Surface Facilities for Oil and Gas Handling

Prof. Abdus Samad

Department of Ocean Engineering

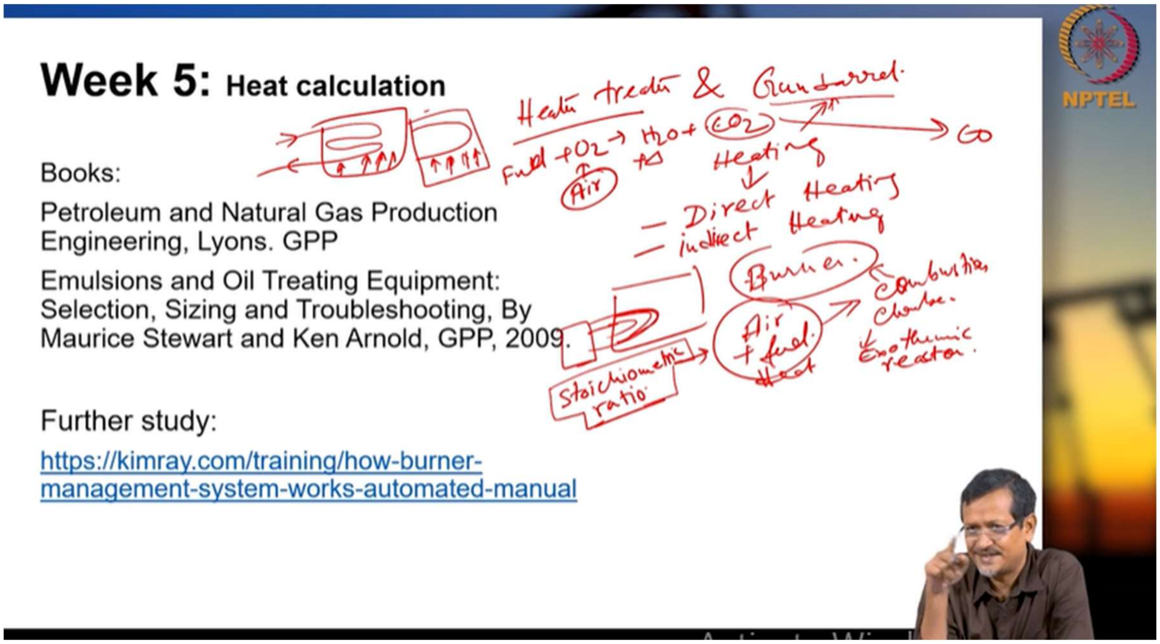
IIT Madras

Heat Calculation-01

So, good morning everybody, we have started week 5 already some portion I taught regarding heater treater and gun barrel. The heater treater and gun barrel. Heater treater, actually you are giving heat in the gun barrel normally you do not add heat, but if required you can add heat. So, normally gun barrels will be used for warmer environments where your heating requirement will be lower, but in a heater treater, you are adding heat. So, you can use it anywhere irrespective of your location. Now, a gun barrel normally will be for multiple wells where a large volume of flow fluid will be there, but a heater treater like a single well bore can be replaced, it plays a gun barrel can not be used you can use a heater treater.

So, there are differences, but these days people are using some heating elements also in gun barrels. So, external heating is possible, and internal heating is also possible. So, now when we are saying heating. So, there will be two things one will be direct heating, direct heating and another will be indirect heating direct heating.

When you are going for direct heating inside your separator system you are giving heat and the hot gas or hot fluid will be heating the metal surface of this pipe. When it is heating directly oil or water or oil-water mixture will be heated up. So, this is called direct heating, but indirect heating is when you are doing you have one separate fire source and where you are heating water and increasing temperature and maybe hot water or steam you are producing that steam will be circulated inside your separator system gun barrel or heater treater. So, that means, high temperature whatever you are getting in heating oil heating water. So, that will be limited.

