Surface Facilities for Oil and Gas Handling

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Introduction to Heat Exchanger-03

Good morning everybody. Today, I will start lecture on Heat Exchanges. So, heat transfer already we discussed heat transfer, there are 3 modes of heat transfer, conduction, convection and radiation ok. We have seen this conduction when particles are resonating it is not moving actually, solid body heat transfer normally it will be conduction, but convection normally it will be liquid or gas. So, particle actually will move from one point to another point. By radiation you do not need any medium.

For example, solar radiation coming to earth. So, it is not heating the atmosphere. So, it is heating only directly to earth ok. So, it is coming through certain media, but media is not being heated or it can travel through radiation heat transfer you do not heat any medium.

So, directly it can energy can come from sun to earth actually ok. When it is passing through atmosphere also it will not be heating up, but where conduction and convection the the medium will be heated up actually. So, in conduction especially solid body, convection especially liquid or gas body right. In liquid or gas also conduction possible, but convection may be more. So, that is why you normally we consider convection term ok, but in some cases we use conduction term also for example, near wall heating.

So, there fluid movement will be very slow very low. So, in that case actually molecular resonance will be effect affecting heat transfer ok. So, heat exchangers are device used to transfer heat from one fluid to another fluid ok. So, one fluid to another fluid and it will be separated by one solid medium ok. So, for example, you have cold fluid is a hot fluid and one solid wall is there.

So, heat will be transferred from hot to cold ok. So, then cold fluid temperature may be will be increasing if it is not flowing. So, slowly the temperature will be rising up, but hot fluid will be giving some energy to cold fluid ok. Typical heat exchanger experienced by us in our daily life including condensers evaporator if you go to your hostel or your mess you will see refrigerator or fridge will be there or air conditioner is there in this room also air conditioner is there. So, air conditioner if you see properly backside there will be some condenser coil like this ok.

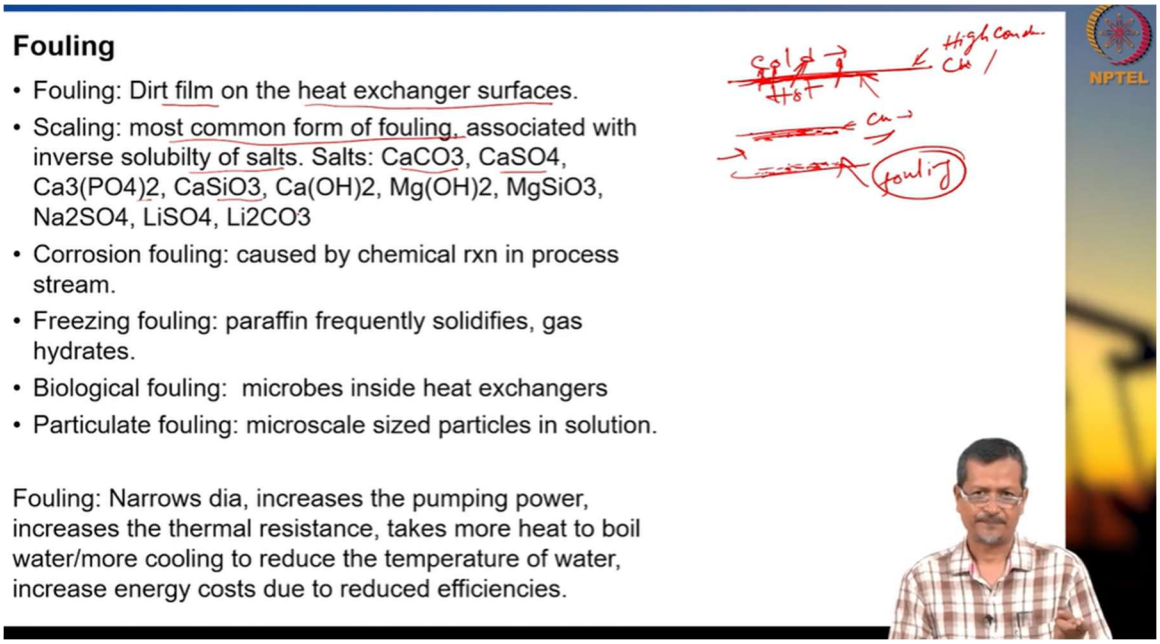
So, condenser coil there is also heat exchanger actually evaporator section in air conditioner or refrigerator there is also some coil will be there like serpentile coil ok. So, that coil will be used as a heat exchanger ok from hot body to cold body ah cold body heat will be transferred. There is a wide variety of heat exchanger for diverse kind of applications ok. One application is that refrigeration I already told engineering application in industries also there lots of applications are there ok. So, in this picture you can see one heat exchanger I have taken picture from this IQS directory ah you see this heat is transferred from ah one pipes are there and this whole system is called shell ok and lots of small small pipes or tubes are there ok.

