Inorganic Chemical Technology
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Lecture - 03
Unit Operations and Other General Principles

Welcome to the MOOCS course Inorganic Chemical Technology, the title of today's lecture is Unit Operations and Other General Principles applied in chemical industries. We will have a recapitulation of what we have seen in last couple of lectures.

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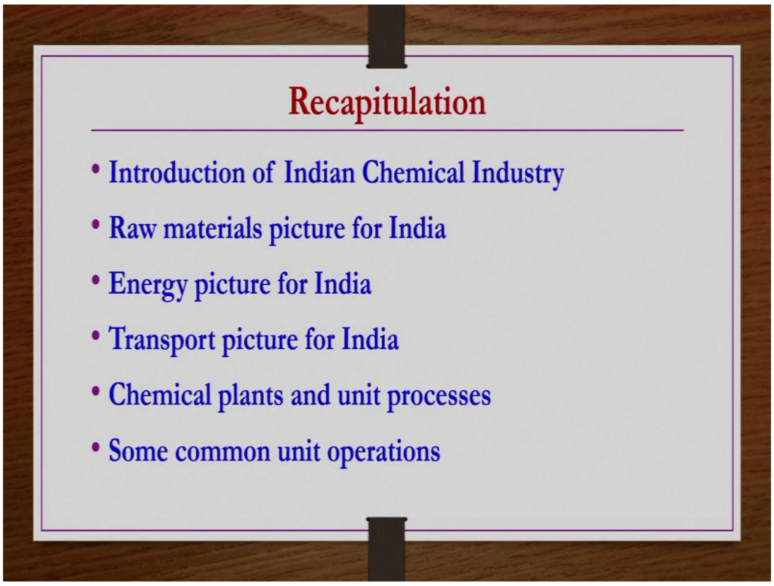

We have seen a few statistics of Indian chemical industries and then raw materials that are available in India then raw materials picture for India. Then energy picture for India and then transport picture for India, especially with respect to the chemical plants, supplying the material and then taking out of the plant etcetera, those things we have seen.

Then we have seen a few basics about chemical plants how we can group them as a combination of a few unit processes and unit operations, then we have seen a few common unit processes. In the last lecture we have also seen a few common unit operations.

In this particular lecture we are going to see a few more unit operations which are commonly used or found in many of the chemical plants and then we will be seeing a few general principles of a chemical engineering that are applied in chemical plants.

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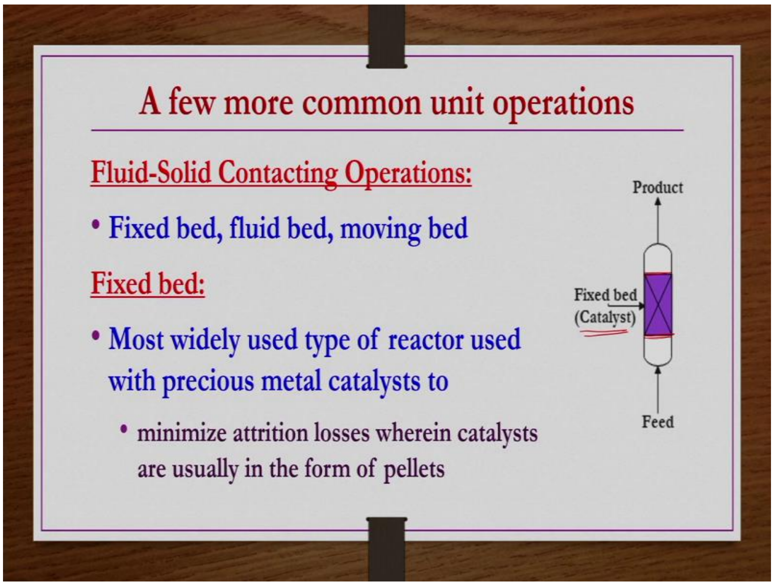

So, next unit operation that we are going to discuss are based on the solid-fluid contacting operations. There are several like a fixed bed, fluid bed or fluidized bed and then moving bed operations. Fixed bed or fixed bed reactor for example, most widely used type of reactor which is used with precious metal catalyst to minimize attrition losses wherein catalysts are usually in the form of pellets.

So, these fluidized beds are not only used for reactions, but also they are used for some kind of heat transfer purposes as well, right. So, let us say if you have a fixed bed used for a reactant. What is fixed bed? If you wanted to visualize let us say you have a cylindrical column, right. So, that particular column what you do you pack with certain packing material let us say in this example it is catalyst particles or pellets catalyst pellets, right.

At the bottom of the bed and at the top of the bed you compactly pack the bed using the perforated plates and then whatever the reactant feed gases are there they are allowed to pass through from the bottom. And, then these gases passes through the perforated plated that are available provided at the bottom of the bed. Then pass through interstitial spaces between the catalyst particles and then reaction takes place.

So, then unreacted reactants and products are again passed through the top perforated plates and then going out. From there, you know, there is a subsequent purification operations take place etcetera that is a different thing, right. So, this is what a common fixed bed reactor looks like, ok.

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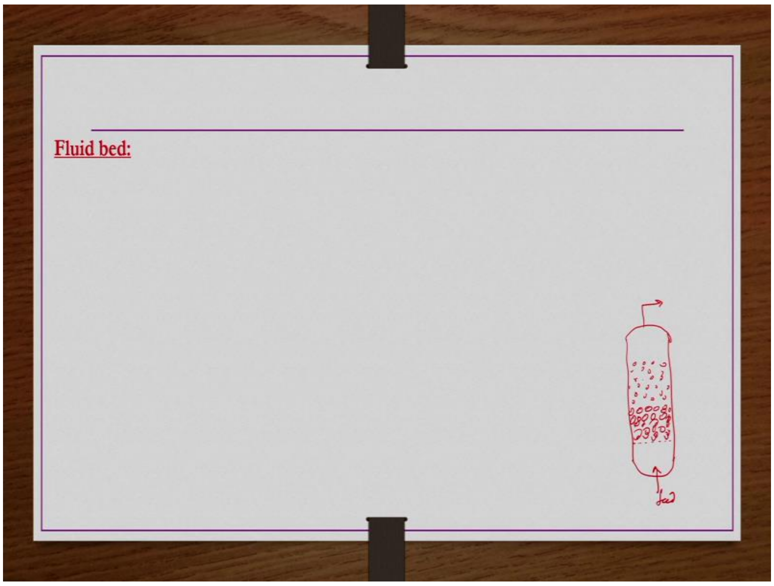

Now, if you have a kind of a fluid bed reactor or fluidized bed reactor so, then how does it look like? Let us say you have a column again. Cylindrical column at the bottom you what you have you have a perforated plate like this right and then this is the top of the column. So, here you are not closing the top of the bed now, rather bed what you have? You have a packing material. now, let us say catalyst like this which is not packed which is not packed initially, right.

Now, these reactant gases or whatever feed is there that passes through the bottom and then there will be a certain point where the pressure drop whatever the pressure drop is there that is provided for this material feed to flow up you know that would be balanced by the drag force experienced by the particles.

And, then once this pressure drop overtakes the drag force then this particle starts as spinning like this. They will be under fluid like phase, right. They will be behaving like a fluid particle like this. And, then how much pressure drop or the flow rate should you should provide you should provide such as this particle should not go out of the column, right.

So, and then whatever the products reactants are there they will be collected from the top and then you know subsequent operations should be done in general. This is one of the type of fluid bed or fluidized bed reactors, then different types of fluidized bed reactors are also there that is what we are going to see, right.

So, here again similar like fixed bed reactors. These reactors also fluidized bed reactors also used for the some kind of unit operations where heat transfer to be done. They are also used for heat transfer purposes not only for a reaction purposes, ok.

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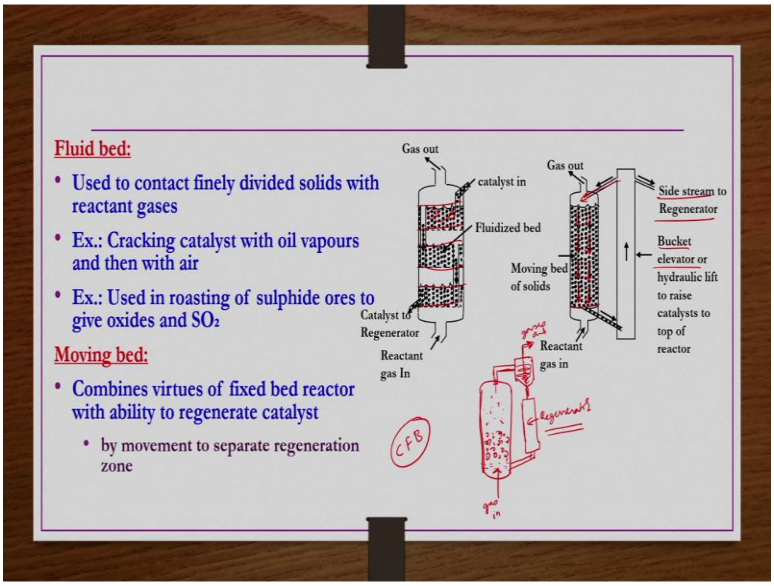

So, these fluidized bed or reactors used to contact finely divided solids with reactant gases in general for example, cracking catalyst with oil vapours and then with air, then used in roasting of sulphide ores to give oxides and sulfur dioxide. These are couple of examples for fluidized bed there are n number of applications, right.

