# Principles and Practices of Process Equipment and Plant Design
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**Module - 02**
**Lecture - 21**
**Tower and Tower internals (Contd.)**

Hello everyone, we are going to continue with the topic Tower and Tower Internals.

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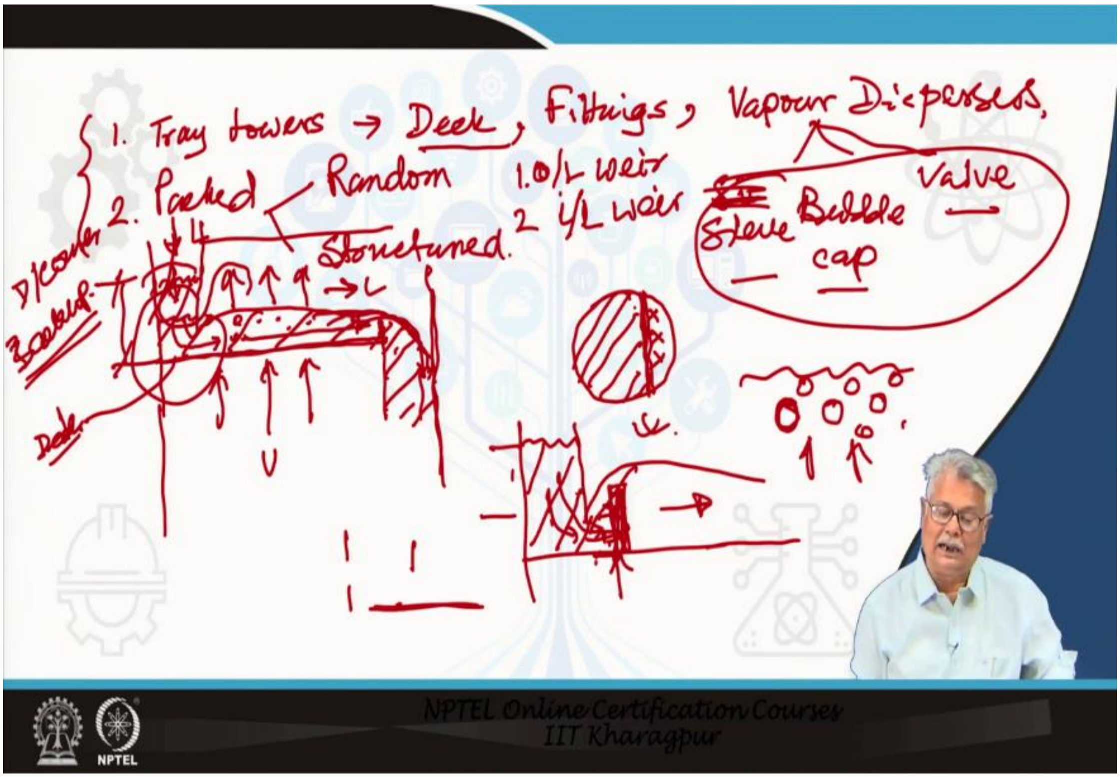


To start with we have a little bit of recapitulation that means, what we have talked about so far includes the tray towers. Whenever we say tray towers, it means the deck, it means the fittings which we did not discuss in the last class but we will do it today, and the vapour dispersers.

Now, when we talk about vapour dispersers, we have found that there are three types. One will be the simple holes that mean a sieve. Then you will have the bubble cap. You also have the valve type. We also have a look at the packed towers which will contain two types of packings. One will be the random packings. The other will be the structured packings.

What we intend to cover certain features which are common to both the tray towers and the packed towers. That means we will look at the different sections of this column and try to see what features are there which are common to both. Possibly, we will talk about some special feature which is required in subcase. The basic thing that we have to talk about is the tray deck first. We will try to understand the construction first.

Just if I look to want to show schematically, a tray deck basically is not a complete circular disc. It is only this part that is present and this is not there. That means, if I draw schematically it will come only up to this. If I take the plane should look like this. we have the down-comer of the upper tray coming and ending with a gap here.

So, what do you have in this case is, you have the liquid pouring in and there has to be a liquid level here. The liquid falling on this tray has to come out of this opening, and it has to fall, flow across the tray. Then finally, use the down-comer of this particular tray and go to the tray below. So, this is our tray deck.