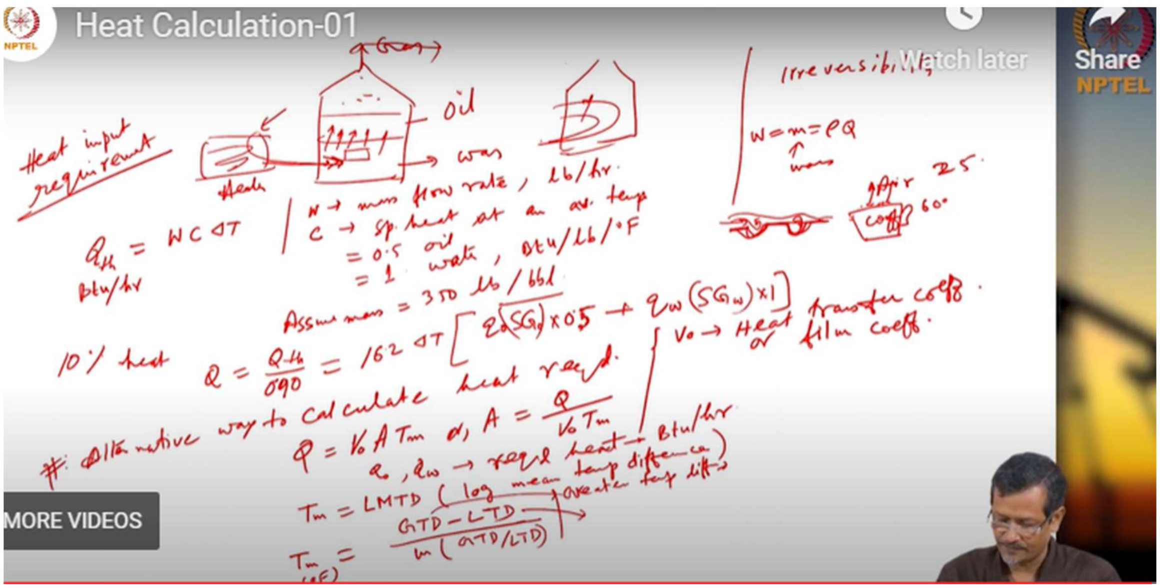


So, because the limited temperature is there. So, the safety aspect will be very good, but if you are going for a direct heating. So, in that case, the temperature can go very high. So, in that case, accident prone it is possible some accidents also. So, in that case, you have to fit like a water level sensor you have to put your temperature sensor you have to put some fire supply cut system.

So, that system can be made safe. So, one burner system will be their burner or we can say the combustion chamber combustion. Where combustion happens when you are combusting something you need two things one will air plus fuel. Another thing also requires heat air and fuel mixture in the atmosphere it is not burning, but if you give heat which will be starting the initial reaction there is a small amount of fuel that will be burning it will be a very high amount of heat. So, that heat will be further heating another fuel particle and finally, an accident can happen if it is useful for your application for you know your cooking for your household application or IC engine combustion or your heater treated application if you are controlling that heat and using for proper purpose.

So, in that case, what you do you put a certain amount of air certain amount of fuel, and give a certain amount of fire spark you may have heard of this spark ignition engine. So, you can create a small spark or a combustion ignition engine. So, here you can create a very high compression ratio. So, the temperature can go up to the burning point or flammable point then the air fuel mixture will burn it will produce lots of heat and I told this is a this is an exothermic reaction ok? So, this is exothermic reaction not endothermic exothermic reaction CTION.

So, and air how much air you have you cannot give air whatever you like you have to give air in a controlled way the term is called stoichiometric ratio. The stoichiometric ratio means let us say air 1 litre of air needs only a 1-meter cube and 1 1-liter oil may require a 1-meter cube of air. Now, you are giving a 1-metre cube of air means a certain amount of oxygen is there at 21 percent. So, that oxygen is exactly what will be burning the fuel. So, if let us say certain fuel plus oxygen you are reacting and H 2 O plus some other component will be created ok.



Now, you get a very high amount of oxygen means a very high amount of air. Very high amount of air we are giving that when after burning the flue gas or burn gas or smoke whatever you are getting going out of the system. So, it will take lots of heat. So, lots of air you are giving means the air also will take some heat and it will go out. So, the actual efficiency of the system will be lower because air is taking a certain amount of you are giving a very high amount of air.