So, ah tube will be carrying one fluid where shell will be having another fluid and heat will be transferred from shell to tube or tube to a shell ok. Later we will discuss in details about this phenomena. Now, whenever talking about heat transfer so, you need one surface solid surface and one cold ah cold fluid will be there or hot fluid will be there and heat will be transferred hot to cold ok. When heat is getting transferred you want solid medium you need let us say copper or iron or some material will be there in between. So, the otherwise if you do not have that solid material then fluid will be mixing up.

So, mixing up you may not allow many time ok. So, if you are separating isolating this hot and cold fluid for example, oil and water water is heating oil. So, in that case you are not trying to mix up oil and water. So, in that case you need solid boundary ok in between two. So, heat will be transferred through that.

So, it must be high conductive material ok high conduction should be there and whenever heat is getting transferred and fluid is flowing actually if fluid let us say water or oil or out of for gas if they have some dust particle if you have some calcium ah salt or other salts then what will happen around the solid body those will get deposited ok. When those are getting deposited your heat transfer characteristic will change. In many cases pipe can be blocked also ok fluid is flowing through this one and you are getting lots of deposition upper and lower area whole pipe area. So, slowly this pipe will be restricted or constricted

ok. For example, gas hydrate if you have low temperature the hydrate will be deposited inside a pipe.



So, that will be blocking the whole system, but if another thing is that if you have lots of dust or dirt particle. So, that also will be deposited over this one, but if you have some chemical ah component also that is also be deposited on this surface. So, when it is getting deposited what is the problem? Problem is there want to be it will be creating restriction of flow ok. Another thing is that heat transfer characteristic change what what is that ah let us say you are using copper pipe it is very high conductive material. Now, you have lots of dust over it.

So, dust will have low conductivity ok. So, your intention is to give very high conductivity, but you got lots of dust and deposit on this one and fouling created this is called fouling ok. So, fouling created that means, it is not allowing to transfer heat. So, you you need more pumping power if it is restricted or you need to heat more you have to get more energy from fuel because heat is not getting transferred actually. So, if it not getting transferred then it will be wasted ok.

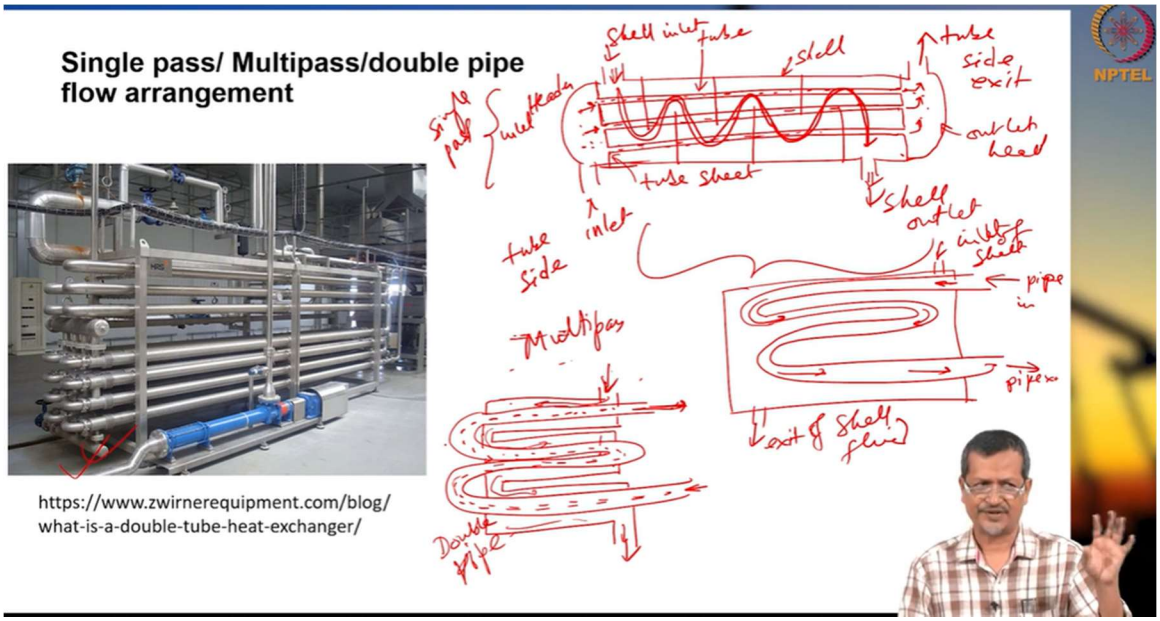
So, ah that means, you you should not allow this deposition of foreign material ok. So, this is called fouling this deposition ok. And you see this definitions are there fouling dirt film on the heat exchanger surface ok. So, dirt film that can be scaling, corrosion fouling, freezing fouling, biological fouling. So, many types of fouling will be there.