Fixed bed reactors are also known as the packed bed reactors. The bed is fixed or packed that is not moving that is what it mean by. In the fluidized bed the bed is moving the particles are fluidized, ok. So, these in inventions packed and fluidized bed inventions are a kind of a breakthrough in chemical industries and then once they have been developed huge lot of changes have occurred in chemical industries, right.

One other kind of fluid solid unit operations is moving bed reactor where it combines virtues of fixed bed reactor with ability to regenerate catalyst by movement to separate regeneration zone. For example, let us say the pictorially if you wanted to see the moving bed. So, here we have a bed, right. So, there is a perforated plate at the bottom, right.

From the top what we are giving? We are giving catalyst. Actually initially the bed is packed with a catalyst particle or whatever the fine particle that are supposed to be used for the packing. Now, here we are taking reaction. So, catalytic bed we are taking. So, these are all catalytic beds, these are all catalytic particles, right. Initially we are giving them from the top and then we fill up to certain height.

And, then what we are doing? These reactions usually occur at high temperature sometimes high pressure also, but let us take only temperature into the consideration to be consistent with the discussion. So, now these catalytic particles are at certain elevated temperature. When the reactant gas passes through from the bottom that gas interacts with catalyst particles and then the reaction takes place heterogeneous reaction takes place product gases are taken from the top through the gas outlet, ok.

Now, during the reaction it is often happens that the catalyst may get deactivated or it may be required to go some certain kind of regeneration processes. So, stopping the process and then again removing the bed regenerating them and then all that is not going to be efficient both from the technological viewpoints as well as from the economic viewpoints of the plant, ok.

So, for that what we do in general? At the bottom there is a opening through which we can collect the catalyst particles, right and then these particles are elevated to the top section again using the bucket elevator as we have discussed bucket elevators in the previous class and then we raise to the top of the reactor, from here we put them back here again.

If you think that you know the regeneration is required for this particle, so, then you can take them through side stream to regenerator. So, since the bed height is almost like fixed like a packed bed, right, but movement of the bed is there because periodically we are discharging and then putting in new catalyst. So, that the height bed height maintains properly.

Amongst the fixed bed, fluidized bed, moving bed, fixed bed reactor are having a certain advantage of you know you know something like you know getting better quality products etcetera. So, that is the reason people try to maintain certain such characteristics by different ways. But, if you do not have the moving bed or you know catalyst regeneration portion properly, then it is not going to efficient.

If you have only fixed bed then catalyst regeneration is going to be difficult because it is a batch wise you have to remove the bed regenerate the catalyst and then put them back you know that becomes process in batch. So, whenever you have a batch process, the efficiency is going to be less, the yield is going to be less in general. So, right. So, the conversion if you wanted to increase if you wanted to make the process continuous so, then it is better to have such kind of provisions.

One other kind of provision for the you know continuous circulation of the catalytic you know bed or catalytic catalyst particle are circulating fluidized bed reactor. So, where what we have here? Whatever the fluidized bed is there, right so, perforated column is there and then particles are there here catalyst particle, right. So, at the top what you do whatever the outlet is through the outlet you connect it to you know a cyclone separator like this.

So, now, the particles whatever are there so, you know so, now this is the column where we have a bed of catalyst which is movable when we are giving the gas in our reacted reactants in. So, then gradually they will fluidize depending on the balance between delta p and then drag force experienced by the particles once delta p crosses the drag force the particles behave like a fluid particles and there will be fluidized like this.

Now, if you further increase the flow rate what happens this particles will go out of the reactor, right. So, those you know what you do those particle going outside of the fluidized bed column, you know you take them to your cyclone separator. Cyclone separator is an again a unit operation which is used to separate a fine droplets or fine very fine particles from the gases.

So, now this gas is including particles also those particles you know when they collected into the cyclone separators because of the you know centrifugal forces, the particles are being hit to the wall and then the circulations will happen. And, when that move at the bottom when this particle reaches then the circulations will take place like this and then gases go out from the top. Almost pure gases go out from the top whereas; the solid particles are collected at the bottom.

So, these particles in general collected in a regenerator this is nothing, but regenerator. So, this in this column the regeneration of the particles catalytic particles takes place and then once the regeneration is done. So, these things are fed back to the inlet of the you know whatever the column that we are having here fluidized column.

So, now, here the catalyst particles are being circulated that is the reason this is known as circulating fluidized bed reactors; whereas, the other model you know there is no circulation. We are maintaining flow rate such as a; such a way that the particles are not going out of the column, ok.

Sometimes you need to have a kind of a rapid or fast fluidization etcetera. So, under such conditions particles will definitely go outside. So, then so, this kind of provision is better even if you not doing regeneration let us say if there is no reaction and there is no regeneration required, then also if you wanted to if you supposed to protect or save if you supposed to minimize the losses of the particles. So, then you have to go for this circulating fluidized bed system even if there is no reaction, right.

This fluidized bed reactor you may be thinking that the picture shown is here shown here is slightly different than what I have drawn in the previous slide. So, this is actually same one. This is actually similar one only. Only thing, that in the previous picture I have drawn only one particular level of packing.

Now, this packing you can do in multiple levels like this. In fact, this is going to be more efficient, right. So, this is actually you know rather one bed you are having three bed and then all these three beds are connected like this, right. So, when the reactor reactance comes into the reactor through bottom. So, this bed fluidizes and then the particles moves off.

Similarly, the gases moving to the next level, next bed level. So, then again the bed will be fluidized and then there would be reaction between the gas particle and then whatever the solid solids are there here and then like that different levels it may happen. So, the catalyst may be drawn into the reactor through the system here.

First it may be coming to the top one. So, then from the outlet of the top bit, the catalyst particles are withdrawn and then sent to the second level like that you know till the bottom level it has been done like this. Only rather having as I mean like in the previous slide I have shown a single bed, now here within a column we have three such beds. All of them are connected and then being fluidized in a sequenced manner, ok.

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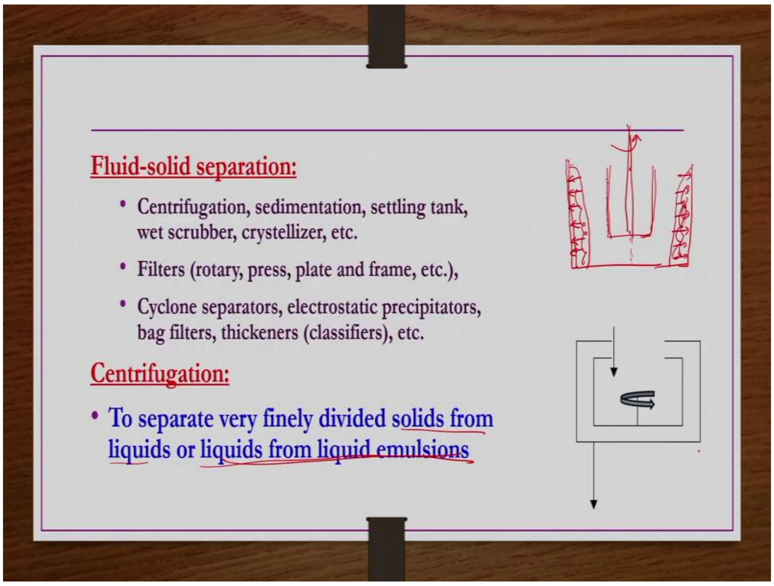

Then fluid solid operations many are there. Some of them are discussed here: centrifugation, sedimentation, settling tank, wet scrubber, crystallizer etcetera. Then filters like rotary filters, press filter, plate and frame filt plate and frame filters etcetera. Cyclone separators, electrostatic precipitators, bag filters, thickeners or classifiers etcetera. Centrifugation, it is used to separate very finely divided solids from liquids or liquids from liquid emulsions. In this section what happens?

You have a ball mounted in another ball like this. So, inner ball in general is perforated sometimes, sometimes it is not, right? So, what happens when you take the material inside and then you rotate the inner ball at certain rotational velocity then what happened because of the centrifugation force heavier particles whether they are fluids or you know solids if they are two liquids then you know you know heavier liquid particles.