Now, let us see a few features which are required, whether we call it a sieve, or a bubble cap or a valve tray. The basic principle is the same. You will have a pool of liquid, you have droplets, you have bubbles that will be rising through this pool. The mass transfer between the vapour and liquid will be occurring in the interface of the vapour-liquid here.

So, there has to be some arrangement to ensure that what you have here on the tray deck is a pool of liquid. That means the liquid level here should go like this and it should have all such fitting – the sieve, or bubble, or the valve submerged in it. That means, the disperse vapour disperser should remain submerged.

Now, once this has happened, we know that we are going to have the vapour coming from the bottom, the bubbles will go up, and actually, the vapour will be going up this way. Now, I come to the earlier problem which I just stated that how do I ensure that I have a level of liquid on my tray. The simplest way to do it is to provide here a weir. A weir is a vertical sheet of metal that will be restricting and if the liquid has to go from the left to the right, it has to flow over it. So, you have a flow over the weir, and you have it through.

Now, let us see; you have the vapour coming in here, and you have the liquid which goes like this. This liquid comes from the upper tray which is here. It is also possible, it is also possible, that means, I will be having another tray above this.

So, if I have a very little amount of level in this particular down-comer and this depth is called the backup or this is the down-comer backup this particular depth. If I have a very little amount of down-comer backup, it is also possible that part of the gas will start short-circuiting through this.

So, I must also ensure that I have during my operation of a good cross flow tray the liquid phase like this, and a reasonable amount of backup in my down-comer. Otherwise, what will happen; the vapour will start short-circuiting through the down-comer of the upper tray, and will be mixing with the vapour of the tray above it. So, you will be losing efficiency in your fractionation.

Now, how to ensure the downcomer backup? If you look at this portion, it looks like this. I have my tray deck, my downcomer ends here. I have some amount of downcomer back up here, a liquid level. And the liquid comes like this, goes like this, and it flows in this direction.

This gap or clearance below the downcomer provides resistance. This is the major component of the resistance that supports this particular liquid column. This liquid column is primarily supported by the resistance offered as the liquid passes through below the down-comer clearance.

So, one thing is true that if I somehow have a very low liquid level or very low liquid flow in my column, the resistance even with a small downcomer clearance typically the down typically such clearance in industrial columns are never below 4 millimetres, no dimension in the industrial column should ever be below 4 millimetres, 3 to 4 millimetres usually.

Particularly, if it is a clearance, then it will get choked up if you are having any smaller clearance. So, if in such case if I have to maintain the downcomer backup, I may require another weir here right after this to provide additional resistance to the liquid flowing out. So, I have now come across two things. One is an outlet weir, the second one is some sort of inlet weir. What we do know is, we have a look at the other features of how the tray is constructed.

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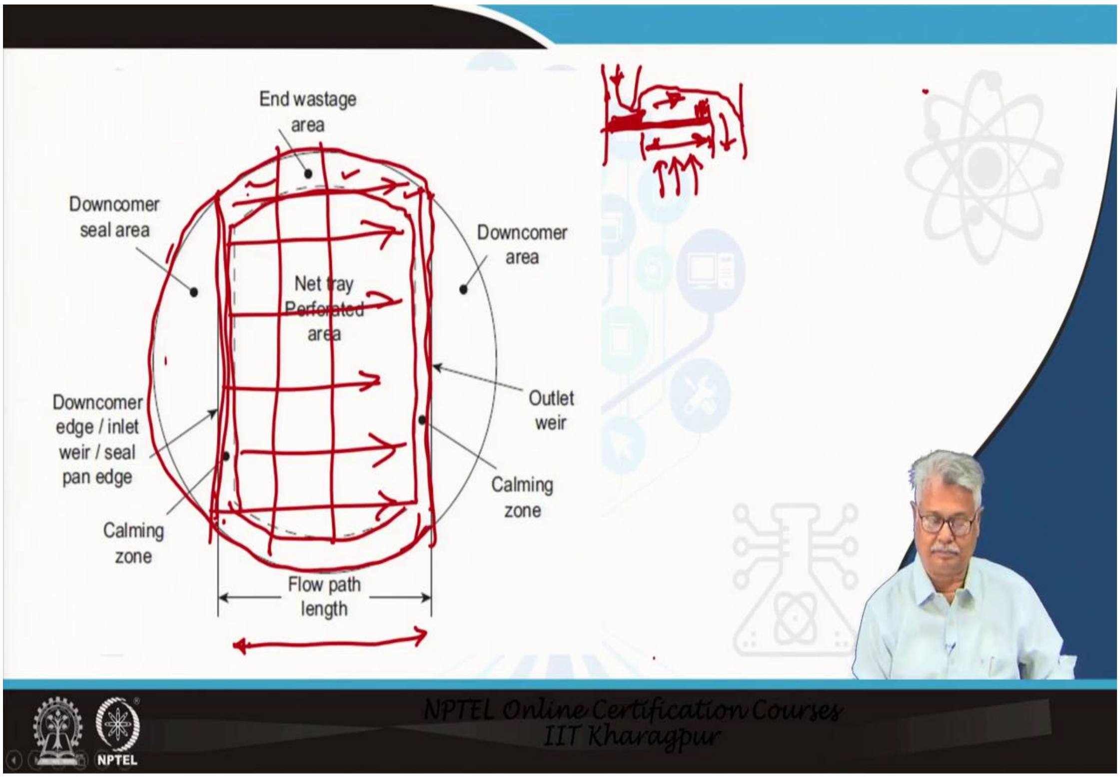


