Principles and Practices of Process Equipment and Plant Design
Prof. S. Ray
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Module - 02
Lecture - 29
Tower and Tower internals (Packed Tower Design)

Good day to you all. We continue with our topic on Tower and Tower internals. We will be talking today about the Design of Packed Towers. So far, what we have covered regarding tower and tower internals are for the different types of tray towers. Then we have come to the packed tower design right.

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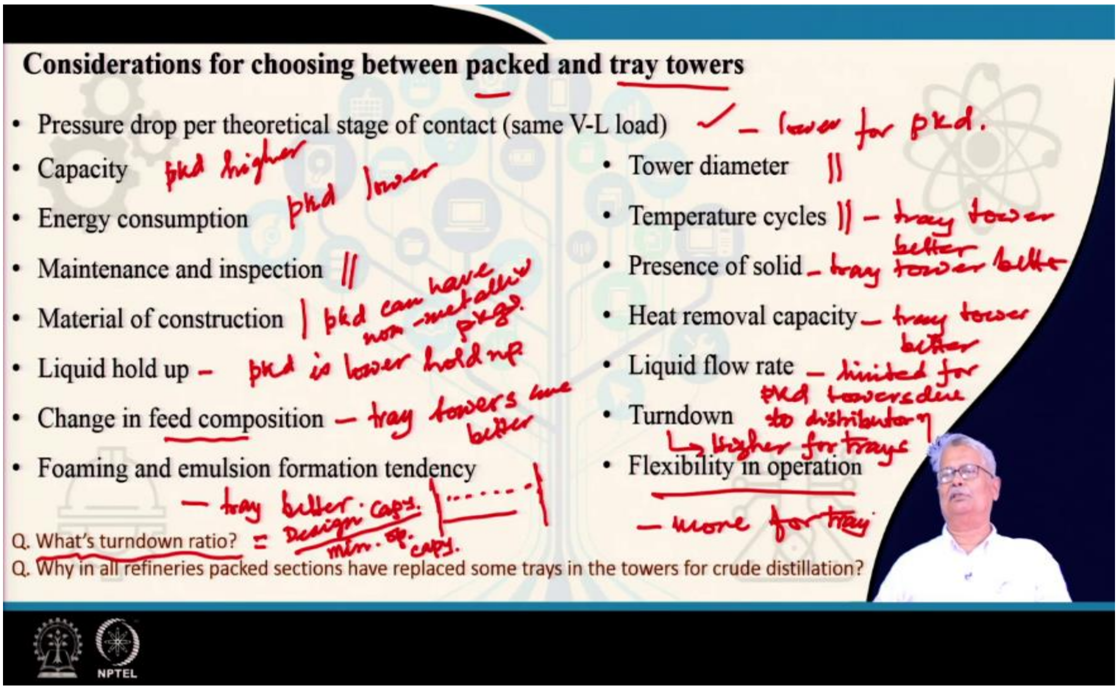

To start with, we need to know that what are the basic considerations for choosing between the packed and the tray towers. So, we have two options of vapour-liquid contracting that is what we have been focusing on and we need to find out the advantages and the limitations of each type.

Here we have a few considerations listed. If we look at the pressure drop per theoretical stage of contact for the same vapour-liquid load, we normally find that the pressure drop per theoretical stage of contact is lower for packed. Compared to the tray towers the packed towers offer a lower pressure drop, per theoretical stage.

Then we if we look at capacity. Well, the same thing follows from the previous one itself. That means, if we have the pressure drop as a limitation for my tower, the capacity could be would be higher in the case of packed. So, in case of packed that capacity will be higher. Regarding energy consumption well that is a very interesting part. Energy consumption will be given in this particular case volumetric flow rate divided by Δp.

If your Δp is lower in the case of a packed tower naturally the energy consumption would be lower in the case of a packed tower. So, I can straight away write that a packed tower will have a lower energy consumption.

It is more difficult to talk about the maintenance and inspection facilities. Maintenance required for the tray towers and packed towers depends a lot on the type of service that it is providing.

For example, trays of the tray tower tend to fall in case of pressure surges. So, they require to be periodically repaired inspected and maintained certainly. The pressure surge of the packed tower will normally disrupt the packing and once disrupted, it has to be repacked at least the top part of it. So, I will not decide between the packed and the tray tower and I will say that they are more or less equivalent.

Regarding the material of construction, we can say that we are going to handle something corrosive. Since your tray towers are always metal towers. It's possible for you to have only the shell to be of a noble metal not the noble metal of higher metallurgy and you can have your fairly inert packing. It could be graphite or something which is non-corroded.

So, you have some advantage in the case of the packed tower, but because the packed tower can have non-metallic packing.

If you talk about the liquid hold up on a tray, typically the depth will be of the order of 2 inches or 50 mm. Whereas, it is expected to be lower in the case of packed towers.

When we compare the hold up on a single-stage equivalent to HETP of the packed tower, your packed tower has a typically lower hold up.

Regarding the change in feed composition here, the tray towers win. Because if you are really to provide multiple feed points, it is much easier to do during the design. The construction in the case of tray towers whereas, its relatively more expensive and it's difficult to do it in the case of tray towers. Because for every fetch section in the vapour-liquid contracting tower you have to have a distributor and similar details which is not so in the case of tray towers. Tray towers are better concerning this point. So, I can straight away write tray towers are better equipped because we can have alternate feed locations.

Regarding the foaming and emulsion formation tendency, it is obvious. If you look at the construction of the tray tower, the foam breaks in the clear space. So, almost the entire tower section will be available for breaking the foam. So, quite naturally for this purpose, I can always say tray towers are better.

If you look at the tower diameter here also, it is very difficult to say. The tower diameter will depend on the approach to flooding. For the same approach to flooding, it depends on what type of packing you have. Well, you can say the tower diameter requirement you cannot straight away comment. In some cases, it will be I mean either will could be better.

Regarding temperature cycles, the trays win. The trays are metallic trays and all components on the tray are metallic and they have a similar coefficient of expansion. Whereas, if you have a packed tower where the packing material expansion coefficient and the shell material expansion coefficients are usually different. During temperature cycles there will be contraction or expansion of these two which will create and usually what happens is if you are having packing of a brittle material the packing’s start crumbling. This is particularly true if you are using some brittle material like ceramics as packing. Sometimes even the carbon rings also crumble down. So, temperature cycles are much better handled by tray towers and the reason is obvious.