So, all the deposition will be there on the surface. So, this is negative ok. ah Scaling most common form of fouling associated with the inverse solubility of salts. So, salt will be soluble, but inverse means it is not soluble. So, calcium carbonate, calcium sulphate, CaPO4 whole 2 Ca Si of silicon oxide, calcium hydroxide, magnesium hydroxide, sodium, lithium.

So, all these salts will be deposited on the surface ok. So, ah normally the boiler thermal power plant people the boiler application in they what they will do they will remove all the debris salts everything from water then they will be using. First they will be removing all the salts then they will be using for your heating purpose ok. Then if you do not have any extra salt or dirt then there will be no deposition ok, but many cases it may not be possible. So, in that case you have to remove this you have to do cleaning operation or you have to replace the whole system ok.

ah Especially boiler thermal power plant application they will have feed water heater or feed water ah system. So, feed water system actually they will be removing all the salts and debris and all dirt particles. Then they will be putting into the boiler system. Boiler system means there is also heat exchanger is there, volumes water will be boiled. So, that boiled water means that will be creating steam high pressure high temperature steam.

So, that will be passing through turbine and they will be extracting electrical energy ok. So, in that case because continuously they will be ah cooling and evaporating this water system and feed water also will be coming. So, feed water if it is dirty then scaling will be deposited pipe can be blocked and pipe blocked and you are supplying constant heat what will happen pressure will be increasing with without limitation. So, in that case burst or accident can be possible ok heat can be shooting up ok. ah So, whenever you are using like high pressure system.



So, you will have pressure sensor temperature sensor anyway. So, in many cases sensor failure may be there. So, accident can occur ah, but before that if precaution action is that you remove all the salt and dirt and use the water ok, but in oil well bore whatever oil you are getting in that case you may not be able to do that one. So, in that case you have to observe whether the salt deposition is happening or your hydrate formation is happening if hydrate formation happening then you have to remove the cause or you have to use line heater. So, increase temperature of hydrate formation temperature right or calcium or other salts are there then again you have to observe it is there and is getting deposited then you have to remove time to time or you have to remove the whole piping system all together or many time they will be doing peaking operation another operation piping pipeline engineering ok.

So, corrosion falling will be there caused by chemical reaction in the process stream. So, if there is any corrosive fluid corrosive fluid let us say H2S or something. So, this corrosion will be occurring. So, corrosion occurring means the salt will be formed salt will be getting deposited on the surface metal surface maybe one portion will be removed and it will be deposited in another portion that is also to be dangerous because whole system is designed uniformly, but because of corrosion if it is getting uninformed heated somewhere more heat somewhere low heat somewhere is somewhere blockage somewhere no blockage. So, that will be creating problem and fluid flow one property is you have to remember every time the fluid wants to flow in smooth straight path.

So, if you are giving any restriction it will be creating lots of turbulence it can create erosion sorry erosion cavitation ok. So, that sort of issue will be coming. So, if inside pipe

if there is any debris or any salt formation or corrosion anything is happening then you need to observe that ok. Observe means from outside you cannot observe, but you will have some measuring equipment or sensing equipment using that one you have to observe and you have to take action because oil and gas industry one small crack or anything can be disastrous ok. So, freezing fouling freezing paraffin or other chemicals are there.

So, thus at low temperature those will be getting deposited on the pipe system ok that will be blocking the flow system ok that is also undesirable biological fouling in many cases microbes and other biological growth will be there. So, that will be blocking also flow path ok. So, so fouling it will be narrowing down diameter increasing pumping power because it is blocking. So, you need more pumping power electrical consumption more.