If it is liquid-solid, then the solid particles would be attached to the outer wall because of the centrifugal force there will be rather attached, there will be force towards the outer wall and then collected as a kind of a you know you know cake towards the outer wall of the outer container; inner one is rotating. Outer one may also be rotating depends on application. So, this is what happens basically in centrifugation.

All these equipment, as I mentioned their detailed working principles, advantages, disadvantages in all other details you will be discussing or studying in different courses like mechanical unit operations, mass transfers and then heat transfers, reaction engineering etcetera. So, here we are only giving a few details minimum details only. So, the same thing about centrifugation is pictorially shown here again.

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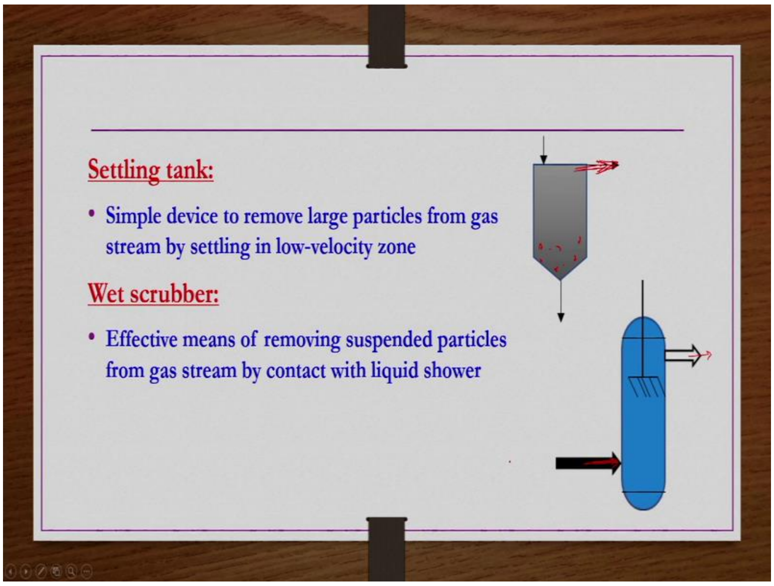

Then, settling tank – they are simple device to remove large particles from gas stream by settling in low velocity zone. So, we have a container here what we do particle lead and gases whatever are they we allowed to come into this container. So, the particles are having you know higher settling velocity compared to the gas particles rather gas particles do not settle at all.

So, those gas particles gas may be collected from the top like this whereas, the settled particles here you know they will be collected through the bottom discharge. Wet scrubbers – effective means of removing suspended particles from gas stream by contact with liquid shower is done in this wet scrubber.

So, let us say in the same container here whatever we have. So, we are here in the settling tank we are allowing the particle to settle on its own based on its settling velocity. A settling velocity depends on the delta rho, viscosity of the fluid and then all that, right.

So, but now if you provide some kind of liquid spray here then what happen? This particles, solid particles would be wet quickly and then they will be collected at the bottom as a wet cake kind of thing; whereas the gas particles or the gas would not be wetted by the liquid and then they will be you know collected from the top you know in a similar way. So, the same thing is shown here, right.

We have a column. From the bottom we are giving or allowing a gas which is containing particles also, right? It is raising up and then from the top we are spraying water, liquid water, water or liquid mostly water only so that this particle get wetted and then collected from the bottom whereas, the clean almost clean gases are collected from the top.

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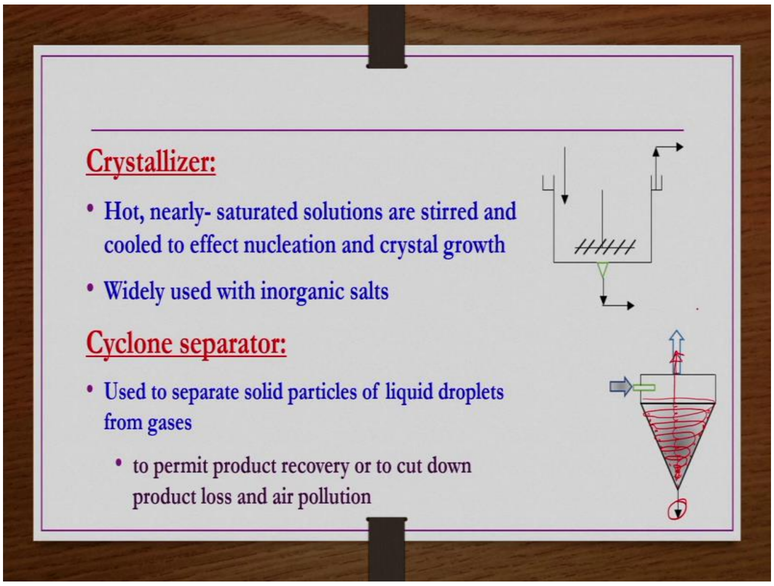

Crystallizer: Hot nearly saturated solutions are stirred and cooled to effect nucleation and crystal growth. Pictorially it is shown here. They are widely used in inorganic salts. Cyclone separator: used to separate solid particles of liquid droplets from gases or very fine or very fine solid particles from the gases – to permit product recovery or to cut down product losses and air pollution.

In air pollution also or whatever the effluent gases there from the industry, you cannot put them or leave them in environment as it is because they may be containing several particles and then they may be harming the environment. So, then that effluent gases air whatever is there that has to be purified through passing through the cyclone separator, right.

So, pictorially as I shown here, so, when the particle lead and gases comes here. So, they come at a certain high speed so, then when they come here they hit here. So, then they lose certain amount of kinetic energy. So, they come here like this. They form a kind of a vertex like this and then moment they reach at the bottom they have some the remaining you know energy whatever is there because of that one they form a secondary circulations or vortex form at the center and then through which the clean gas goes out.

Whereas, when these streams coming and hitting the walls, so, then when they hit the wall so, the particles whatever are the droplets whatever are there they will lose their kinetic energy and they will be falling down like this. And, then from the bottom we will collect we will be collecting the solids and then clean all or almost clear gases we are allowing to pass through from the top.

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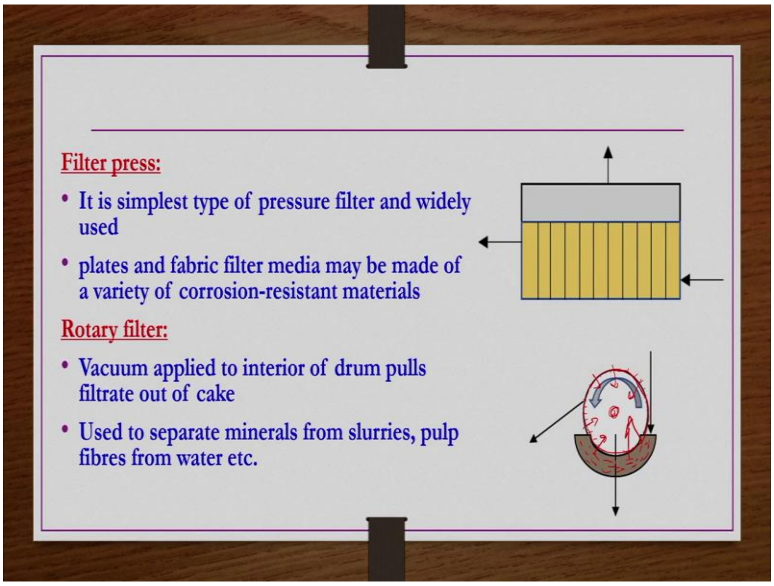

Filter press it is simplest type of press filter and widely used pictorial it is shown here. Plates and fabric filter media may be made of a variety of corrosion resistant materials. Rotary filters vacuum applied to interior of drum pulls filtrate out of the cake. Used to separate minerals from slurries pulp fibers from water etcetera.

So, pictorially what you see? So, let us say you have a cylindrical drum like this two d visualization we are showing here like this. This drum usually a perforated one. It is a perforated one there is a filter cloth. There is a filter cloth covering this particular drum right, ok.

Now, what you do you apply vacuum inside the drum this is rotating and then you apply a vacuum inside the drum. So, then what happens? So, then from this slurry tank whatever is there from here, this is a slurry tank you know in which this drum is inserted like this.

So, and then you are taking out the liquid from this you know slurry tank so that you can get a concentrated cake and or a clear liquid filtrate both are both, ok. So, now here so, when apply the vacuum the clear liquid goes through and then will be collected inside the cylinder and then through the exit this this clear liquid is collected.

At the outlet you know filter cakes forms like this. Unit operations are very essential part of mechanical unit operation course, where you will be discussing you know what are they what are the filter media and then what are their properties should be, what are the working place or principles, how to design them, what are the equipment available and all those things you will be studying in a different course.