Regarding the presence of solid, tray towers win. The tray towers win because of a very simple reason. For example, if I have a tray tower that is fitted with bubble caps, I can have a long riser and a fairly large clearance below the skirt of the bubble cap. This is something that we have already discussed earlier while discussing the bubble caps on the trays and we can still have a little bit of solid deposition on the tray rack. Whereas, if there is some solid deposition on the packing material, it will restrict the flow of the gas and the liquid both.

So, that way to some extent I mean in no vapour liquid contracting you expect that there should be a large amount of solid, but even if it is there due to some unavoidable reasons your tray towers will be performing better.

Regarding heat removal capacity, you can have some sort of heat removal arrangements like embedded heat transfer tubes and all in the case of tray towers. If you are talking about the divided wall column or something it is possible to have it in case of tray towers, but you cannot have such facility in the case of in packed towers. So, if you look at the heat removal capacity, I will say that tray towers have the advantage.

Regarding liquid flow rate, the ideal liquid flow rate for a packed tower is just wetting of the surface of the packing. If you have a very thin layer on the packing surface what happens is your diffusion length inside the liquid is less. You will have a sufficient amount of turbulence on the liquid film that flows on the packing surface also. In the case of trays, if you are going to have a large amount of liquid flow rate, you have a large gradient. But in the case of the packed tower, there is a limitation. The limitation is it is not due to the packing.

The limitation is in the case of the packed tower is of utmost importance to avoid channelling. The channelling is better avoided by having a uniform distributor for the uniform distribution of liquid over the packing itself. Normally, whatever type of distributor you have in case of packing, they have a limited range over which they functioned well.

So, this is limited for packed towers due to its due to what? It is basically due to the distributor efficiency that means, if I have my distributor to distribute the liquid evenly, there will be a fairly narrow range of liquid flow rate and that limits the operating range of liquid flow for your packed towers whereas, it is not so, in case of tray towers.

In the case of tray towers well, if you have a very low rate possibly your height above the outlet weir would be small and if it falls below 6 mm, you do not have good distribution and a uniform flow. At the same time if you have a very high liquid flow rate what happens is if the gradient of liquid across the tray is large and you may have channelling wherever you have a lower depth of liquid that we have already discussed in the case of tray towers.

Now, we talk about the turndown. Before we talk about turndown perhaps we should answer this question what is the turndown ratio? The turndown ratio is basically the design capacity divided by the minimum operating capacity. So, one thing is true the turndown ratio if I define it this way the turndown ratio is going to be above one true.

That means, higher the turndown ratio, we can have a lower operating capacity. That means if I have a turndown ratio of say 1.5. That means if I have my design capacity of 1.5, I can still go up to a capacity of 1. That means, higher the turndown ratio lower the feasible minimum operating capacity.

Quite naturally, in the case of turndown, you will naturally find that you have a very limited range of distributed operations in the case of the packed tower. So, this is definitely higher for trays. You will notice one thing the turndown ratio is not only for the trays, but it is also true for any equipment for that. Now, there is a question here. For example, you will also notice that the turndown ratio does not necessarily depend on the major component of your equipment.

For example, the turndown is limited by the distributor which is fitted to your packing. So, it is not the packing that resides it. It is a distributed fitted on the packing liquid distributor which we shall design decide the turndown now regarding flexibility and operation.

Well, if you are asking me, I will say that the flexibility in operation is fairly in the sense particularly if I have a higher turndown ratio my flexibility would be more. Because I can operate over a large capacity range without much loss in efficiency of contacting.

So, I will say this is more with the same logic more for the tray columns. I believe with this we have discussed the different considerations for choosing between the trays and the packing. If you are facing a design problem, you can use these points to find out what exactly is the best option that you can have for your contacting of the vapour-liquid mixture.

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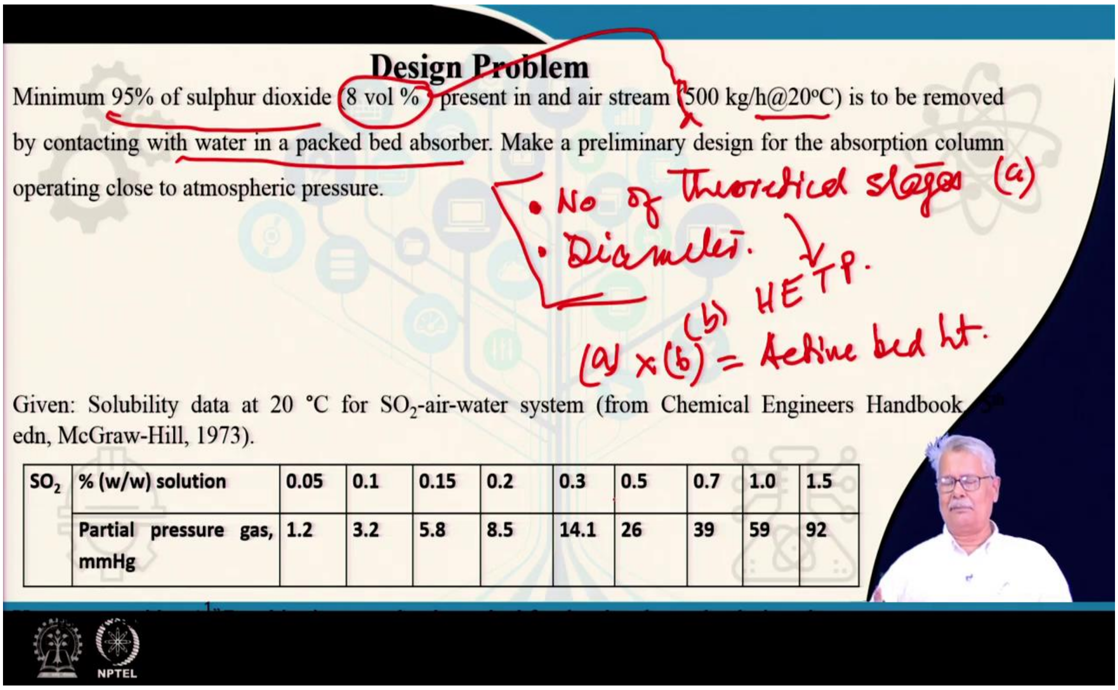

Before we go into the design of the packed towers, let us look at typical design problems as are faced. Here we have a design problem that simply says that a minimum of 95 % of sulphur dioxide is present in the air stream. I could have put it like this.

