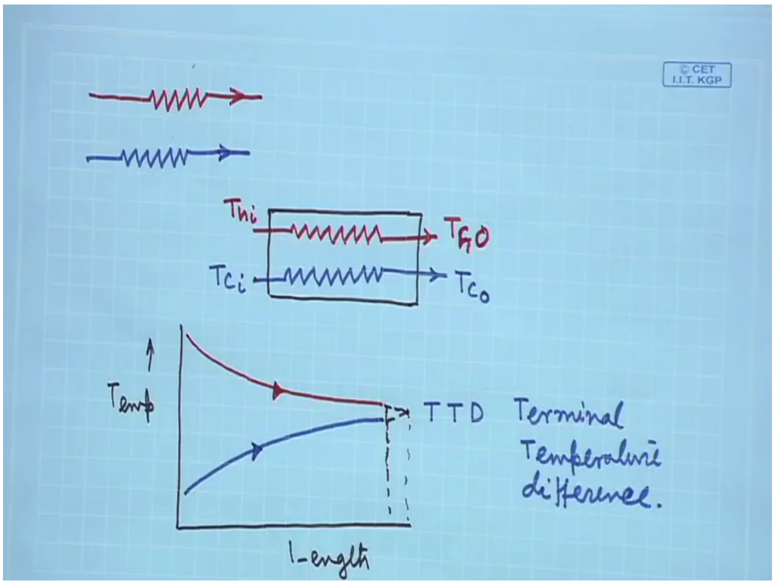

Let us say that we want to extract some thermal energy from a hot stream there is a hot stream and there is a cold stream. So, I like to extract certain amount of thermal energy from the hot stream and when I want to pass it to the cold stream and then how can I do it good way of doing it is to employ some heat exchanger.

And let us employ a heat exchanger for exchanging heat from the hot stream to the cold stream let us first think of a let us first think of a parallel flow kind of heat exchanger. So, parallel flow kind of heat exchanger the heat exchanger looks like this both the fluids they are entering on the same side of the heat exchanger and going back to going out through the other side opposite side of the heat exchanger. So, something like this schematically I can show it like this and let us say this we call Thi hot stream entering temperature, this is Tci and sorry Tho; this would be Tho; that means, hot stream inlet temperature hot stream outlet temperature.

Similarly, we will have Tci cold stream inlet temperature and cold stream outlet temperature let us assume that hot stream as at an elevated temperature and cold stream that is at a temperature, when it is entering that is at ambient temperature now the hot stream to which degree, it can be cooled theoretically, it can be cooled to the ambient temperature, but then what is happening in this heat exchanger, if we see the hot stream will lose its temperature, this side the cold stream will gain temperature for a finite length of the heat exchanger we have to end somewhere over here this is length and this is temperature.

So, what are we getting from this what we are getting from this figure is like this the hot stream could have been cooled up to the ambient temperature, but and the same heat could have been used in the cold stream, but that we cannot do this is the physical limitation of the heat exchanger there is something very important in heat exchanger that is called TTD terminal temperature difference. So, here you see in case of parallel flow heat exchanger up to certain point we have gone; that means, the temperature difference between the hot stream and old stream we have reduced up to certain point, but beyond that we cannot proceed.

And if we proceed also theoretically where we will reach we will reach some point over here let us say theoretically we have reached some point over here, but that is again not cooling the hot stream up to the lowest temperature possible and this zone is not achievable by any practical equipment. So, we will not be able to achieve this. So, what we can see that there is physical limitation; so, that we cannot recover enough a recover the entire amount of thermal energy possessed by a particular stream. So, this is the limitation of the physical limitation of the equipment.

We can think of very quickly let us see if these streams are arranged in counter current manner.

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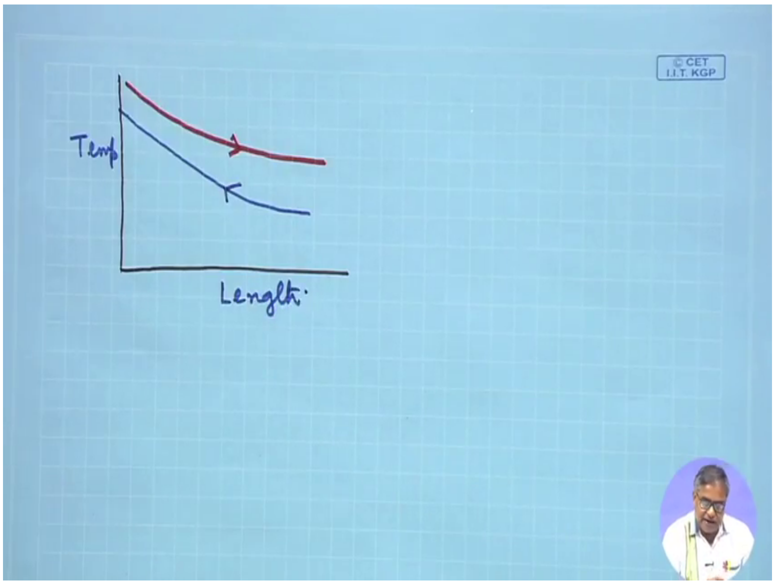