The tray as I have said is only this part. Now, you will have your vapour dispersers quite well located here. The next question perhaps you will have is how is this tray to be fixed? We always draw the tray as something which looks like this in a schematic. This is my outlet weir. This is the downcomer of this particular tray. This is the downcomer of the upper tray. We always say the liquid flows like this over the weir here.

Now, quite naturally such a tray has to be fixed to the wall of the column. That means, I will be fixing it on some fixture which is there which is permanently fixed with the column, it will be bolted. We will look at the features of those. Quite naturally if you are bolting it here you cannot have anything, any vapour dispersers placed in this area. So, this area will be the end wastage area. You will also notice that the actual cross flow path is only from this point to this point on the tray. And it is through this zone only the vapour goes up.

So, what you have here is, this is going to be your flow path length, and it is the path of flow. There is a very special thing, you must have noticed already that it does not have the same flow cross-section. It is maximum at the centre. Minimum at the starting point and at the end. We hope to have a uniform flow, but it never happens.

So, this is also one such reason why you do not achieve 100 % tray efficiency. This portion will not have any perforation, it will have the fixing arrangement with the tray support ring. This is the area that is under the downcomer of the upper tray. So, this is the downcomer seal area. There are downcomer seals that are provided. There are downcomers without the seal also. The downcomer seal will be discussed when we go to the further diagrams.

Immediately, after it comes out, you have a lot of turbulence. Quite possibly you will not be placing here your vapour disperses too close. So, quite naturally what you have after it has come out from this is another zone where you do not put your vapour dispersers. Exactly in the same way you will not be putting the vapour disperser right before your outlet weir. So, this central area is the area where you have either the sieve holes or the bubble caps placed, or the valves being placed there.