Now, some smart student can ask sir then we will be putting lower amount of air then what will happen? If you put a lower amount of air what will happen? Fuel will not burn completely. So, fuel is not burning completely. So, what will happen instead of CO 2 in after burning a hydrocarbon it will be producing CO2 after combustion right? Hydrocarbon means petrol diesel or any other kerosene if you burn coal or wood it will produce carbon dioxide high water and some other molecules. If you give a low amount of oxygen.

So, instead of CO_2, it will be producing CO carbon monoxide. Carbon monoxide is harmful to any engine designer a combustion chamber designer their main aim will be to produce carbon dioxide, not carbon monoxide. Carbon monoxide is harmful carbon dioxide is not harmful although this greenhouse and all these things they will say carbon dioxide carbon dioxide, but in combustion engineers aircraft engine designers IC engine designers your boiler systems designers here will try to produce carbon dioxide, not carbon monoxide. Carbon dioxide is not harmful because it is already there in the atmosphere in the body also producing carbon dioxide, but carbon monoxide will be creating problems. So, you have to give a proper amount of oxygen maybe a little bit higher amount, but a lesser amount is dangerous ok?

So, your combustion chamber in the heater system will have fuel system fuel injection system and an air injection system. So, control way you have to give air and fuel ratio that ratio is called stoichiometric ratio ok? So, just the same amount of air whatever is required for burning fuel you are giving a little bit more not less ok?

So, in this term, you should remember the stoichiometric ratio. Then you need one fuel source one oxygen supply source then fuel and an oxygen-controlling mechanism.

For example, direct heating system I say that the temperature can shoot up suddenly, but the water level can go up and go down when the water level is going down then your firebox and fire combustion happening in that area then the area temperature will be very high. So, that system can melt and burn also possibly right leakage and possibly rupturing. So, in that case, you have to control the temperature how to control it? Cut the fuel supply, not the oxygen supply cut the fuel supply first then give less amount. So, the total amount of heat economic reaction is the total amount of heat you are getting right you see this in my equation. So, some delta also will come delta heat ok.

So, less amount fuel less heat. So, the temperature will go down if further it is not controllable completely cut this oxygen and fuel both then you see you check where the problem ok. The water level is going down or maybe any other problem with the whole piping system or any leakage is there or unnecessary fuel is going very high rate oxygen supply is lower. So, all these things you have to check ok? So, you will have one burner or combustion chamber your combustion chamber may have lots of pipes normally in a boiler lots of pipes will be there ok?

So, combustion is happening water is going through the flame it will be like this let us say I am creating one flame source ok. And the water pipes will be like this ok? So, when water pipes move inside the flame you can give one pass also let us say you have one combustion chamber you are giving one pipe and flames are here like this ok? But people will be giving multiple pipes you know the reason reason is that you are increasing surface area ok? Surface area increasing means if you remember the convective heat transfer coefficient formula h a delta t right heat transfer equals h a delta t later we will discuss details about convective heat transfer.

But the basic formula is h a delta t h means convective heat transfer coefficient a means area of the pipe surface area means how much contact is contact area is there ok. And delta t temperature difference now if you have one pass pipe means the total surface area of the pipe is low, but if I multiple passes then L into that pi d right pi d means perimeter into L. So, that means total surface area.

So, multiple passes mean the total area increased. So, in total my heat transfer rate increased.

So, heat transfer increase means whatever heat is getting produced. So, everything will come to your water water inside the pipe right? So, that water you are passing through your boilers then is an indirect type of heating. But for the direct type of heating you do not need this sort of water pipe directly to your heating and metal surface let us say this is one box inside a fire is there. So, the box's outside temperature will be high, and touch anything touching like water or oil anything it will get heated up simply right the flue gas can heat directly things right.

So, so, when you are burning something burning must be controlled way fire flames should not go outside because in a separator system in surface production operation, everything is safe, but if there is any leakage and you have any fire source that can be dangerous. So, every fire must be within a certain box or certain control system your air must be controlled your fuel supply must be controlled your temperature must be controlled your pressure in the separator system must be controlled. It should not go beyond certain limits and you have to monitor also regularly whether valves are working any valve is leaking the temperature sensor working properly pressure sensor working properly. Now, let us see how to calculate the heat transfer. We have seen some calculations and in the previous lecture, I think in week 1 or 2 we will see some more calculations of heat transfer yeah.