We know that in counter current manner the heat exchangers we have a better capability of transferring heat. So, let us say, we are having hot stream getting cooled like this and the cold stream getting heated like this here also you will find that though we go on increasing the length and though due to this arrangement the amount of heat transfer between these 2 streams are more compared to the previous case.

But again we cannot extract the entire amount of thermal energy which can be extracted from the hot stream by the cold stream that cannot be done with a finite length of the heat exchanger. So, this shows the limitation physical limitation of the equipment then there are other constraints why we cannot why we generate waste heat the third thing which we see that characteristics and chemical composition of exhaust streams let us say we like to extract some amount of thermal energy from the exhaust stream.

But the exhaust stream is. So, corrosive that we cannot extract heat by some sort of a profitable manner from this exhaust stream the exhaust stream is having. So, much of particulate that if I try to extract thermal energy out of heat it will give the problem of fouling it will give the problem of erosion and the investment will be too much to extract certain amount of thermal energy which will not be beneficial profitable then minimum allowable cooling temperature or temperature of cooling.

Suppose I have got a gas and it has got such certain amount of thermal energy which I can extract out of it if I cool it, but then if I cool it what will happen there are certain gases components which are which can be called as permanent gas and there are certain vapors particularly water vapor from in combustion product there will be water vapor the water vapor condenses and then it will produce some sort of acidic liquid which is corrosive for steel component, never, it is allowed to cool the gas below the acid dew point what is acid dew point we may discuss sometimes later on, but below the at acid dew point we cannot cool the gas and then certain amount of heat we have to dump to the atmosphere and that is your waste heat.

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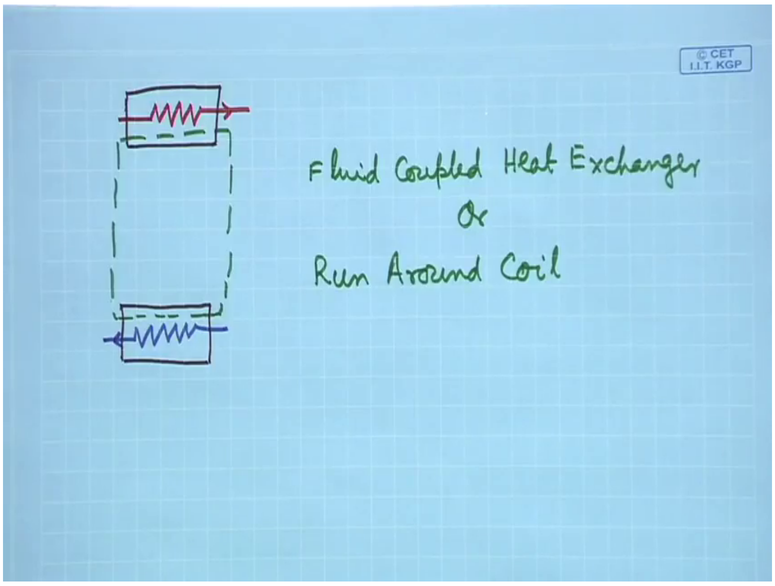

Then plant layout and space available let us say that we have got a hot stream somewhere in the plant in the plant somewhere we have got a hot stream and somewhere else far apart we have got a cold stream. So, there is a potential; that means, the cold stream we need to heat and; obviously, this can be done without spending any kind of extra fuel with the help of hot stream, but these 2 streams are so far; apart that it is it is not possible, it is physically not possible to exchange heat between these 2 streams and this is due to the layout of the plant there are some means by which this type of energy exchange can be taken care of we will discuss one solution of heat not that it is possible always, but in some cases it is possible.