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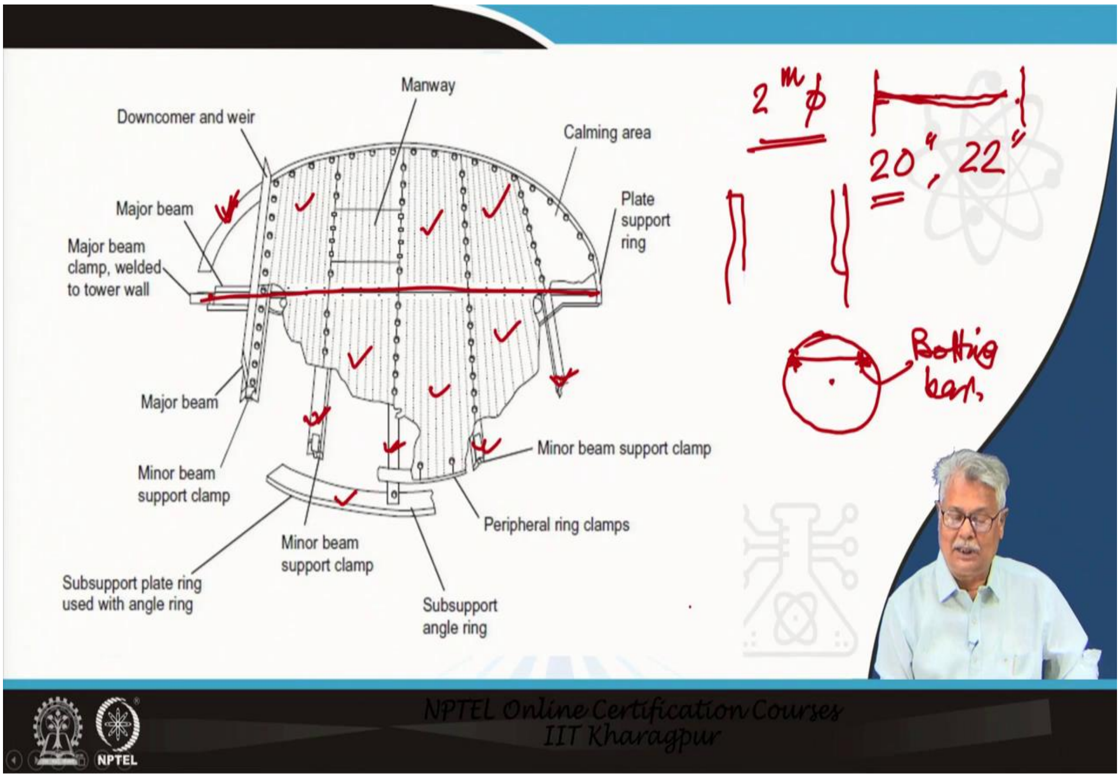


Here is what we have in an actual tray. Let us say the tray diameter is 2 m. Now, the first question is we were saying that the 2 m diameter, we how will we fix the tray? So, what will be there is actually something like this. You will have a tower on which a ring will be fixed. I am not showing this part of the ring and on the ring, the tray deck will be placed.

Naturally, the ring is this one and in this part, this is the ring. Now, there is one more thing the tray has to be fairly rigid. I cannot have any sort of sagging here. In fact, there is a sagging limit when you check your construction. You ensure that your limit is within that particular segment limit and normally you check it with a water level.

Now, we have talked about a 2 m tower which is very common. Now, that means, your tower diameter is 2 m, and 2 m is also the diameter of your tray. So, one way is to have the tray and the tower constructed together, but that is impractical. How will you replace the trays in that case?

So, what is done; the trays are particularly in such type of towers, but always in segments. This is a segment, this is a segment, this is a segment, this is a segment, this is a segment that means all these are segments, and these pieces are assembled inside the tower.

Now, the question comes how will you place it inside? Your tower shell has been erected. So, quite naturally it has to go through the manholes. Typical manhole size will be anything 20 inches or 24 inches or usually 22 inches. That means, the second-largest dimension of your tray segment has to be such that it can be passed through the manhole.

So, quite naturally I by this time you must be appreciated that the dimension of the tray segments has got a very strong relationship with the size of the manhole which is there on the tower shell. Now, once you have put these, they have to be assembled. So, naturally you require support from the bottom.

Usually, there will be at least one major beam, this is the major beam. That means, it is a diametrical beam that is providing sufficient support – a good amount of support to the tray on it. You also have minor beams. This is the minor beam, this is the minor beam, this is the minor beam, these are minor beams. So, you have the minor cross beams which are also attached to the major beam, and they end at where they end at the tray support ring itself. What you have boltings all along.

The tray support ring is bolted. There are boltings on the minor beam support. There are boltings across the major beam support also. I believe by this time you have got a fair idea of placing the deck. You will definitely notice that here there is a downcomer and a weir. Here only the weir portion is shown the downcomer is below this, it is not in view and that is also bolted.

Now, you have a query; I mean you have a very interesting situation here. Suppose, I have a downcomer, which has to be placed. How is it? If I look at the tower, its center is here, and I require a downcomer to be placed here. I cannot afford to have any leakage across this.

So, what is done; you have here, you have here a bar welded which is called a bolting bar. In fact, there are two bolting bars at the two ends of the downcomer, and your downcomer below the deck is bolted here, you have to bolt here. Let us look at a little bit further details beyond this.