So, pump will be working more ok. So, it is it will be consuming more electricity then it will be pumping because it you are creating restriction ok. Larger pipe means restriction will be lower lower smaller pipe means restriction will be higher higher restriction means more pressure will be required to push the fluid through that restricted area. Thermal resistance will be increasing thermal resistance will be increasing means like deposited deposition is there their conductivity lower than actual metal conductivity. So, it will be creating thermal resistance your purpose was to increase heat transfer rate, but this is not helping ok this is opposing heat transfer. Then takes more heat to boil water or more cooling ok.

So, more heat means heating is heat transfer not proper ok. So, your target to reach certain amount of temperature, but heat is not getting transferred. So, you have to give more fuel because you are assuming there may be some other issues and you are giving more fuel more burning fuel, but you are getting less heat transfer ok that will be one problem. Increase energy cost due to reduced efficiency the system efficiency will be lower ok. So, if fouling you have to consider whenever any piping system is there ok any because oil and gas industry means lots of piping systems.

So, in piping system you have to check all these things actually fouling you have to check you have to check any erosion corrosion is there any dirt is getting deposited any sand is getting deposited is if any hydrogen sulfide or other corrosive material is there. So, again you have to check whether that is creating corrosion and creating fouling or any other leakage ok. So, all these things you have to observe actually as a production engineer you have to keep in mind all these issues ok. When system is running smoothly ah, but suddenly you find something is not working maybe among this many of these reason one

may be the reason or maybe multiple of causes will be affecting things ok. Single pass multi pass double pipe flow arrangement.

So, whenever you are talking a heat exchanger normally it will be shell type shell and tube type like one shell is here ok and you can draw also if you like ah, one in one out. So, one in one can be out ok. So, one structure here lots of pipes will be like this ok. You can draw like this I can explain what is this one ok. So, this whole body separator type big system is called shell ok and these are tubes ok and this is header inlet this is inlet tube side inlet ok and the tube side inlet fluid will be collected here then fluid will be entering here through this tube ok then it will go this through this the tube side exit this is shell.

So, inside part is shell actually this part is shell ok big pipe and these are small small tubes are there I will make little bit different just wait I will make like this I will make like this. So, it will be better to understand ok. So, like you see fluid will be entering here and it will be exiting here ok. So, these are pipes. So, this is single pass single pass means one time fluid entering and exiting ok from left to right entering entering and exiting this is inlet header inlet header this is outlet header and this is called shell shell ok I have written already this is called tube bundle tube tube sheet tube sheet ok and this is shell inlet shell outlet ok.

So, shell fluid will be entering then shell fluid will be going out ok you see this ok and there will be baffles. So, baffles will be like this vertical line vertical line vertical line vertical line. So, fluid will be entering here it will go like this it will go like this it will exit ok you see this I have drawn line shell fluid will be entering and it will be going like this baffles will be increasing more turbulence ok. So, when heat transfer if you want to increase you have to increase turbulence rate ok if you have laminar flow laminar flow will be creating 2 layer and will be passing smoothly, but there will be no mixing, but when you are creating turbulence flow mixing will be happening low temperature high temperature will be mixing more when mixing more it will be carrying more heat actually why a turbulence like for example, I have one pipe ok and some fluid is touching here and if it is laminar flow this is high temperature maybe ok if it is laminar flow though some laminar layer will be created and fluid will be smoothly passing, but if I create turbulence like this.

So, fluid will be mixing up. So, hot fluid will be touching cold fluid cold fluid will be touching heat. So, heat will be exchange will be more. So, heat exchange more means more heat transfer rate ok. So, in heat exchange actually create turbulence. So, that is why you create baffles ok baffles will be giving more heat transfer rate.

So, this is single pass ok. Now I will try to create double pass multi pass multi pass means how do we do my pipe will be like this ok maybe multiple arrangement will be like this ok let us say fluid entering fluid exiting through pipe you see this this is single pass this one ok and this is multi pass ok multi pass means again I created shell shell will have maybe like this shell entry shell exit maybe and pipe in pipe exit exit of shell fluid inlet of shell fluid inlet of shell ok. So, that way you are creating multiple pass ok. So, you are getting longer flow path. So, heat transfer rate will be more ok and double pipe flow and double pipe flow actually this side picture shows drive double pipe flow how double pipe flow works it will be like this. Now I have one pipe and this pipe is going like this ok.

So, fluid entering and there will be something and fluid entering ok. Shell in or outer pipe in ok outer pipe inlet is here outer pipe. So, one pipe inside outer pipeouter pipe will be carrying different fluid with different temperature ok and inner pipe is here inner pipe let us say I am putting some dots. So, that it will be visible more visible ok this is inner pipe and outer pipe you see this fluid is coming a mixing up it is going like this again going like this going like this and it is exiting ok.