This belongs to the air stream which is having 8% sulphur dioxide in it and the flow rate is 100 kg/h at a 20 °C temperature and this is to be removed by contacting with water in a packed bed absorber. You are asked to do a preliminary design for the absorption column operating close to atmospheric pressure.

That means, one thing is true that possibly there is a low-pressure blower, which is going to supply this particular SO_2 laden air to the absorption column and you will have a counter correct contacting over here. You will send obviously, the air from the bottom and the liquid and water will be coming from the top. This is a typical absorption problem.

So, if we know that this is a typical absorption problem and we already have done the lecture and the notes on the absorption already have is possible for us to find out two things. Number 1, the number of theoretical stages and the diameter. Once we have these the next thing that is that we are required to find out is for this system what is the height equivalent to a theoretical plate.

Now, when I multiply this, a and this b item what do I get? We get the active bed height that is required for this particular contacting. So, with this, we understand that we are going to require some active bed height of a particular diameter and we know the number of theoretical stages that are required for this contacting as well. The procedure for finding this, we already have covered in your lectures in absorption.

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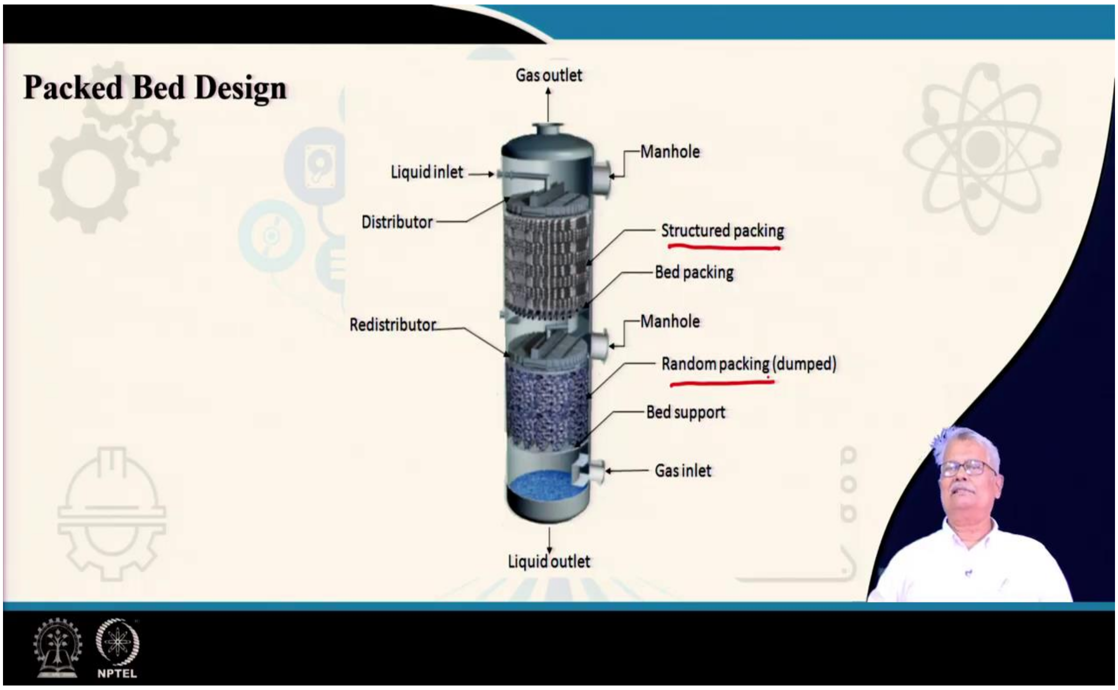

This is the diagram which we have already seen earlier where you have a typical demonstration pack tower and what are its components. Quite naturally the gas is exiting from the top and the liquid is distributed from the top itself through the liquid inlet and it comes out from the bottom and here it as it shows you have a redistributor.

We will see how to arrive at the basic dimensions and the features of each of these. There are two packed sections; one section is packed with structured packing. The other is with random packing which is doubt perfect. Let us look at the other features now.

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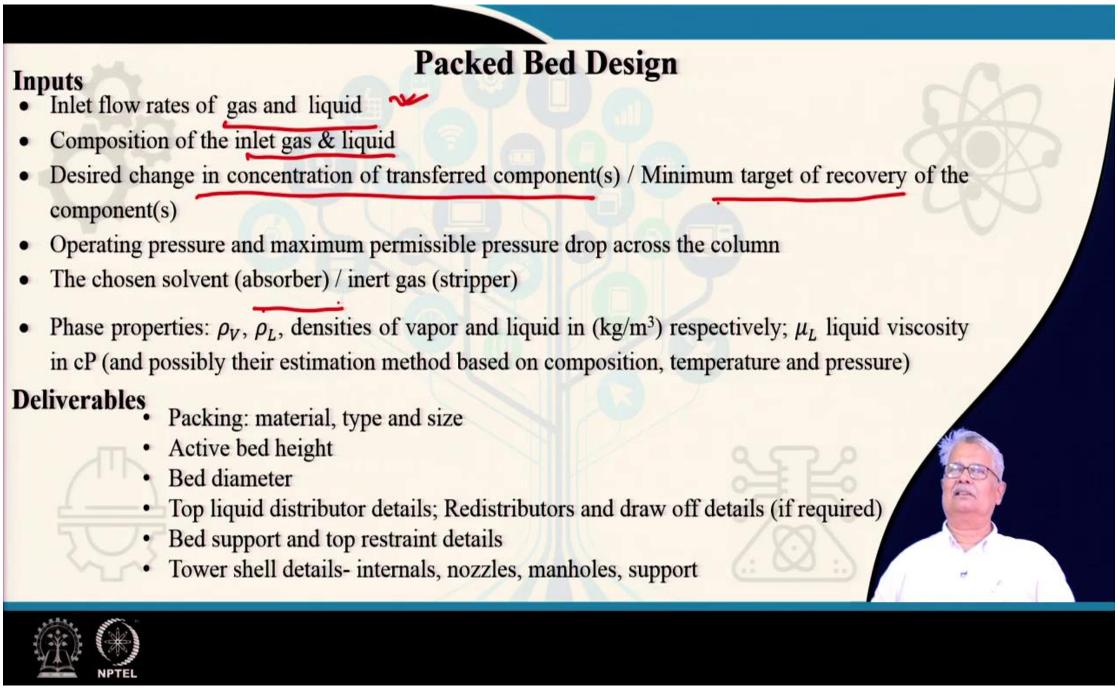

You have been supplied with a design problem. What are the inputs? These are the inlet flow rates of gas and liquid. Yes, you already have found out how to find out the minimum amount of liquid required. Based on the minimum liquid, you have assumed about 1.5 terms of that liquid rate and possibly by definitely by this time when you have come to the design of the bed itself you know what are the inlet flow rates.