What we can do we can have 2 heat exchanger and in between we can have some sort of a coupling fluid this is called fluid coupled heat exchanger or this is called run around coil, but again in all the places we cannot have fluid couple heat exchanger or run around coil sometimes; what happens that one hot stream is there and one cold stream is there and due to safety consideration we should not bring them close together one of them could be a clean stream of gas and another could be hazardous or corrosive and for safety consideration for avoid the hazard etcetera we should not bring them in close proximity.

And in that cases the recovery of waste heat is not possible or generation of waste heat becomes mandatory then economy and energy policy you see waste heat recovery is not fully this is very important waste heat recovery is not or the operations of waste heat recovery is not fully technology driven. So, this is also political see; what could be the taxes for energy what could be the incentive for waste heat recovery what could be the incentive for having laser emission; these things also have effect on how the industries will adopt the waste heat recovery principle.

In countries where the environmental rules are very stringent where the fuel is a rear commodity the cost of fuel is high, there is no fuel supplement then probably industries have to be more cautious more conscious regarding waste heat recovery principle and they have to adopt many of such principles, but in countries where these environmental rules are not that stringent where the fuel is available then probably the industries will be reluctant in adopting the waste heat recovery principle because this needs cost then the last thing is that scope of profitable use of waste heat.

Let us say in an industry there is scope of waste heat recovery by waste heat recovery they can generate low pressure steam, but the industry itself cannot use there is no use of low pressure steam or there is no other industries nearby there is no other buyer or user nearby who can purchase the low pressure steam then; obviously, the industry will not have the option will not take the option of having the extra investment for having the waste heat recovery device rather it will prefer to dump this heat dump this thermal energy to the environment.

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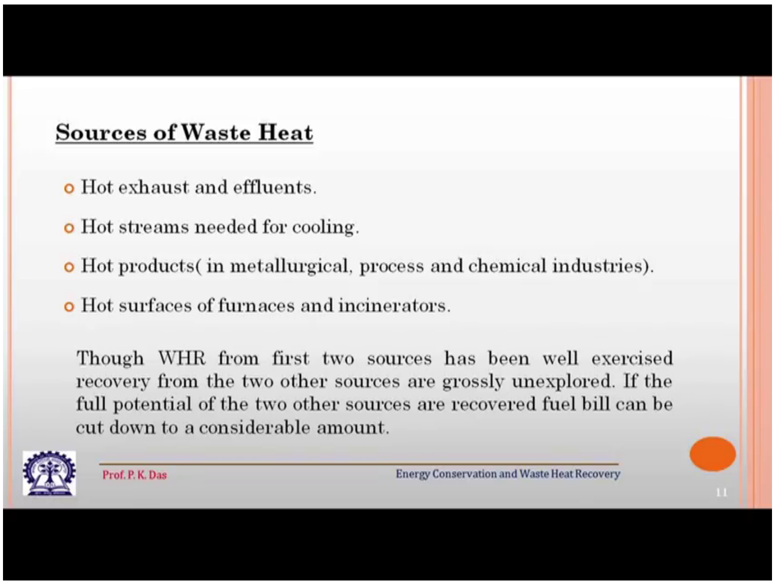

So, waste heat generation in this case is due to the lack of scope of profitable use of that kind of energy which is recovered sources of waste heat the sources of waste heat there is hot exhaust and effluent generally hot exhaust and effluent, they are fluid stream, but hot exhaust have higher amount of potential for waste heat recovery because effluents are generally dark, but both of them can have good potential for waste heat recovery then hot streams which needs cooling there could be some intermediate stream; it is not exhaust; it is not going to be a ambient; let us say in an refinery there is a hot stream which needs to be needs to be cooling which needs cooling and then of course, from the from that hot stream the thermal energy can be recovered and used in hot products.

Hot products in metallurgical industries in process industries chemical industries there will be hot product and hot product will have thermal energy which can be recovered then hot surfaces like furnaces incinerator etcetera in this regard I can say that generally the approach has been till date mostly to recover waste heat from hot streams and hot effluents, but not that much from hot products and hot surfaces hot products particularly have got lot of potential for energy recovery and this is one field which needs further research innovative ideas so that we can recover good amount of energy from the hot product from all metallurgical industries, etcetera.

So, with this I like to end this lecture we will proceed in the next lecture for different options of waste heat recovery. So, so far whatever law we have learned we have in the in the in the present lecture which we have learned we have shown the energy flow process how it differs without waste heat recovery and with waste heat recovery and then we have discussed that what are the reasons so that an industry there is generation of waste heat; obviously, these are important inputs and with this understanding. Now we can go for different options of waste heat recovery in our coming lecture.

Thank you.