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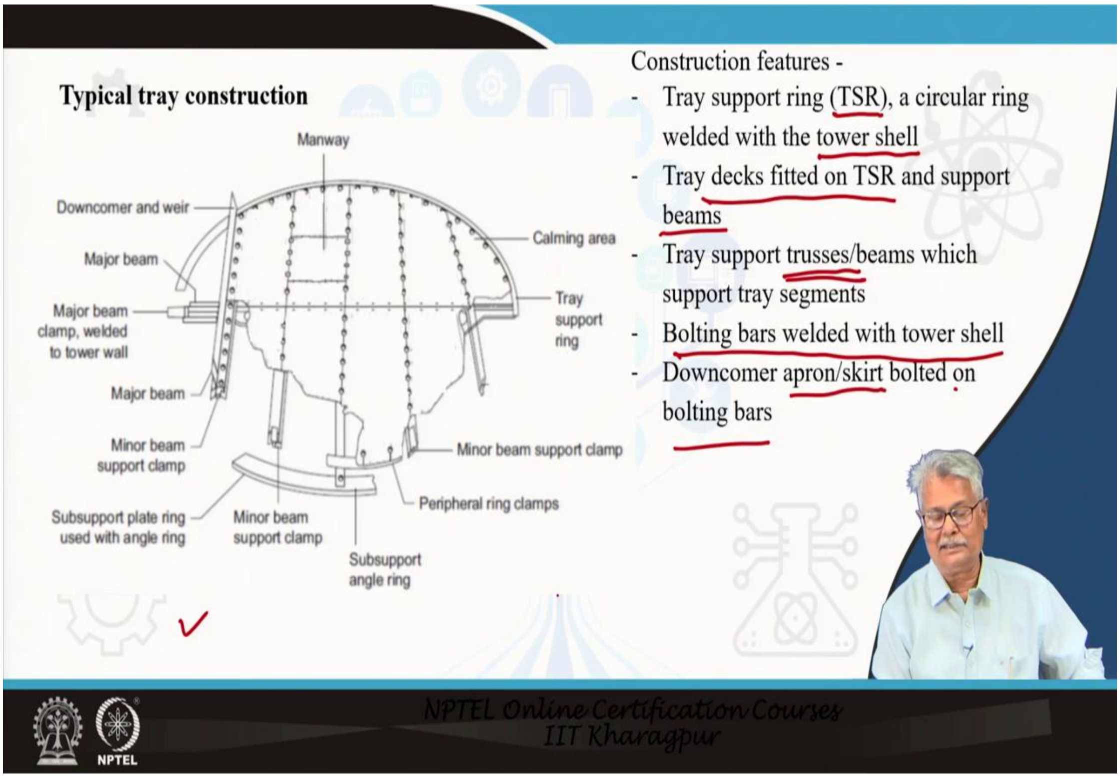


It is the same diagram that you have here. There is nothing else. It only mentions that below the tray support ring, you usually have an angle to provide extra strength. It may be there in some cases, it may not be there in other cases.

So, what features we have so far seen regarding construction? We are aware of the tray support ring which is a circular ring, not complete circle of course but it is welded to the tower shell. It is bolted to the deck. The tray deck is fitted on the TSR and the support beams that we have already seen. The beams may be simple beams, or they could be trusses even.

The trusses are used in case you are having a case in which your construction dimensions are really big. Bolting bars are welded to the tower shell that we have seen. Now, the downcomer apron skirt is bolted on the bolting bars. So, this ensures the placement of the deck. On the deck, whether you have the orifice which is the sieve, or the bubble caps, or the valves these vapour dispersers are placed or fitted.