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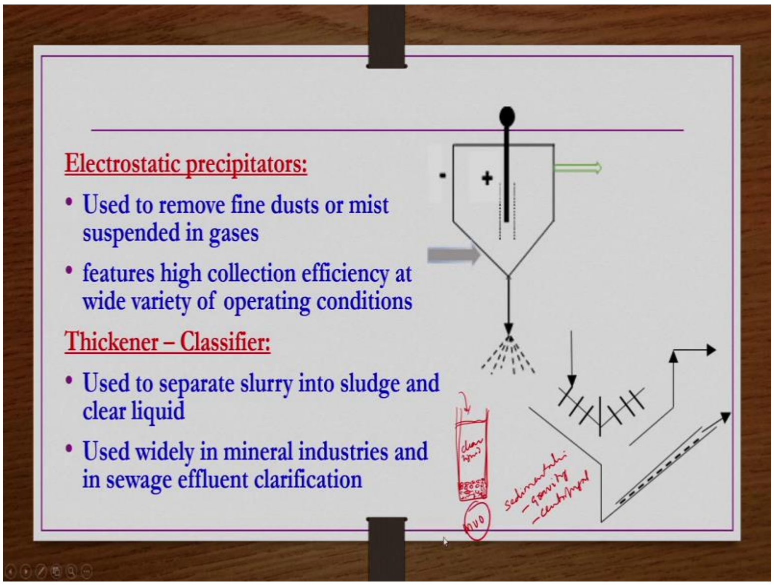

Electrostatic precipitators: used to remove fine dust or mist or mist suspended in gases. Features, high collection efficiency at wide variety of operating conditions. Pictorial it is shown here. So, it is looks similar like you know whatever we have a cyclone separators etcetera, but only thing that here electrostatic precipitation precipitators are used. So, then you have a charge column.

So, different charges are there. When the particles comes here based on the charge differences the separation occurs whereas, the clean gases are taken from the top. Thickener or classifiers used to separate slurry into sludge and clear liquid; used widely in mineral industries and sewage effluent clarifications. So, they can be of batch process, they can be of continuous process like this. The continuous thickener one of the continuous thickener is shown here pictorially.

Batch thickener is nothing, but simply a container tall container in which you are allowing the slurry in which you are you are allowing slurry or pouring in the slurry and then you allow for certain time. So, after certain time what happens all the solid fine particles should be settled at the bottom as a kind of thick you know slurry. So, thickness. So, and then above you have a clear liquid. After certain a certain time you have above a clear liquid kind of thing. This is a batch process.

Same thing occurs here, right. So, but this occurs at a continuous mode, so that you know the clear liquid as well as the solid settled at the bottom are removed continuously, right. They are also called as you know sedimentation tanks or the process is known as the sedimentation. They are again based on the driving force. They are gravity sedimentation and then centrifugal sedimentation are all there. So, that again you will be studying in mechanical unit operations course anyway.

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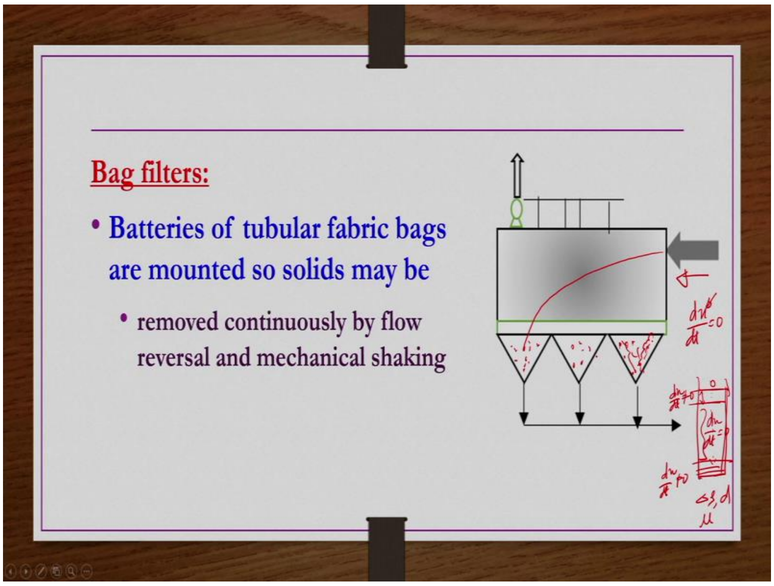

Then bag filters is very simple process where batteries of tubular fabric bags are mounted. So, solids may be removed continuously by flow reversal and mechanical shaking. So, let us say you have a you know a column like this. Now, what you have? You are you are having different bags fabric bags like this 1, 2, 3 like this and number of you can have.

What you can give input? You know gas which are containing solid particles; solid particles of different size different density, right. So, then depending on the size and then density difference these particles would be having different settling velocities free settling velocity.

Free settling velocity you might have seen studied what it is like you know if du by dt is equals to 0 or with time the settling velocity u it does not change, then we call it as a free settling velocity, ok. So, what do you mean by it is? Let us say you have a column right in which let us say your particle you are releasing. This column is filled with some kind of solvent or liquid or whatever. So, gradually this particle settles in.

So, when this particle is settling, so, initial certain reason of settling distance, the particles will have a different terminal velocity. So, that du by dt will not become 0, at the bottom also similar kind of situation should be there where du by dt will not be 0, but in between there would be certain distance. The velocity you know the velocity changes with respect to time would be 0. So, that region is known as the free settling region and then the velocity that particular velocity is nothing, but free settling velocity, right.

So, this depends on the delta rho and then size of the particle and then viscosity of the fluid in free settling etcetera, all those things. These details also you will be discussing in mechanical unit operation course anyway. So, but basically what you understand if the particle is bigger if the particle size is bigger and then delta rho is larger, so, then such particles can have a higher settling velocity.

So, that means, moment they enter in so, the particles which are having higher settling velocities will be quickly collected or quickly settling at the moment they enter the bags and then they will be collected here in a bag, right. So, then here you can have the bigger particle or heavier particle. Let us say if density difference is same for all of them. So, then probably the bigger particles you collect here.

So, the particles which are having the free settling velocity very small value so, they gradually you know lose their energy kinetic energy and then they settle here at the last, right. So, then here these particles you know are very fine or delta rho is very small for those particles. So, such kind of particles will be collected here and then in intermediate particles will be collected in between like this. So, these principles also you will be discussing in other courses.

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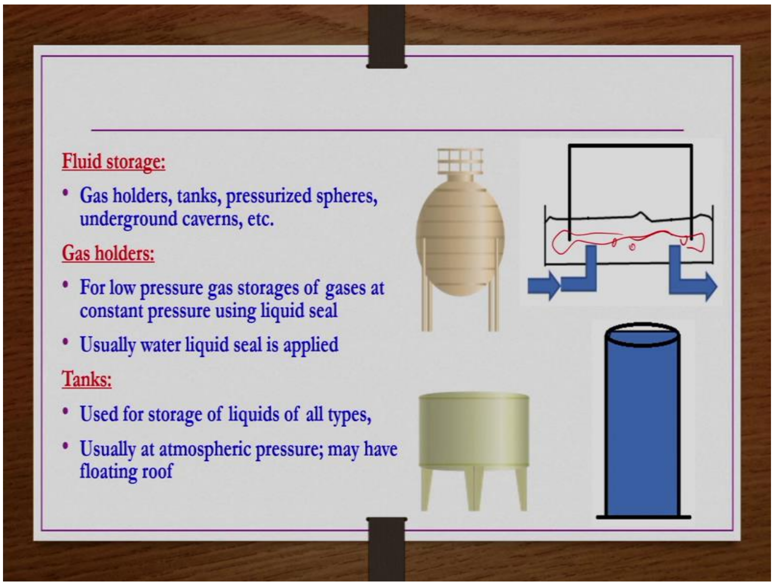

Next is the fluid storage equipment. There are several fluid storage equipments are there like gas holders, tanks, pressurized spheres, underground caverns, etcetera. Pictorially it is shown here. Let us say gas holders for low pressure gas storages of gases at constant pressure using liquid seal we use such kind of gas holders. And, then usually water liquid seal is applied and then pictorially it is shown here.

So, whatever the low pressure gases that you wanted to store. So, that is what it is occupied here and then at the top of this one you have a kind of you know water liquid seal. Another kind of storage is simple tanks storage of liquids of all types can be done in these kind of tanks. Usually they are stored at atmospheric pressure, may have floating roof. For example, they are shown here simple tanks in general you might have seen several tanks such kind of tanks.