So, we discussed gun barrel rights. So, in a gun barrel normally I say like there will be no heating element, but we can give heat also. So, how can we create one external heater ok? The heater will supply hot fluid inside the gun barrel then you can create a layer you can get gas out water out water leg you can create like we have we had done only calculation or directly you can take and oil ok. So, why are you creating a water leg by using a water leg actually, you can control the interface level ok, from outside instead of working inside the system.

The heater will have multiple coils ok? So, hot fluid will be coming it will be heated up then hot fluid will enter into your separation. So, this is a heater, and then fluid enters here. So, the same spreader will be there. So, you are spreading the hot fluid ok, inside the water zone not in the oil zone.

Your spreader will be in the water zone ok, below the interface level. So, there you are heating heating or you are giving hot fluid ok? Then slowly these oil particles will move up and move up because you changed already viscosity and density because of that oil particle moving up you take oil and if any dissolved gas is there anyway because of creating low-pressure and high-temperature gas will be going out through this top section fine. So, this is an indirect type heater and direct type heater like one possible like you have fire box inside and you can burn ok, burn fuel and you can get heated. So, we will calculate the heat input requirement.

So, how much heat is required to increase the temperature within the heater. So, theoretical heat transfer rate you know W c del T, W instead of W you can put m also mass flow rate Q t is Btu per hour. Based on this formula actually, we will be solving some problems. So, maybe you can note down this formula m or W is called mass flow rate, mass flow rate of liquid all right and unit is lb per hour pound per hour. And C specific C heat ok, at an average temperature this is the average formula.

So, specific heat at average temperature what happens. This is a pipe that is going inside and going back. So, when entering a hot pipe. So, the inlet temperature will be higher when the pipe is exiting. So, that temperature will be lower. Then what will be the value for C? So, in this case, they are assuming C for average temperature.

It will not be average, but assume average temperature later we will modify the value for C and T ok. Specific heat at an average temperature at an average temperature. I am writing a short A V only. So, you can write in full form the average temperature.

And value will be 0.5 for oil and 1 for water And the unit is. So, the C value of the unit will be Btu per lb per degree Fahrenheit. Assume water, water mass 350 m A s s pound per barrel.

So, unit conversion is given here. So, if heat loss is 10 percent. So, for 10 percent heat loss when you are transferring heat from one or transferring energy from one, one form to another form or transferring heat, there will be certain losses because heat is transferring. So, radiation loss will be there, convection loss will be there, and there will be some leakage somewhere maybe. So, they are assuming less than 10 percent loss will be there like the thumb rule.

It may be more or less. So, whenever any conversion is happening by the second law of thermodynamics you can remember first law says that heat can be transferred from heat that can be converted into work first law says, that how much heat will be transferred does not. But the second law says heat cannot be transferred 100 percent. You are converting heat to work 100 percent conversion is not possible some losses must be there. So, that is why the irreversibility term will be coming to this irreversibility. This is some heat you converted into work and again same work you are converted into heat.

So, you cannot get the same amount of heat again this lost again lost. So, some energy will be lost. So, that is irreversible. So, you change back to the system's original system. So, some energy lost which is why it is irreversible, but is complete energy you are getting back then is reversible.

So, the second law says Clausius's statement I think the second law says, heat or work if you are converting one form of energy converting another form there will be a certain amount of energy lost. So, heat transferred from one point to another point will be flowing through a pipe or some mechanism will be there. So, there will be certain losses. So, you cannot prevent that loss. There will be heating heat already it is there there will be loss due to radiation convection.

If any other mechanical element like friction rotating machine other machine is there. So, there will be heat generation losses, but here you are generating heat. So, the heat generation loss is not there final form of any energy is heat. So, whenever any machine element is working moving element or IC engine or any other engine. So, the final form of loss is that the loss part will be heat actually, but when heat energy is there.