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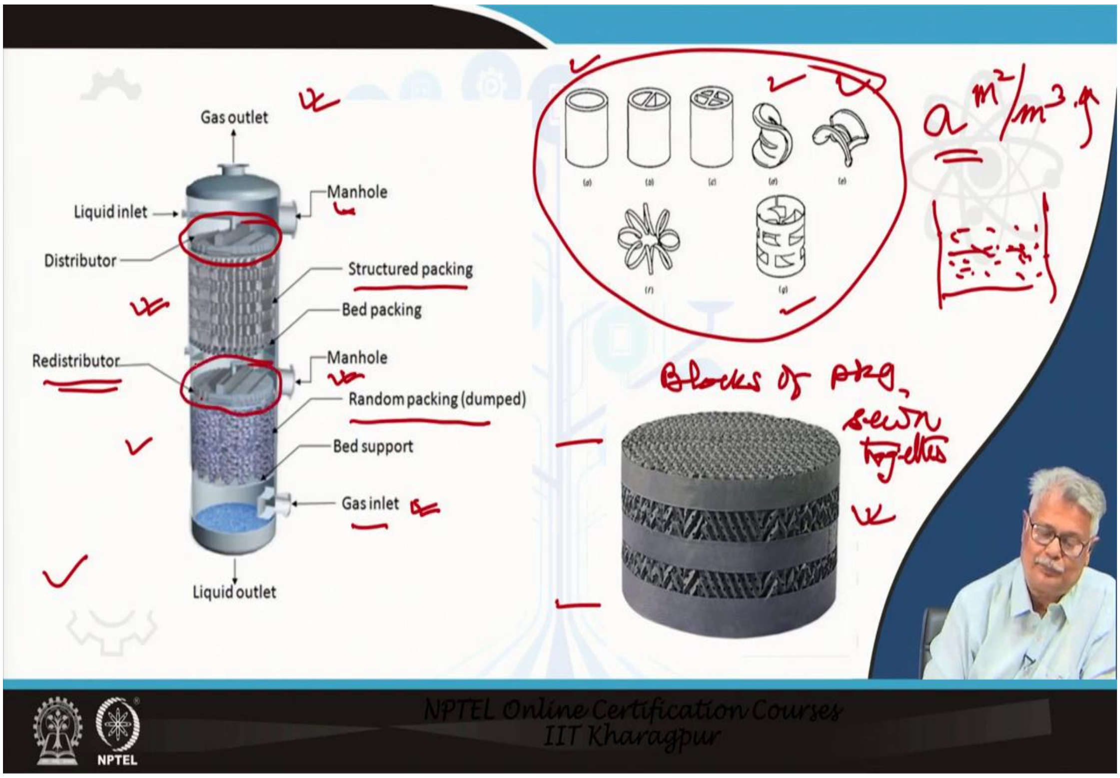


Now, we talk about a packed tray. Normally, whenever we talk about a packed tray, we talk about the different shapes of packings that are used. We can just have a there are different names. I am more than sure that you have learnt about the names of these.

There are saddle shapes, berl shell is one, interlock shell is another. You have pole rings, and there are plenty of proprietary packings. What is the purpose of the packing? The purpose of the packing here is primarily to ensure that the specific area in ($m^2/m^3$ of packed bed) goes up.

What is the advantage you have? Ideally, if you have a packed bed, the surface of the packing should be kept wet with the liquid over which or across which the vapour would flow. There are two types of packings. One way is use all these packings which are all random packings. What we do here is basically we take the tower, we dump it. So, what you dump? You dump your material here, your packing material here, and you build up a bed.

Here we have an example where there are the two types of packing present. This portion is your random packing, but this portion is called structured packing. Let us see what exactly it is. Structured packing has a definite shape. Typically they are sewn together. In fact, they are layers. There are blocks of packing sewn together. This you can see from this diagram itself.

So, what you do or what you normally find is these will have a circular cross-section and it will be placed here. What are the advantages of this type of packing? They offer you a higher "a"(Specific surface area) – number one. The second thing, they offer you a lower pressure drop per depth. So, in both ways, they are advantageous.

Now, if you are talking about the packed bed or the tray tower even, there will be other components. You will definitely have a manhole. Here it is a vapour liquid contracting, so there will be a gas or a vapour inlet and a gas outlet. Naturally, the inlet is from the bottom; that the exit is from the top.

Here in this particular case, if there are two manholes, you have a liquid from the top and there has to be distributed. In fact, in case of any packed bed distribution of the liquid is extremely important. If the uniform is distribution is not ensured, part of the packing will remain unutilized and possibly your total efficiency of contacting will be falling drastically.

What happens is quite often one may require in case of packed towers, some amount of redistribution as well. This particular tower has got a redistributor that means it collects all the liquid which is falling from the upper section. Then what it does is, it redistribute; in fact, the construction of this redistributor and the distributor is not much different.