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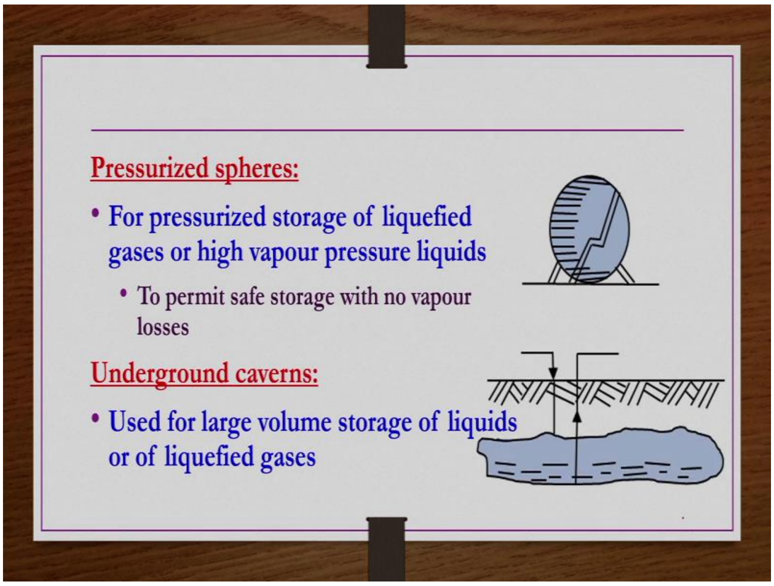

Pressurized spheres – for pressurized storage of liquefied gases or high vapour pressure liquids these pressurized spheres are used so that to permit safe storage with no vapour losses. Pictorially shown here. Then underground caverns – used for large volume storage of liquids or of liquefied gases. Pictorially they are shown here like this, ok.

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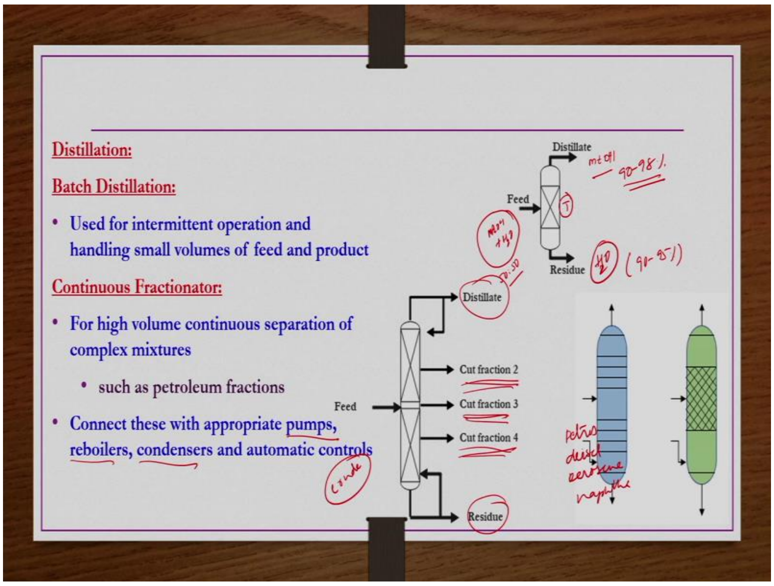

Next important unit operation is distillation. There are different types of distillations are there. So, then we are going to see only batch and continuous distillation. Batch distillation used for intermittent operation and then handling small volumes of feed and product.

Pictorially it looks similar like you know fixed bed reactor, but it is not like it is not a fixed bed reactor. So, whatever the feed, actually distillation is used for a purification purpose. Let us say in the feed you have a methanol plus water you have a plant where methanol has been produced, but it is not in pure form; lot of water is there. So, right after the unit process you have this is the product.

So, this one you wanted to purify this probably you can take to the distillation column and then you apply temperature such a way that you know one of the component which is more volatile you know the temperature should be lower than the boiling point temperature of a more volatile component or close to the boiling point temperature of a more volatile component.

So, that more volatile component can evaporate quickly and then that forms a kind of a distillate. Here at the top again we have a condenser and then in the condenser that which is in the condenser the vapours are being condensed. Now, since this temperature operating temperature is at the boiling point of more volatile component or close to the boiling point of more volatile components, most of the vapours containing more volatile components.

So, then more volatile components are collected from the top through condenser as distillates whereas, the less volatile components are collected from the bottom as a residues. So, let us say in this case if you have methanol water, so, the distillate is pure in methanol and then residue is pure in water. How pure, it depends on your operating conditions and then and all that, right.

So, let us say initially you have 50 versus 50 50 by 50 ratio, then here methanol may be 90 to 98 percent or even more and then here water may be 90 to 98 95 percent or something like that remaining small amount is methanol. Here remaining small amount is water like that. So, it is more concentrate more purified methanol you get it. So, this is what happens in distillation.

Then, continuous distillation or continuous fractionators: for high volume continuous separation of complex mixtures these are used such as in petroleum fractions. Connect these with appropriate pumps, reboilers, condensers and automatic controls etcetera. What are these reboilers condensers they are again other kind of a unit operation that we are going to see.

Let us say pictorially if you see, we have a feed and now this fractionator is having different you know sections, so that you know high volume of the feed can be taken and then different cut fractions may be collected. In addition to simple distillate and then residue unlike in batch distillation in between you can get a different cut fractions often you know different product qualities like that is also possible.

In petroleum crude you know when you do the distillation or fractionation like this you know there are different components are possible to get like you know petrol diesel and then kerosene and then after etcetera these kind of things are possible. So, they may be collected like this in different fractions, ok. One fraction may be pure in petrol, another fraction may be pure in diesel, another fraction may be pure in kerosene like that, ok.

A similar kind of representation is given here as well for a continuation fractionation continuous fractionators. They are all representation. They are not true schematic of any of the distillation or any of the unit operations as I mentioned at the beginning of the week they are a representation only, they are a schematic representation only.

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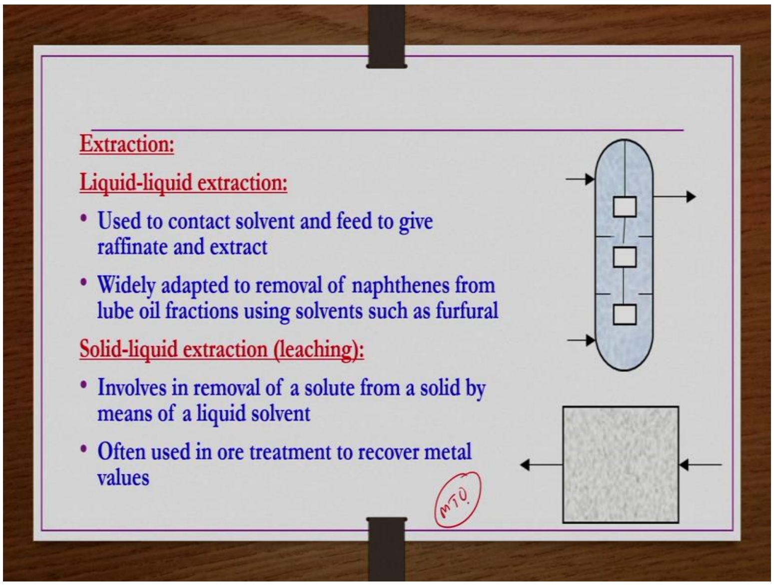

Extraction: liquid-liquid extraction and solid-liquid extraction are possible. In the liquid-liquid extraction they are used to contact solvent and feed to give raffinate and extract. Widely adapted to removal of naphthenes from a lubricated from lube oil fractions using solvents such as furfural. Pictorially it is shown here.

Solid-liquid extraction which is also known as the leaching. It involves in removal of a solute from a solid by means of a liquid solvent. Often used in ore treatment to recover a metal values etcetera. So, whatever the distillation in previous slide that we have seen in the extraction this slide we have seen, this these topics you study in mass transfer operations, right which you may be studying in 5th or 6th semester of your UG course.

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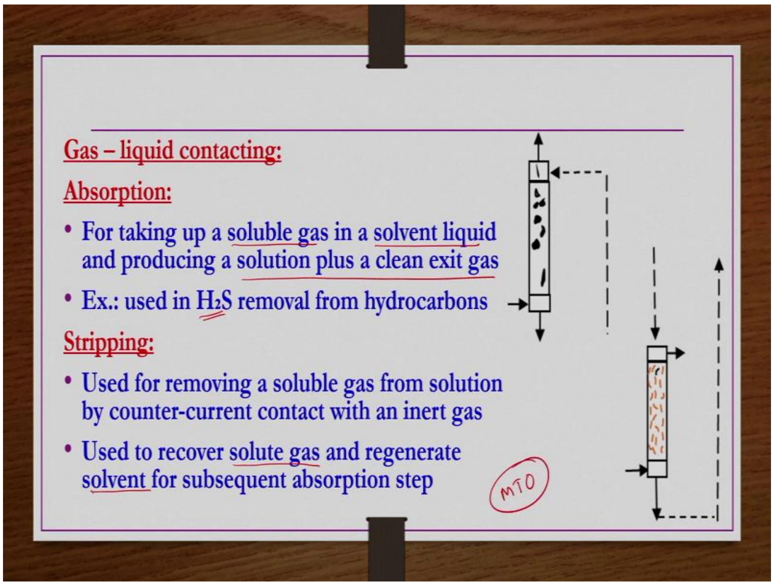

Gas-liquid contacting: absorption: for taking up a soluble gas soluble gas in a solvent liquid and producing a solution plus a clean exit gas we are using this absorption, alright. Such as, used in H 2 S removal from hydrocarbons usually also contain H 2 S because petroleum crude whatever we have the sulfur components would also be there.