You know obviously, the composition of the inlet gas and the liquid. You know the desired change in concentration of the transferred component and or the minimum which is certainly related to the minimum target of recovery of the components. Here in the specific problem, you have a requirement of a minimum 95 % recovery of the sulphur dioxide that means removal in that case.

You know the operating pressure and the maximum permissible pressure drop across the column. We are going to have a very small pressure drop across the column itself because we know that ultimately the pressure supplied is not very large and we cannot afford to have a higher pressure drop. The chosen solvent or the inert gas is not a stripper. So, in the case of the absorber that you have been given the solvent is just a stream of water.

So, this is also known. Phase properties I am not going into the details of these, but these are all known. As well as a design output you got to first choose the deliverable; that means, you have to tell the packing material type and size. Naturally, the size is usually nominal. The type is there could be various shapes of the packing material which will just seen after this.

The active bed height, definitely we have to verify that whatever we are delivering now is in a position to provide the desired active bed height which we had seen in the last slide, the bed diameter certainly. So, we have to provide the details of the top liquid distributor and if you require any distributor redistribution or any side stream draw off which is not required in this specific design problem. If it is required, we have to provide the basic design features of these as well.

The bed has to be supported. So, naturally, we have to talk about and we must know about the bed support and the top restraint details. Packed beds often require a top restraint. So, that the top layer of the packing does not get blown off during mild pressure surges even. You have to provide the tower shell details the internal fitting that we have been talking about now, but you are also to provide the location, the elevation of the manholes and nozzles and the support details.

The support details; obviously, the first thing that you have to provide is the elevation of the bottom of your column. That depends on the NPSH requirement of the pump that is supposed to pump out the liquid from the bottom of this particular tower. We have discussed this earlier.

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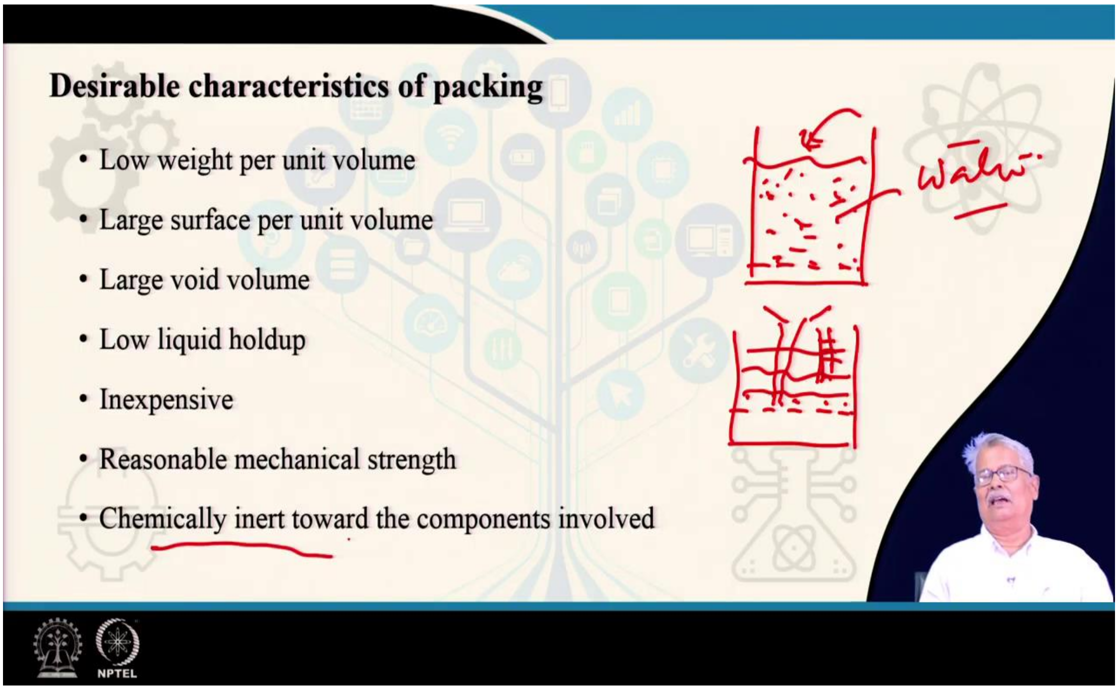

Now, let us look at the desirable characteristics of the packings. The packing has to be supported. So, the lighter the packing the better it is. So, lower weight per unit volume, when I say unit volume it means, the packing packed bed volume.

The same thing is true in the case of larger surface area per unit volume which is the emitted square surface area per m^3 of the bed volume. The larger the surface over which the liquid can spread and can contact with the vapour which passes by.

You must remember one thing whenever you are talking about the pressure drop in case of similar this type of beds or vapour liquid flow the pressure that is lost by the gas is primarily at the vapour-liquid interface. You require a large void volume because a large void volume of your packing the type of you choose if you have that your pressure drop is going to be much less.

The void volume can vary anything between 60-65 even less than that 58 maybe 60. In case of ceramic packing or stoneware pack is to roughly about 95 % void in case of metal packings. Low liquid holds up is something we desired.

We already have said that we will always prefer a thin liquid film waiting for the surface of the packing. So, naturally, if you have a thin film you have a low liquid hold up. So, they are complementary qualities. Inexpensive; it is too obvious to say that why we require something to be inexpensive because the material that is required in case in order to have as packing usually the volume is large the quantity is large. So, it should not be too expensive.

The packing has to survive its weight the tower packing. So, naturally, it must have a reasonable amount of mechanical strength. It should not get crushed by its own weight. Not only that there is another thing which requires the mechanical strength to be high that is when you fill a tower what you have to do is you have to there are two ways you can do it.

You can have a tower that is filled with liquid. If you are sending random packing's you will be dropping the packing's after if this is water or some liquid possibly it will be water in most of the cases then you will be dropping the packing's and the packing's would come and settle down at the bottom and gradually there will be a bed build up like this. The other way is to have a chute that is also quite common.

So, you have bottom support here, and you have a funnel to which a chute is here. Possibly there will be someone who will be hanging here almost with a ladder and he will be directing the chute and this pollution will be gradually building this up.