So, the loss is there in the form of radiation convection, conduction is also possible like you are heating something, and the material and everything will get heated up slowly. So, that is also loss of right heat heated up means MST is this formula you see mass into C heat capacity or specific heat and del T temperature difference. So, something is getting heated up means it is taking already a certain amount of heat.

So, that heat you are not using. So, there is a loss. We are calculating only the usable heat, right? So, we are assuming 10 percent heat is lost for this purpose although the designer will be trying their best to reduce the loss, there will be certain loopholes where losses will be there. So, there is no perpetual motion machine in the world perpetual machine is one machine you design that will be running continuously not possible. So, Q equals Q theoretical divided by 90 0.

9 because 10 percent lost . So, total heat input will be like Q theoretical 116.2 del T this formula Q oil flow rate S g of oil 0.5 plus Q water flow rate S g of water. Then 1 water is 1 already I told and why S g is coming if you see flow rate into density is called mass rho into Q equals mass here we are assuming W.

So, we can say W rho into Q. So, flow rate if you know you multiply with density it will be creating mass and here we are assuming density constant because it is liquid if it is gas then density also will be changing liquid compressible actually if you increase the very high amount of pressure, but presently for the normal application, we are assuming density not changing. Alternative way alternative way to calculate heat. So, Q equals V o as per the book I am writing V o is the symbol they are using instead of h or other symbol V o a T m or a equals Q V o T m V means field coefficient or heat transfer coefficient. So, V o we can write heat transfer coefficient heat transfer or film coefficient sometimes they say. Heat transfer coefficient varies if you change fluid if you change surface profile if you change fluid velocity let us say 1 cup of coffee I am right and in this room, it will be cooling quickly because the environment is a lower temperature.

Now, if I have a fan also. So, it will increase the heat transfer rate. So, it will be changing your h actually what happens when certain fluid near my coffee air is air and this is coffee. So, coffee is heated.

So, coffee temperature is higher let us say 60 degrees air temperature let us say 25 degrees.

So, coffee will transfer heat to air right. So, nearby coffee surface cup surface what air particles be heated up. Now, if there is no airflow so, the air particles because of buoyancy, move up slowly. So, because of buoyancy particles move up slowly, and again fresh air and low-temperature air will be coming on the surface it will get heated up again it will be moving up. So, buoyancy means that again particle settlement formula whatever you have calculated you can assume right. So, smaller particles slowly move up because of viscosity and density differences right.

Now, if you have a blow of air on the fan you take and fan or maybe a ceiling fan or anything then you blow. So, particles are heated up and blowing. So, hot particles move up quickly fresh low-temperature particles will come again they will get heated up and move quickly. So, quickly you are removing the hot particle.

So, the cooling rate will be very high. So, the h value will be changing again surface area. So, my PhD thesis was not thesis PhD I have done some work on dimple surface. If fluid is flowing on a flat surface like say even a table, and the table is heated up. So, the cooling rate will be lower if your cold fluid or air is flowing over it, but if I have roughness on the surface. So, the cooling rate will be higher surface it is depending on the surface also.

You see this picture I am drawing here right side. So, it creates a loss of turbulence when fluid is flowing turbulence is created. So, turbulence will be taking more heat. So, your heat transfer rate will increase based on your surface area and your fluid medium velocity there it is natural convection force convection or free convection. So, natural convection buoyancy because of buoyancy it will remove heat slowly if you are creating forced convection-blowing air.

So, the heat transfer rate will be higher. So, h value will be changing again such as what type of wood or metal surface roughness. So, many parameters are there to change your convective heat transfer coefficient. So, Q o Q o and Q w water and oil heat required Q small ok capital Q required heat required heat unit is BTU per hour. And T m T m T m term I have used T m logarithmic mean temperature difference you may have studied heat transfer logarithm L m T d or logarithmic log mean temperature difference. So, this T m, m is the surface area of the pipe or T whatever you are using.

So, T m formula I think you should know T m degree Fahrenheit G T d They created the short form G T d minus L T d L L T d divided by the log of G T d by L T d. What is G T d greater temperature difference greater temperature difference? This is G G T d and L T d L T d is the least temperature difference. So, what are G T d and L T d better I will go to the next slide.