One of the common reaction in petroleum industry is that hydro treatment of a different types of crudes. When you do the hydro treatment, so, then this H 2 S will also form and then that has to be removed. Removal from hydrocarbons if you wanted to do, you have to do the absorption, right. So, pictorially it is shown here.

Next is stripping. Stripping is opposite of a absorption. What does mean by opposite of absorption? Here it is used for removing a soluble gas from solution, from solution which is containing gas also. If you wanted to remove a gas which is already dissolved in a solution then you know you have to you will be doing the stripping by counter current contact with an inert gas.

It is used to recover solute gas and regenerate solvent for subsequent absorption steps in general, ok. Pictorial representation is shown here. These two topics also discussed in thorough in a mass transfer operations course.

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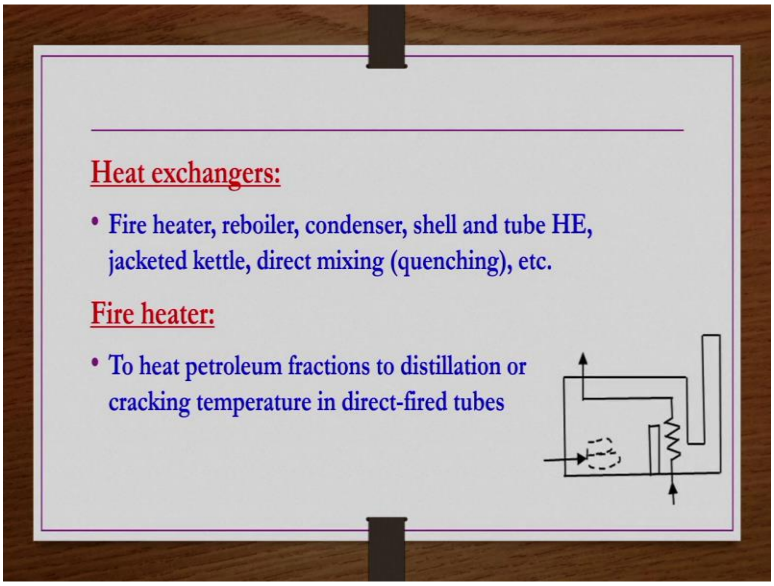

Heat exchangers: there are different types of heat exchangers are there. One particular type of heat exchanger which is very common is a shell and tube heat exchanger. Others are like fire heater, reboiler, condenser, jacketed kettle, direct mixing or quenching etcetera.

So, fire heaters – to heat petroleum fraction to distillation or cracking temperature in direct-fire tubes. It is used pictorially it is shown here.

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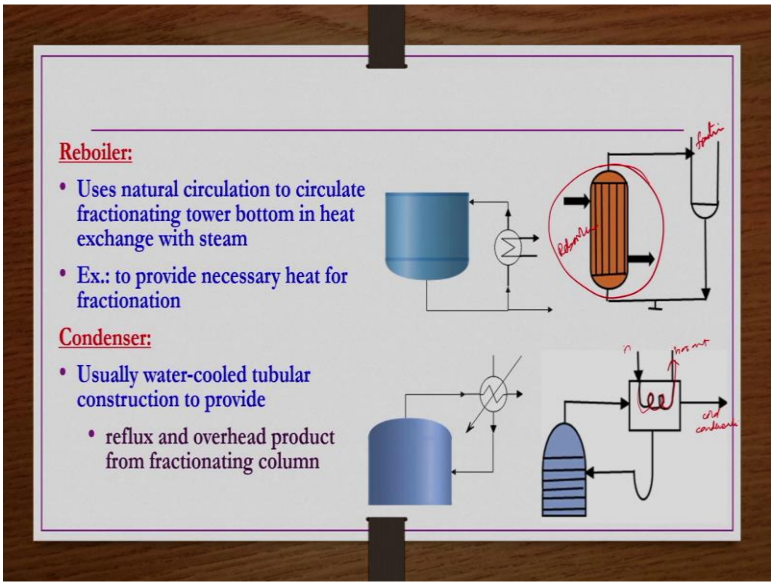

A reboiler uses natural circulation to circulate fractionating tower bottom in heat exchange with steam. Example: to provide necessary heat for fractionation. Pictorially if you see, so, this is the fractionator. This column which is not completely shown now here the reboiler is important. So, this is reboiler actually.

So, whatever the residue that you have from the bottom that you collect and then pass through the reboiler and then where you are providing certain amount of steam etcetera. So, that to heat it again and then that particular after passing through the reboiler that will be fed back to the fractionator column.

Fractionation column, actually fractionation column is very tall very big and then reboiler is very small in comparison to each other. So, but however, now here we are talking about reboiler. So, it is shown in a bigger size. Condenser usually water cooled tubular construction to provide reflux and overhead product from fractionating column, these are used.

So, the at the top whatever the distillates are there so, vapours whatever the more volatile component vapours are there, they are passed through a condenser where water cooling tubular construction is provided so that you know actually the gas passes through here like this whereas, the water cool jacketing tubing is provided something like this here.

So, water cold water in is passed through here and then when the hot vapors comes through here. So, the heat transfer takes place. So, then cold or you know condensate taken from here whereas, the hot water out is taken from the here out like this. So, this is a continuous continuously cold water is provided. So, that sufficient you know condensate condensation can take efficiently, ok.

So, then whatever that is not being collected as product that can also be sent back to the fractionator again. Another representation of same condenser is provided here.

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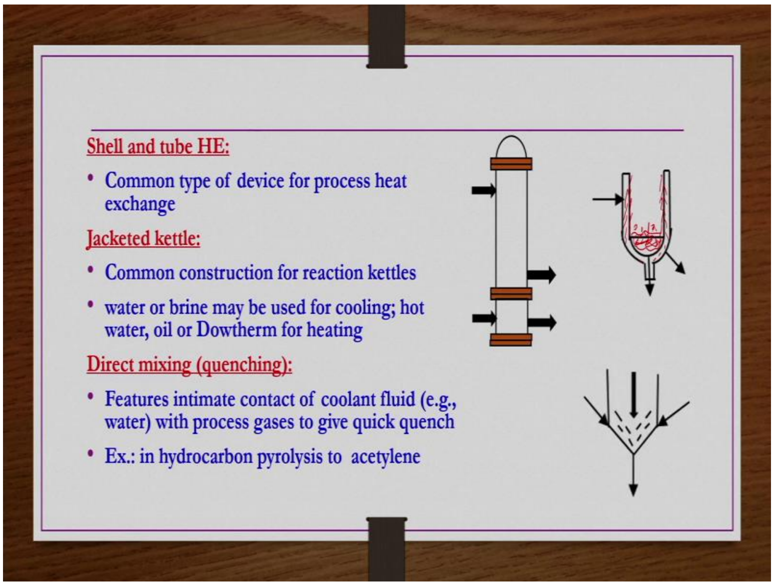

Shell and tube heat exchanger common type of device for process heat exchange. Pictorial it is shown here. Jacketed kettle: common construction for reaction kettles; water or brine may be used for cooling; hot water oil or dowtherm for heating is used in general. So, let us say what we have? We have a reactor vessel like this. This is the reactor vessel and then whatever the reactant that you wanted to react with or the provider, they are taken here.

There is a kettle like this jacketed kettle is I mean is there. So, that is jacketed like this. So, through this one you supply like you know water or brine or hot water, oil etcetera. So, that required a energy may be transferred to the contents that are present inside the container like this, very simple.

Direct mixing or quenching: features intimate contact of coolant fluid example water with process gases to give quick quenching. In a chemical process industries there are several gases are there hot gases are there which may require to cool down immediately or as faster as possible under such condition this direct mixing or quenching is carried out. For example, in hydrocarbon pyrolysis to acetylene production.