So, both are required and particularly you require a reasonable mechanical strength because if your packings are dropped from the top it should not break. So, that your impact is less. You usually fill it up with water and let it settle down at a slower rate. It is too obvious to ask for this. Your packing must be inert towards the component that is involved here and it should not rust also.

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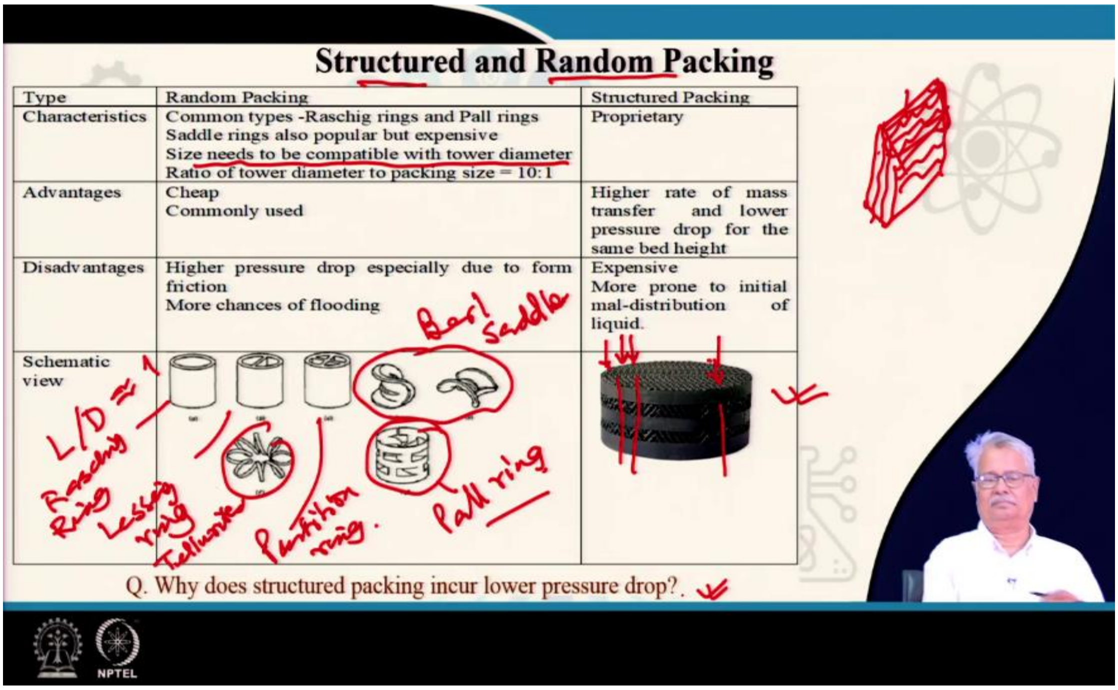

We have been introduced to the structure and the random packing. Random packings have different characteristics, advantage, disadvantage and there are different types. Here L/D of this cylinder is nearly 1. This is a Raschig ring. There is a partition in between, this is a Lessing ring. You have a cross partition here. So, this is called a partition ring.

These two are saddles. These are called they have the saddle shape. So, they are called berl saddles. This is called telluride packing and here what you have is a slightly more complicated structure usually made of metal, this is called a pall ring. There will be nominal sizes of these. Typical sizes could be 1 inch, one and a half inch, it could be even lower and there is something which is very important. If you look at the characteristics you will find that the size needs to be compatible with the tower diameter.

If you have two larger sizes of packing, there will be more channelling. The tower diameter has to be a minimum of 10 times larger than the packing or rather in other words my packing size should be one-tenth or even lower.

Next regarding the structured packing what we can say the structured packings are proprietary. Many of these designs are also proprietary.

That means, many of these random packings are also proprietary, but Raschig rings and Lessing rings and partition ring you can make yourself. They usually have L/D is equal to close to 1 and you can make yourself or you can source it from somewhere. If you have to have berl saddles, pall rings and tellurides, you have to buy them from the standard vendors who are available.

Now, let us look at the structured packings what exactly they are. Structured packings actually contain passages and they come in blocks. So, if I have a block of structured packing that is going to look like this somehow. You will have corrugated sheets which are like this. They are vertical corrugated sheets and these blocks can be placed side by side they can be placed one above the other also.

So, one good thing about if you are tracing these blocks one over the other is you can almost align one block outlet with the inlet of the block which is above that. That means, there is less amount of deviation in the flow direction of the fluid I mean basically the liquid and gas both as it flows from one block to the other block element.

All these usually are tied with a ribbon of metal. Ribbon is made in this particular shape and these shapes are placed one above the other and while you place these. You have to be very careful that you try to have as much alignment as possible. These are proprietary these are much more expensive. But obviously, since all the holes are I mean aligned to the extent possible the pressure drop in these are much less.

Number 1, for the same bed height the pressure drop in the structured packing is much lower as compared to the dumped or the random packing. They are expensive and it will be more prone to maldistribution if there be a maldistribution of liquid initially. Suppose you have more liquid falling in here and you have less liquid falling in here. Obviously, the same thing will tend to continue.

That means in the case of structured packing it is very important that you have as uniform a distribution of liquid at the top as possible. Now, I already have answered the question which I have put at the bottom that is why do structured packings incur lower pressure drop because of the alignment of the openings.