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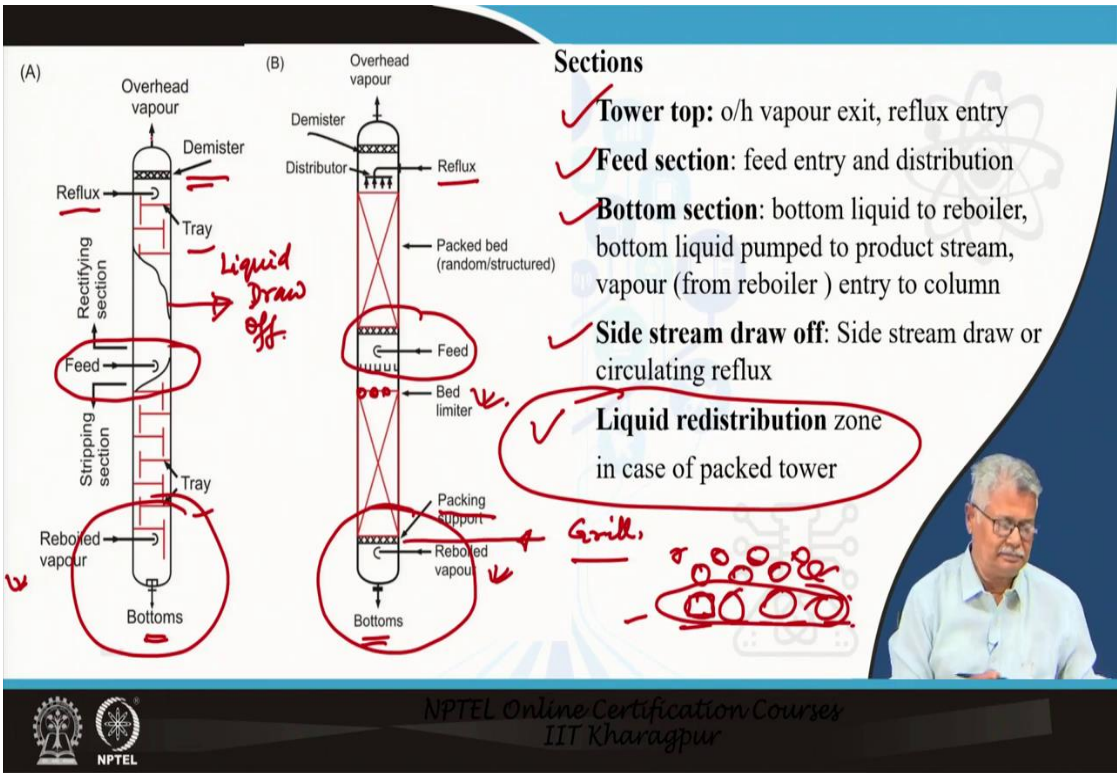


Let us look at the various sections of these two towers. The left one, obviously, is a tray tower – you have trays here. On the right side, you have a packed tower. If you are talking about the packed tower, the packing requires support because it has its weight has to be supported by something strong. So, often you will have a pack.

This could be a grill type of structure. It could be a perforated plate as well. The opening in the grill or the perforated plate should be such that the packing element should not fall through those. Quite often what is done is you have this particular support on that you have a set of bigger packings. On that, you will have your smaller packings.

The bigger packings will be ensuring that you have a fair amount of gas and liquid distribution here among the smaller packings. The smaller packings do not fall off. What you will always find is not only that there will be packing support, and possibly some sort of bigger packings or larger size packing above it. You will also ensure, it will also be ensured that your smaller packing pieces at the top do not fly off whenever your velocity is high.

So, you usually will be having a bed limiter also. A bed limited will also be a similar gate or a perforated plate. Remember all these add to the pressure drop in your column. So, whenever you are designing you have to ensure that you are always within the total pressure drop. When you estimate your total pressure drop, you must include all the components through which the vapour has to flow through.

Typically, if it is a distillation column, you will have a reflux entry. The same thing is true in case of the tray as well as the bubble column. You are going to have a feed section; you are going to have a feed section in both. You are also going to have a bottom section as well.

In your bottom section, if you are talking about a vapour liquid contacting column for distillation what you are going to have? You are going to have an entry for your revolved vapour, you are going to have a takeoff for your bottom product. Where will this bottom product go? Part of it will be vaporized, and it is going to generate the reboiled vapour which is sent back to the column below the bottom-most tray. You can see here, and part of it will be taking taken off as a product.

Similarly, in large columns not always very common in all the applications, there may be intermediate refluxes which are called circulating refluxes also. That means, you will have to have an arrangement for taking off some part of the liquid from your column. So, you will require some sort of liquid draw of arrangement. So, what you have here, the liquid draw of arrangement could be for a side stream draw or it could be for circulating reflux also.