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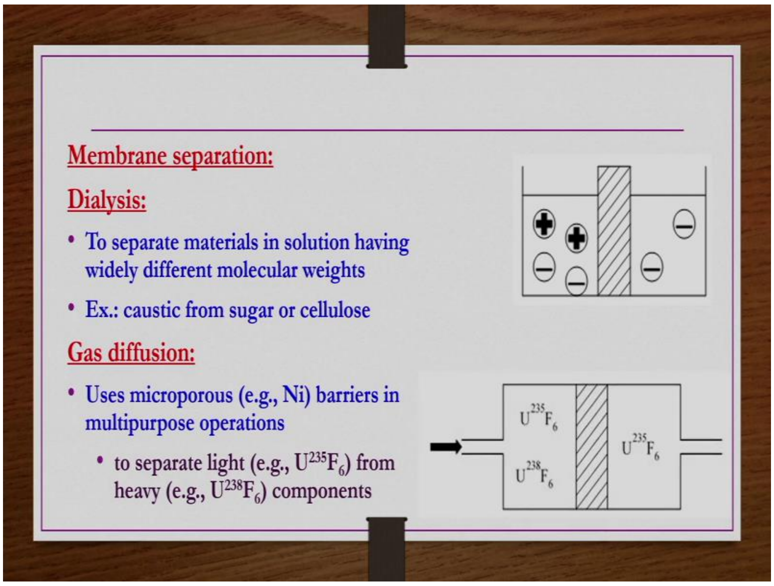

Membrane separations, there are different types of membrane separation processes are there like you know micro filtration, ultra filtration, nano filtration, dialysis, electro dialysis like several types are there. So, some of them based on the size, some of some of them are based on the delta p, some of them are based on delta c, some of them are based on the delta charge whatever electromagnetic force difference differences are there.

So, emf delta, emf etcetera those things are the driving forces, right. We can we are not going into all details. In fact, membrane separation itself is one separate course probably taken as a course one single course. So, we see a couple of membrane separation processes here. So, one is the dialysis: to separate materials in solution having widely different molecular weights; caustic from sugar or cellulose etcetera pictorially shown here gas diffusion also.

Similar way uses microporous barriers let us say nickel barriers like you know nickel plate is there which is having the porous structure which is very small micron size or even smaller in multipurpose operations such kind of barriers are used so that gas diffusion can take place which is.

It is used like you know for example, to separate light uranium 235 F 6 from heavy uranium 238 F 6 components pictorially they are shown here. So, these are a few type of common unit operation that we may encounter in majority of the chemical plants, right. So, till now what we have seen?

Chemical plants, what are the unit processes and then what are the unit operations that are very common in most of the chemical plant that is what we have seen, right. So, next week what we do? We start discussing on production of different types of inorganic chemicals. So, there you may be seeing in flow sheets different types of this unit operations or unit processes may be occurring, right.

So, but however, before going into those details what we see? We see a few general principles of a chemical engineering which are more essential from the chemical plant viewpoints, right. So, its again huge amount of information like if like you know you know entire chemical engineering is useful in chemical plants, right. So, including process control kind of subjects optimization kind of subjects etcetera are also be used most in most of the chemical plants, right. So, but we cannot discuss all of them, right.

So, but however, before going to see production of certain kind of chemicals inorganic chemicals, it is rather important rather directly going into the production details of such chemicals, it is very essential to have a kind of recapitulation of some of the important chemical principles or some of the important principles of chemical engineering that are very essential in chemical industries.

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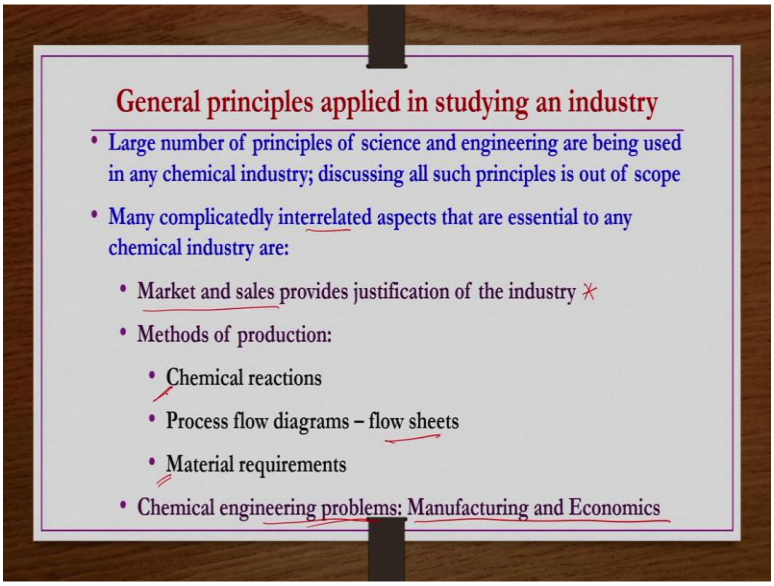

General principles applied in studying an industry. Large number of principles of science and engineering are being used in any chemical industry; discussing all such principles is out of scope as I mentioned. However, many complicatedly interrelated aspects that are essential to any chemical industry are provided below: like market and sales provide justification of the industry that is very essential very essential a priori of chemical engineering knowledge, right.

You have all chemical engineering knowledge and then you can successfully install a plant and then produce the material, but there is no market then there is no use at all, ok. Then methods of production: in the methods of production what are the important things that you feel to have a kind of information a priori?

Like chemical reactions, process flow diagrams or flow sheets, then materials or material requirements etcetera. These things are very essential from the methods of production viewpoint then chemical engineering problems where manufacturing and economics should also be considered.

Now, what we see? They are you know very wide. So, one is chemical engineering problems talking about manufacturing and economics, other one is talking about talking about market and sales, another one talking about the reactions and then flow sheets and then materials etcetera. So, they are very different from each other. So, they are complicated and interrelated as well, ok.

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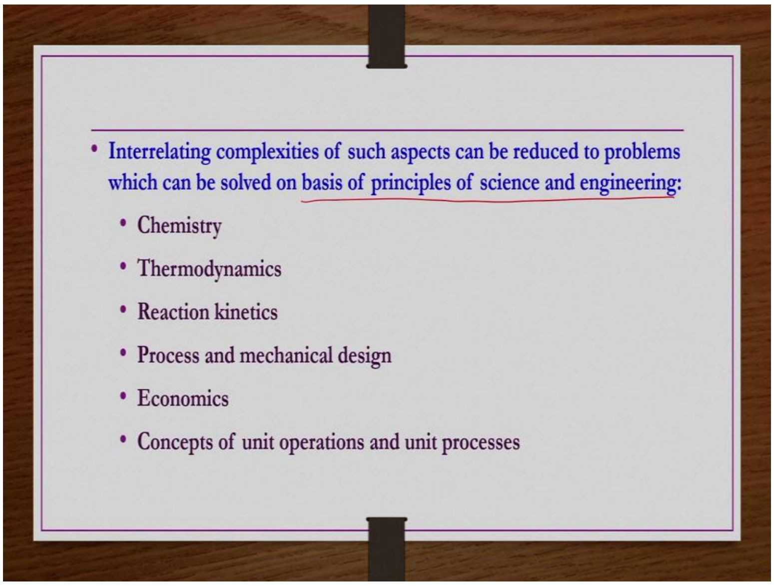

So, interrelating complexities of such aspects can be reduced to problems which can be solved on basis of principles of science and engineering. We will see what are those you know principles of science and engineering that are important; only a few of them that we are going to see.

One is the chemistry is important, next one is the thermodynamic information is important, reaction kinetics is very essential for any chemical plant, then process and mechanical design of the plant is usually two types – one is the process design where you use the all chemical engineering principles make.

Another one is the mechanical design where you use some of the mechanical engineering and information like construction material, you know thickness of the material, react thickness of the material that is used for constructing a unit operation or reactor etcetera those kind of things are coming from mechanical design point. So, those things are also important.

Then economics is very essential that is also important. Concepts of unit operations and unit processes are anyway very very important. That is the reason you know you know for three to four semesters of the UG courses are dedicated to different types of unit operations and unit processes in chemical engineering. So, we see a few basics of them rather going in detail of each of them is not possible. So, we see only a few details.

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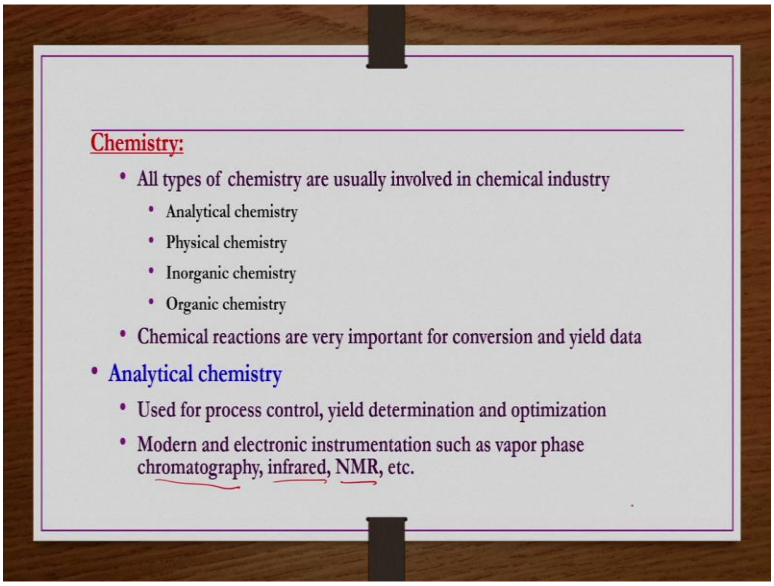

Coming to the chemistry, all types of chemistry are usually involved in chemical industry like analytical chemistry, physical chemistry, inorganic chemistry, organic chemistry. Chemical reactions are very important for conversion and yield data, obviously. Then analytical chemistry why it is used? Because, it is used for process control, yield determination and optimization etcetera.