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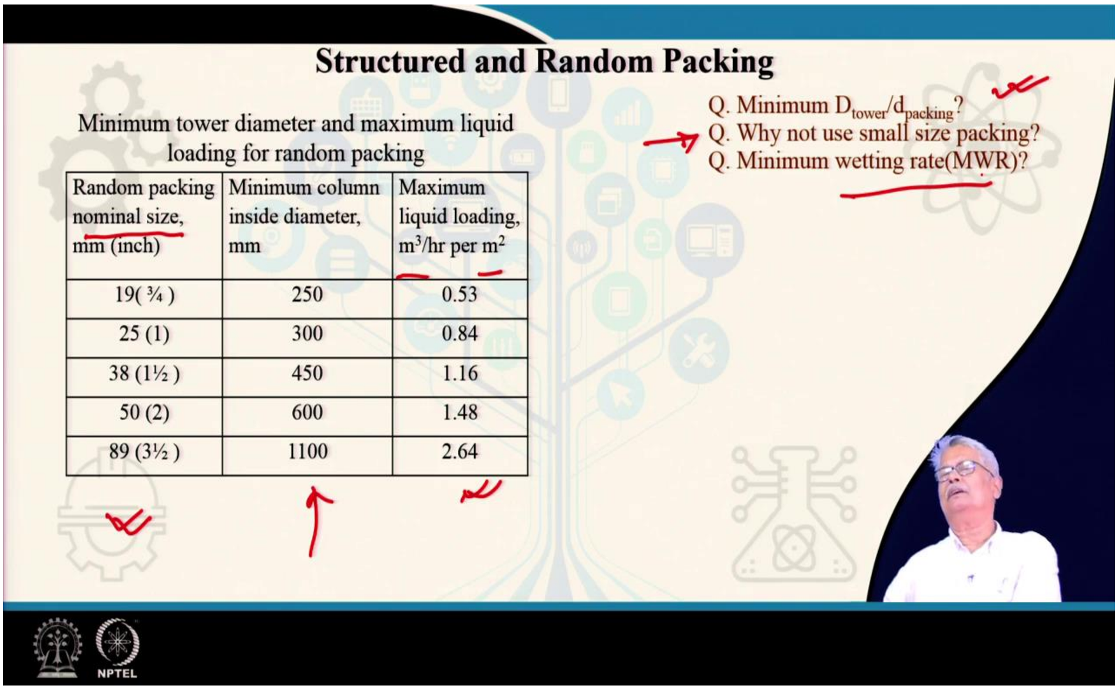

Here we have some limitations whenever you are going to design a tower. There are certain practical limitations you got to honour. There is a minimum tower diameter and maximum liquid loading for random packings. The random pack depends on the nominal size of the random packing itself.

The nominal packings are typically three-fourth inch, 1 inch, one and a half inch, 2 inch three and a half inch. So, these are the typical sizes and quite naturally we have to if this been a size the minimum column diameter has to be at least 10 times. So, typical industry standards which are used are given here.

Now, there is something which is also quite important, the maximum liquid loading. The maximum liquid loading would depend on what? If I have a particular size of packing and if I want to push too much liquid through it, it will not simply flow through the opening that it provides the pressure drop would be large.

So, quite naturally if I have to provide a large amount of flow rate of liquid in m^3/h per m^2 of tower area and if it is large enough I have to go for a larger nominal size of packing. The minimum D_{tower}/ $D_{packing}$, I already have told you is basically around 10. Some people say that it is around 12.

Now, you could also use a smaller size packing because a smaller size packing usually will be having a higher specific area. That means, the specific area means meter square of surface area per meter cube of the bed, but a smaller size packing will definitely have a problem of will be offering you a higher pressure drop.

So, it is not always desirable to go for the smallest size. The pressure drop could become a limitation. There is something that is very important in the case of the wetting rate. That means, in the case of the packed bed, we already have said often the rate of liquid flow is guided by the distributed design. The range in which the distributor can distribute fairly uniformly in the range of operation of your packed bed.

Now, there is something else also. For example, when you are choosing a particular packing there is a minimum wetting rate (MWR). That means, if I do not supply a packed bed with a sufficient amount of liquid flow, the entire bed will the entire bed surface will not get irrigated properly some of it will run dry. So, that is a loss.

So, quite naturally if you are deciding on a bed your liquid flow rate has to be reasonably above the minimum waiting rate. How will you define a minimum waiting rate? We will see later, but obviously, it is something like this. It is m^3/h per m^2 of tower area again.

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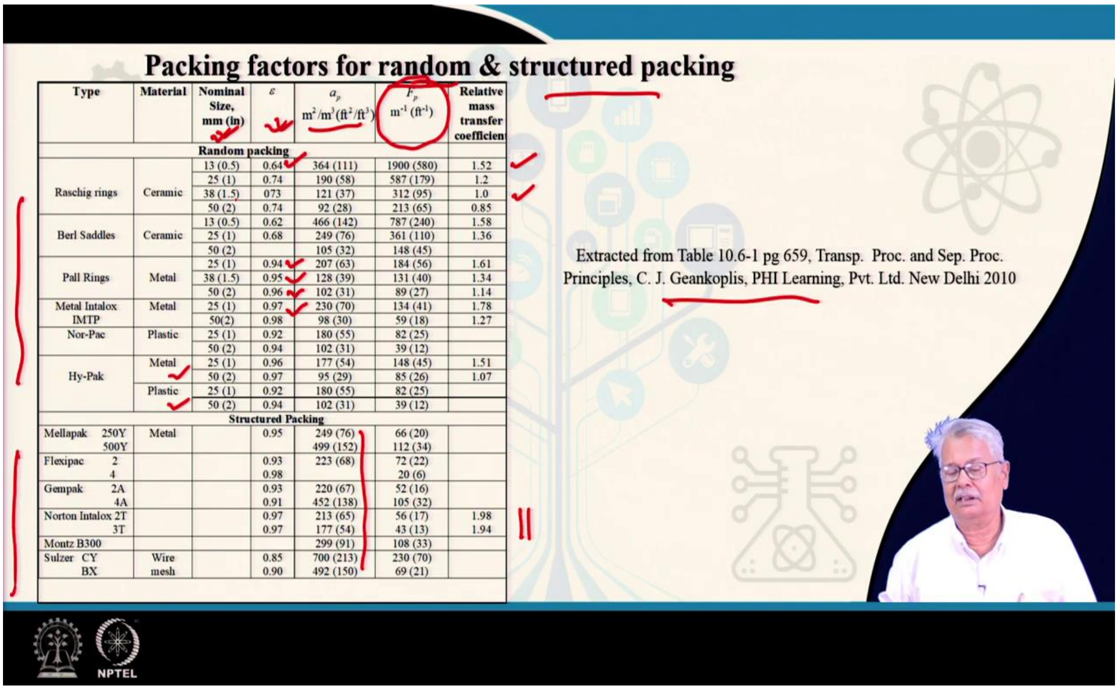