So, we just very quickly have a look that what are the sections of typically; typical columns that we are going to concentrate on, the tower top section, then you have a feed section, the bottom section, the side stream draw off, and a liquid distribution zone where we are dealing with a packed tower.

I will just add one more thing here when the vapour goes off, we do not want liquid droplets to be entrained in it. So, what you usually have is a demisted pad above or rather just below the exit or the overhead vapour. It is nothing, it is typically around 100 mm thick stainless steel weir that goes fixed there. So that the fine droplets of liquid hit it gets stuck, coalesce into bigger drops, and fall off. The vapour which goes off is practically free of liquid droplets.

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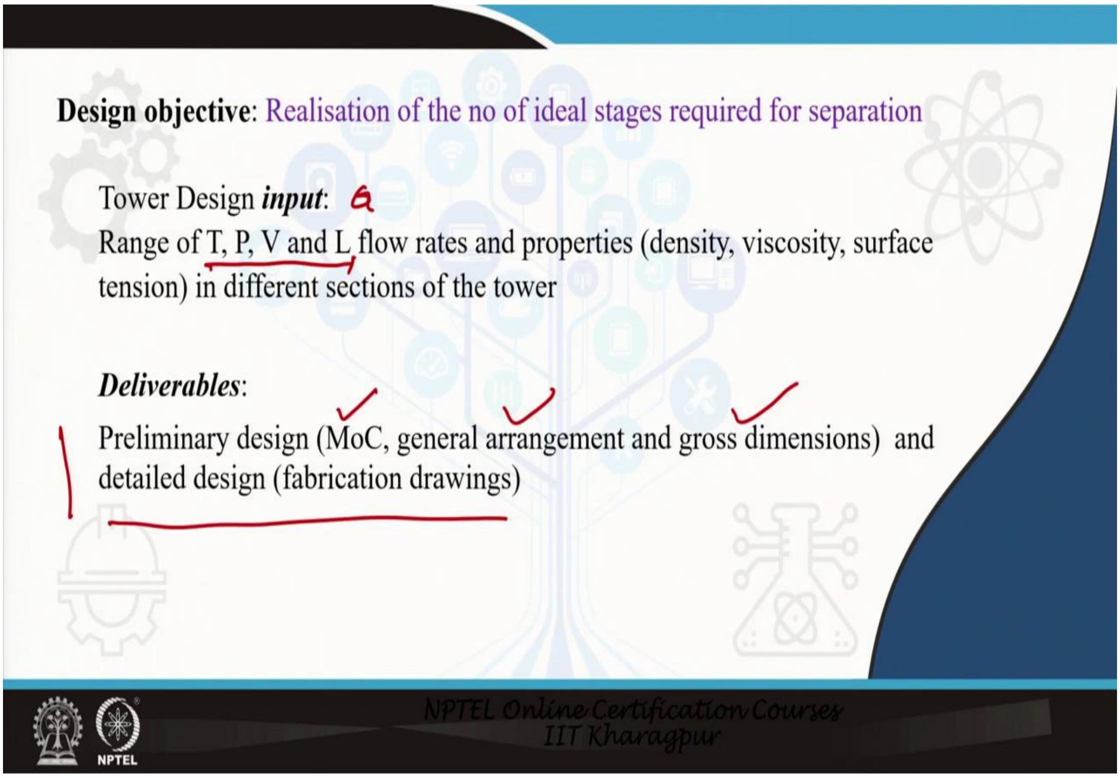


Now, I show you here that the purpose of the practical tower is the realization of the number of ideal stages which are estimated to be required for the separation itself. Now, in order to do it, you shall be requiring the temperature, pressure, volume, and liquid flow rates, and also gas flow rate, and properties in the different sections of the tower.

What you deliver, initially you deliver a preliminary design which consists of material of construction, general arrangement and the cross dimensions. The cross dimensions to start with will be the total height of your tower and its diameter. The final delivery that the designer has to provide is a fabrication drawing which will go to the fabricator with which he will start fabricating his tower, and then it will come to the field and will get installed.

I think with this, I will stop here. In the next class, what I will do is I will start with the individual section that I have mentioned in the last slide and will give you certain dimensions and considerations for arriving at those specific features which are present in those sections.

Thank you.