So, two pipes you are getting. So, and pipe flow direction I am showing like one bottom side sometime arrows some upside arrow there should be one in one exit. So, that will be parallel flow counter flow based on that the arrow direction will be changed ok. If I say parallel flow then you see the top picture it is showing a fluid is going same direction this is parallel flow actually ok. This single pass picture I have shown you see this flow is in the same direction this parallel flow actually co-current flow ok.

But if I change any shell inlet direction. So, then it will be opposite flow or counter current flow fine. So, there will be different types of heat exchanger different combinations may be possible one is that like single pass multi pass double pipe maybe many other combinations are possible different company will make different arrangement to sell their product and they will have some merit demerit also they will try to make compact heat exchangers. So, many places space will be one constant. So, in that case they will be making compact heat transfer compact means no space will be required ok ok.

So, heat exchanger in facilities. So, in oil and gas facility heat exchanger means shell and tube type most common. So, this is shell and tube type whatever I have drawn and left side picture also. So, shell and tube type shell is there inside tube ok this is called shell and tube type. So, double pipe also maybe there.

So, this one double pipe the lower one DOUBLE pipe ok. So, shell and tube type also will have different combinations. So, double pipe is there plate and frame type is there I am not showing that one bath type I will explain a little bit forced air direct fired. So, in different other types also possible. So, based on their company invention and many other requirement they develop many types. So, we we are not going to discuss everything that only few thing we will try to discuss.

So, heat exchanger facility ok heat exchanger facility like basically shell and tube type ok. And double pipe and bath type and many other types possible ok. And so bath type if I see bath type will have two type direct indirect ok. So, in direct type what happens heat source for bath heater can be coil of a hot medium of steam waste heat exhaust from engine or turbine.

So, that heat can be used in a direct heating system. So, you have hot gas and directly you are heating oil or whatever you want to heat. For example, immersion heater normally you may have used immersion heater right you immerse directly. So, directly heating coil will be there. So, that coil will be transferring heat to your water ok.

So, heat transfer directly to the oil bath ok. Indirect type in indirect type heater actually you are using third fluid let us say you are heating something water. So, water will be passing to your oil system ok. So, heat somewhere and you are heating somewhere actually. So, and medium will be like water you are using as a medium. So, heat and intermediate fluid like water you are heating using for first heating then trying to heat oil ok instead of directly heating oil.

So, heat to an intermediate fluid this gives heat to fluid ok. Example a line heater ok line heater in a gas well stream to keep temperature more than hydrate formation temperature ok. Fire tube heat fire tube there also you can use water and then you are using heat to increase oil temperature ok. So, baffles I told already baffles where is baffles ah baffles used separately ok. So, whenever you are buying shell and tube heat exchanger or any other type heat exchanger also there will be tuber exchange tubular exchanger manufacturer association they will have specification they will nomenclature specification you have to follow their regulation. So, I am not going to details of their rules and regulations, but you should remember that this organization will be standardizing things ok.

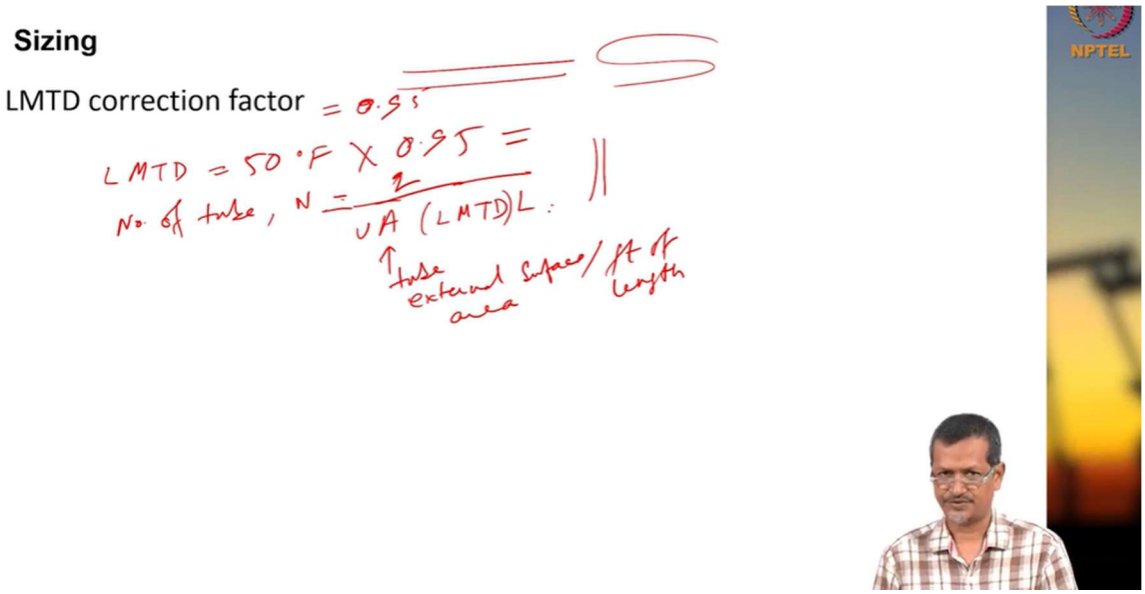
So, this shell and tube type already I explained it is a cylindrical vessel it will have multiple pass of pipes. So, single pass means one pipe is going through the system ok. So, I will draw one simplest one you will understand this single pass, but if you want to make multiple pass it will be like this ok. I have ah maybe ok entering exiting entering exiting ok and flow direction anyway it will it can change it is based on parallel flow or counter flow ok ah.