Type	Material	Nominal Size, mm (in)	ε	a_p $m^2/m^3 (ft^2/ft^3)$	F_p $m^{-1} (ft^{-1})$	Relative mass transfer coefficient
Random packing						
Raschig rings	Ceramic	13 (0.5)	0.64	364 (111)	1900 (580)	1.52
		25 (1)	0.74	190 (58)	587 (179)	1.2
		38 (1.5)	073	121 (37)	312 (95)	1.0
		50 (2)	0.74	92 (28)	213 (65)	0.85
Berl Saddles	Ceramic	13 (0.5)	0.62	466 (142)	787 (240)	1.58
		25 (1)	0.68	249 (76)	361 (110)	1.36
		50 (2)		105 (32)	148 (45)	
Pall Rings	Metal	25 (1)	0.94	207 (63)	184 (56)	1.61
		38 (1.5)	0.95	128 (39)	131 (40)	1.34
		50 (2)	0.96	102 (31)	89 (27)	1.14
Metal Intalox IMTP	Metal	25 (1)	0.97	230 (70)	134 (41)	1.78
		50(2)	0.98	98 (30)	59 (18)	1.27
Nor-Pac	Plastic	25 (1)	0.92	180 (55)	82 (25)	
		50 (2)	0.94	102 (31)	39 (12)	
Hy-Pak	Metal	25 (1)	0.96	177 (54)	148 (45)	1.51
		50 (2)	0.97	95 (29)	85 (26)	1.07
	Plastic	25 (1)	0.92	180 (55)	82 (25)	
		50 (2)	0.94	102 (31)	39 (12)	
Structured Packing						
Mellapak 250Y	Metal		0.95	249 (76)	66 (20)	
500Y				499 (152)	112 (34)	
Flexipac 2			0.93	223 (68)	72 (22)	
4			0.98		20 (6)	
Gempak 2A			0.93	220 (67)	52 (16)	
4A			0.91	452 (138)	105 (32)	
Norton Intalox 2T			0.97	213 (65)	56 (17)	1.98
3T			0.97	177 (54)	43 (13)	1.94
Montz B300				299 (91)	108 (33)	
Sulzer CY	Wire mesh		0.85	700 (213)	230 (70)	
BX			0.90	492 (150)	69 (21)	

This is a very important characteristic of the packing that you have. The different types of packing are set here. The different types of random packings are here. Raschig ring, berl saddle, pall ring, metal interlocks IMTP, Nor-Pac, Hy-Pak and all these are proprietary ones and these are all random packings.

You have structured packings also which are obviously, proprietary and here is a list of structured proprietary packings which is here. If you look at the material of construction you see that the material could be ceramic. In some cases, you can have Raschig rings of ceramic. You can have Raschig rings of aluminium also.

Similarly, there are it is also possible to have Hy-Pak which could be metallic packing. It could be a plastic packing also. Now, there is a nominal size that is given here. The void fraction is here. You will notice one thing very interesting that whenever you have ceramic you need to have a reasonable amount of strength you must have a thick wall.

So, that limits your maximum amount of free space which is epsilon. So, you have a 0.64 here whereas, if you look at any metal packing it will be 0.94, 0.95, 0.96, 0.97 of this order. In fact, it has gone up to 0.98 in case of metal interlocks IMTP. The specific area of the packing is definitely in m^2/m^3 of the bed.

So, you see here how it varies and you will see one big difference compared to this. In general, these are higher; that means, structured packings normally will offer a little bit higher contacting area or specific service area. Now, here is one very important thing. The pressure drop in a packing or a packed bed is related to the characteristics of the packing.

This F_p is a factor which you will be required later on to compute or estimate the pressure drop in your packing which you have to whenever you are designing there must be a maximum limit of pressure drop in your bed. So, for that calculation, you require the packing factor of F_p to be defined decided. Here this this document has been taken from Geankoplis's book and here there is one more thing which is quite important.

How important or rather how much it facilitates the mass transfer operations like the in during vapour liquid contacting a relative term is given here. See if it is say for one and a half inch Raschig ring. If it is 1, then on a comparative scale you can see these and you will find here that it is much higher as compared to the rest given here.

You will also understand one thing very clearly. The smaller the size like if you go for half-inch Raschig rings the relative mass transfer coefficient is 1.5 to the same thing with one and a half-inch size. So, smaller the size usually your mass transfer coefficient will be higher on a relative scale.

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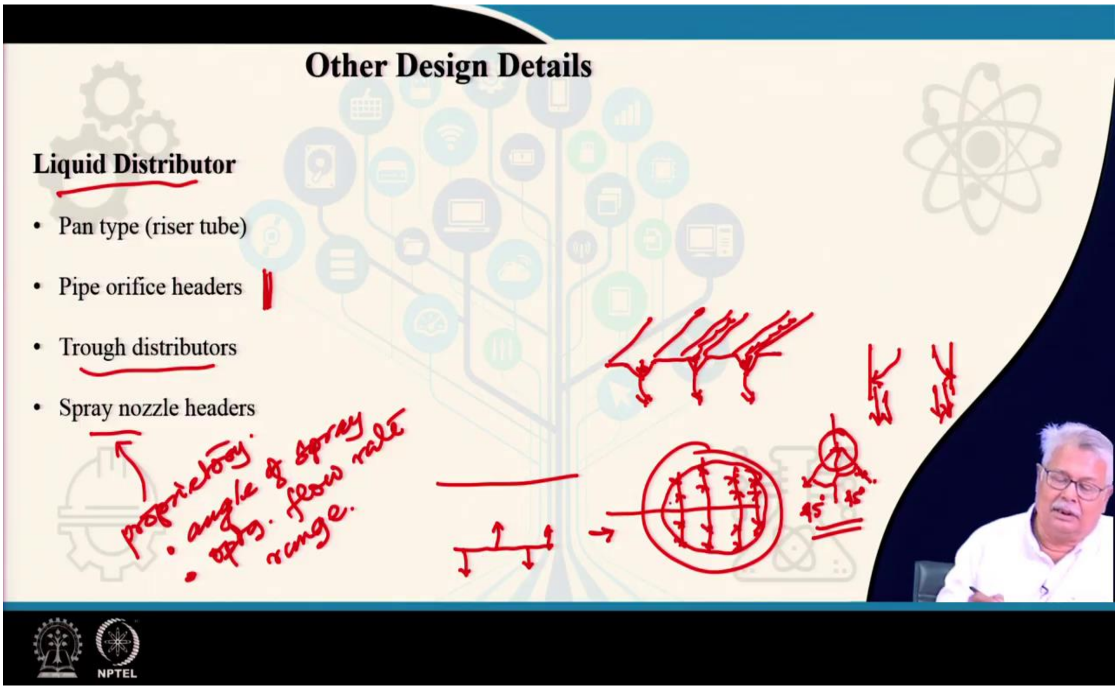

Now, you need to know about the other design details. The liquid distributor in the case of a packed bed is very important. We talked about the different types of distributors. The spray nozzle header is very very simple basically what you have is if you have a tower in which you have to spray you definitely will be having this type of branch coming from a liquid entry distributor and you will have your sprays located here.