Why it is important? For example, modern and electronic instrumentation such as vapour phase chromatography, infrared, NMR etcetera. All of these are based on this analytical chemistry principles. And, then we often use these you know characterization techniques for analysis of the products etcetera in chemical plants as well as the chemical engineering laboratory. So, it is very essential.

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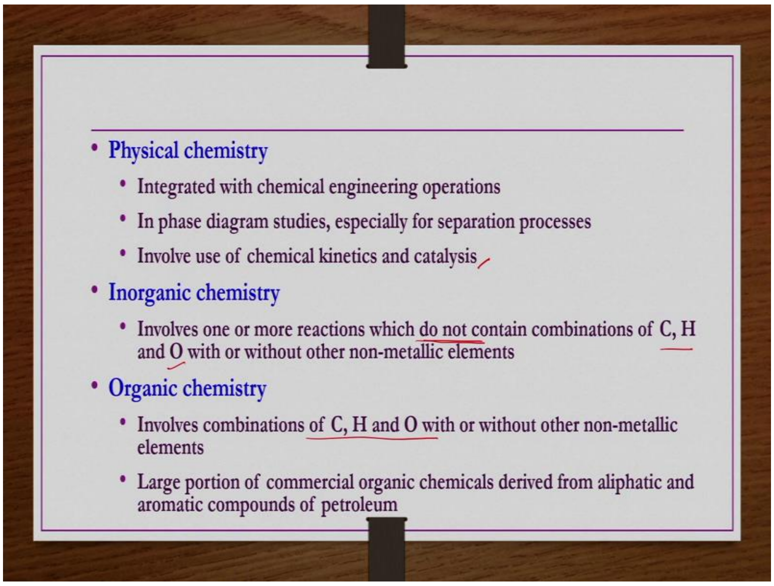

Next one is physical chemistry. It is integrated with chemical engineering operations. In phase diagram studies especially for separation processes. Involve use of chemical kinetics and then catalysis. Then, inorganic chemistry – it involves one or more reactions which do not contain combinations of C, H and O with or without other non-metallic elements.

Then, organic chemistry: it involves combinations of C, H and O with or without other non-metallic elements, ok. Large portion of commercial organic chemicals derived from aliphatic and aromatic compounds of petroleum are coming under organic chemistry part in general.

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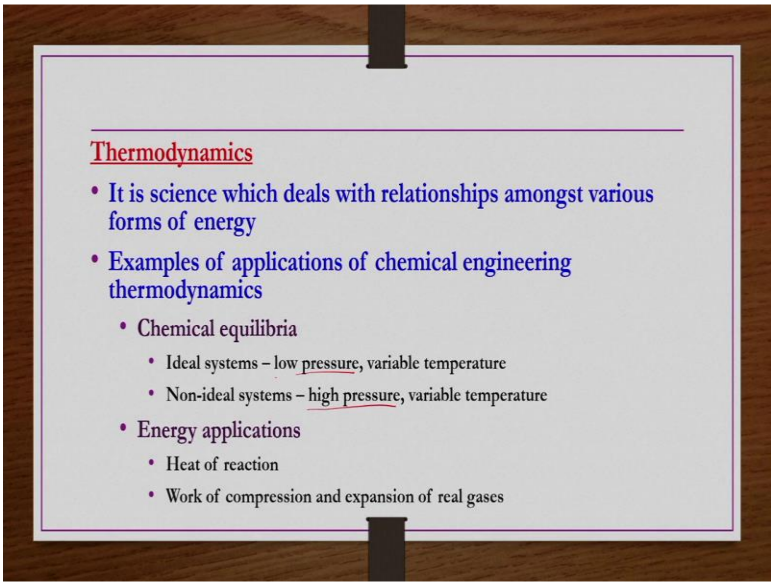

Next is thermodynamics. It is very essential part of chemical engineering. Why because it is a science which deals with relationships amongst various forms of energy and then without energy you cannot run any of the chemical plant, right. Definitely you need energy. So, then energy calculations are very essential to understand to understand whether the process is thermodynamically feasible or not.

So, once you understand that once you realize that process is thermodynamically feasible then only you can take that process to industry level, ok. Examples of applications of chemical engineering thermodynamics are like chemical equilibria, then energy applications.

Under chemical equilibria, we have ideal systems and then non-ideal systems. Ideal systems are usually at low pressures; whereas, the non-ideal systems usually at high pressures whereas, the temperature may be variable in either of the system. In energy applications heat of reaction and then work of compression and expansion of real gases are very essential.

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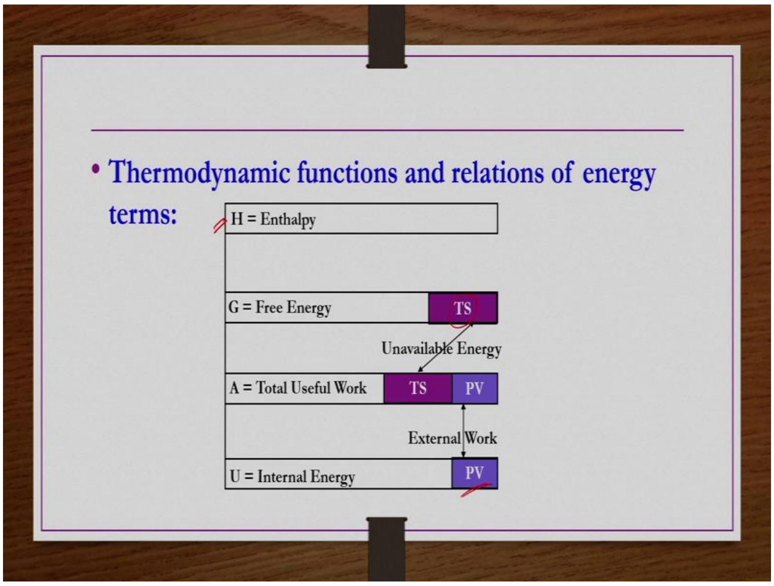

So, thermodynamic functions and relations of energy terms if you pictorially put as a kind of bar diagram if you put, what you can see? You can see let us say the enthalpy of the system enthalpy is the complete one. So, out of which only Gibb's free energy is the free energy that is available. That is, from enthalpy unavailable energy TS if you remove then you get the free energy, and then this free energy is also not useful energy. Out of which only some of them is useful for the total useful work.

So, from here further if you subtract in addition to unavailable energy, if you subtract the external work PV, then whatever the energy is that is only total useful energy for the given process, right. If you wanted to know the internal energy of the system from the enthalpy, if you remove this external work so, then whatever the remaining is that is nothing, but internal energy.

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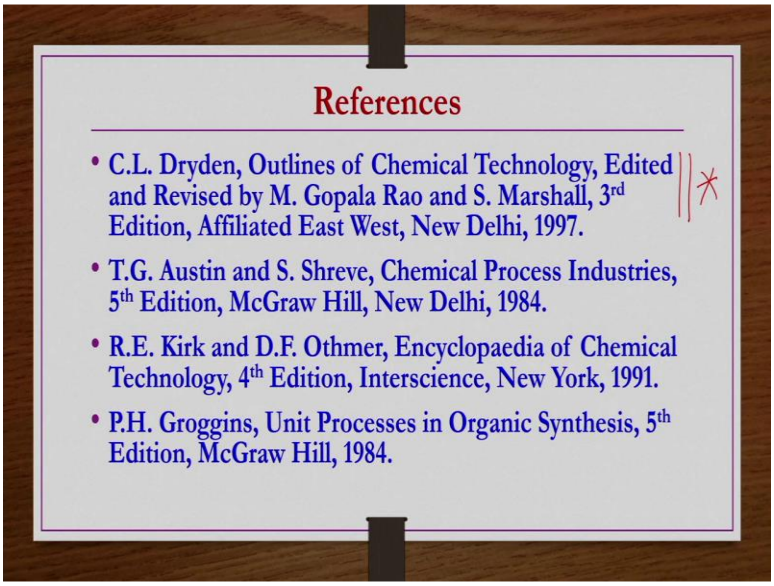

The references for today's lecture are provided here. This particular book is more suitable from the slides point of view that I have shown in this today's lecture.

Thank you.