Tube side fluid is isolated from the shell side fluid ok. So, in that case many cases you will have some separating thing. So, that upper pipe and lower pipe temperature should not be equal ok. Common type heat exchanger used in production operation is tube and shell heat exchanger fine and ok. Now, baffles I will go to baffles ok baffles baffles means like you are creating turbulence.

So, baffles if I draw 3D picture I will draw like this. So, baffles will be like 50 percent ok. If you see this picture top one ah baffles will be like 50 50 like this I will not looking good ok. So, it is like this. So, tubes ah shell fluid will be creating lots of turbulence.

So, when it is getting turbulence you are getting increase heat transfer. So, baffle will not be complete circle rather it will be cut in one portion. So, the fluid can pass through this ok ah. So, some will be like this some will be like this ok ah. And you can you will be creating lots of turbulence because of this one and there will be tubing arrangement also. So, square pitch tubing arrangement like if you see this picture right side here square pitch ok 4 tube ah tubes are there and in another case like triangular pitch.

So, here 3 tubes are there. So, many other type of combination also possible ok. So, just you should remember the different orientation or combination of tubing also possible ok. So, heat exchanger tubes steel ah it will be steel copper steel copper because copper will be having higher heat transfer rate, but steel will be it will be lower heat transfer rate, but strength megalic strength is higher. So, many time steel will be used, but copper will be very high heat transfer rate, but strength wise lower than steel ok.



So, you have to compromise somewhere ah. Copper steel brass also can be used 70 30 copper nickel alloy 70 percent copper and 30 percent nickel ok c u n i ah can be used. Aluminum also can be used aluminum very soft metal, but heat transfer rate is very high ah bronze also can be used thickness ah whenever wall thickness you are talking about. So, one term they use Birmingham wire gauge B W G you should remember the term B W G ok Birmingham wire ok. So, they use this unit for thickness measurement of tubes ah sizing whenever talking about sizing again LMTD will be coming with parallel flow counter flow when you are talking about shell and tube basically. So, LMTD will be coming, but an LMTD you are talking about fixed length of tube, but many time multiple pass will be there.

So, to end there will be certain portion you have to exclude from the system. So, there will be one factor called LMTD factor. So, normally like 0.95 or something will be multiplied for example, LMTD you get ah let us say 50 degree 50 degree Fahrenheit or centigrade whatever ah. Because of this LMT factor actual temperature difference you have to consider lower. So, if you are considering factor also then we have to consider 95 then you have to multiply then you have to use that value ok.

If in problem I do not give any factor value or if I ask you ignore then no need to consider, but if I give the value then you have to consider otherwise your answer will be wrong ok. So, ok then number of tubes number of tubes n how many tubes will be required. So, it will be like heat transfer rate divided by u overall heat transfer coefficient a LMTD into L ok. So, we will solve some problems.

So, that time we will see this all the units and everything ok. A means area LMTD logarithm mean temperature difference if we have consider factor. So, you have to use width factor then length of the tube ok. So, that way you can calculate how many number of tubes will be required. A is tube external surface area tube external surface area of feet of length of length ok.

L is ok this one L is length of the total pipe. So, this can be coming from chart if or if diameter is given then you can calculate also.