We will not go into the design details of this, but one thing we understand is that we would like to design such that you get a fairly well amount of spray distribution here and one thing is very very important. Your spray nozzles usually are proprietary and definitely the angle of spray is an important point.

What else? The operating flow rate range and particularly when you are talking about the liquid distributor you will understand or you must appreciate or you definitely keep in mind one thing in a packed tower usually the liquid will have a tendency to go towards the wall. That means, the channelling normally will be happening close to the wall. I leave it to you to think that why during channelling in most of the liquid field. I mean most of the liquid will tend to go towards the wall.

That means there will be a higher flow of liquid close to the wall, why it is so? Now, what I do is you have the other type of distributors which are the trough distributors. What is a trough distributor? The trough distributor is nothing. It is normally used in case of very large is reasonably large towers. You have a trough that looks something like this.

I will just draw part of it and here what happens is you have liquid, you have liquid here, you have liquid here and the liquid falls to these troughs. So, what you have is you have a trough these in these locations which is fed by a header itself and it overflows from the trough. You can have pipe orifice headers which are very similar to this. Here is what you have instead of a spray, spray nozzle being fitted to that particular header. You will be having orifices.

Normally if you have an orifice what you will find is something like this usually. If I look at the pipe which is having an orifice and this is my vertical line, typically you will have one hole here, one hole here that means, and this angle is keeping around 45 degrees.

So, what I would like to say is if you have an arrangement of pipe orifice distributors it will be like this, but at the same time, you will find they are not aligned in the same line. Possibly one will be here, the second one will be here they are offset. Now, you have a pan type of riser pan type with a riser tube.

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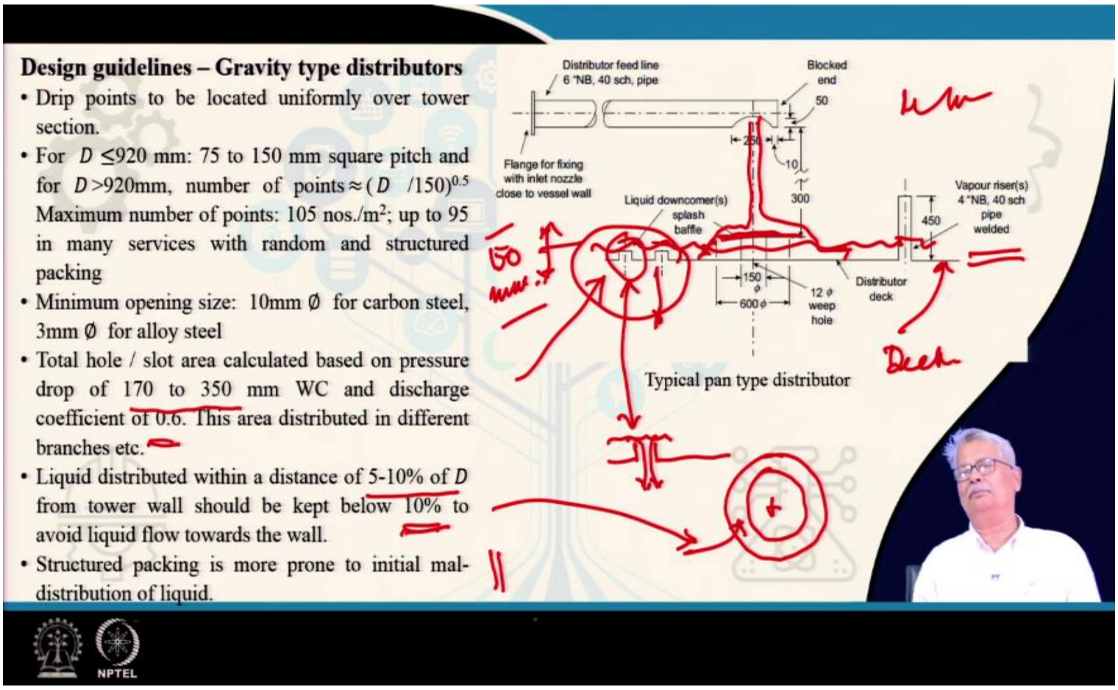

This is something which we have discussed earlier and this is the simplest type of distributor which you use and what you have here is a pan deck. Basically, this is your deck with liquid downcomer; that means, on the deck, you will have a liquid and the liquid will flow through these.

So, this is the same thing here. That means you have here a baffle plate, basically, it is a flash baffle on which you are having a distributive feed line. Typical dimensions are given here either I mean these are all in mm. So, the liquid would fall, it will get distributed here, it will fall here. It will get distributed here there will be a level of liquid and the liquid would fall from these. Here only two downcomers or liquid downcomers have been shown.

So that the vapour which is coming below that it goes up there has to be a vapour riser. The vapour riser typically could be 100mm and it normally will be having a about 450 mm height. Typical depth of liquid here could be around 220 mm or something like this, 225 mm.

The variation in liquid height on this particular arrangement could be by about say the liquid height may vary typically 6 inches; that means, 150 mm depending on the liquid load here. The different technical details the points are given here so that you can read yourself. I do not think that I need to read it out for you, but there is something very important here. This deck must have weep holes. You have to have some arrangement for draining it when it is not in operation.

The weep holes could be a good number. We have designed we have talked about providing weep holes on the decks earlier also in one of our heat towers internal classes. Based on that standard you can provide weep holes of 3 to 5 mm size, typically 3 mm. How many to provide, you can find it out based on the weeping time that you decide for here.

The pressure drop, the pressure drop here you definitely have to find out that what is the allowable pressure drop here. It is given here that the typical pressure drop could be about point 170 to 350 mm water column and the discharge coefficient is 0.6 and based on that you will be designing these what is the diameter required.

You will understand one more thing that is whenever you are talking about the liquid distribution within the 5 to 10 % of the D. That means, if this is your tower diameter and this zone should be getting below 10 % of the liquid. Because if you put more amount of liquid here it will have a higher tendency of channelling and it will go and stick to your wall and fall down the wall itself.

One thing is repeated here; structured packings are more prone to initial maldistribution. Because once it enters a particular set of partition of the corrugation or the corrugation it moves down and if it is and the maldistribution does not get connected automatically. To some extent, there is a chance of correction of the same in the case of random packings.

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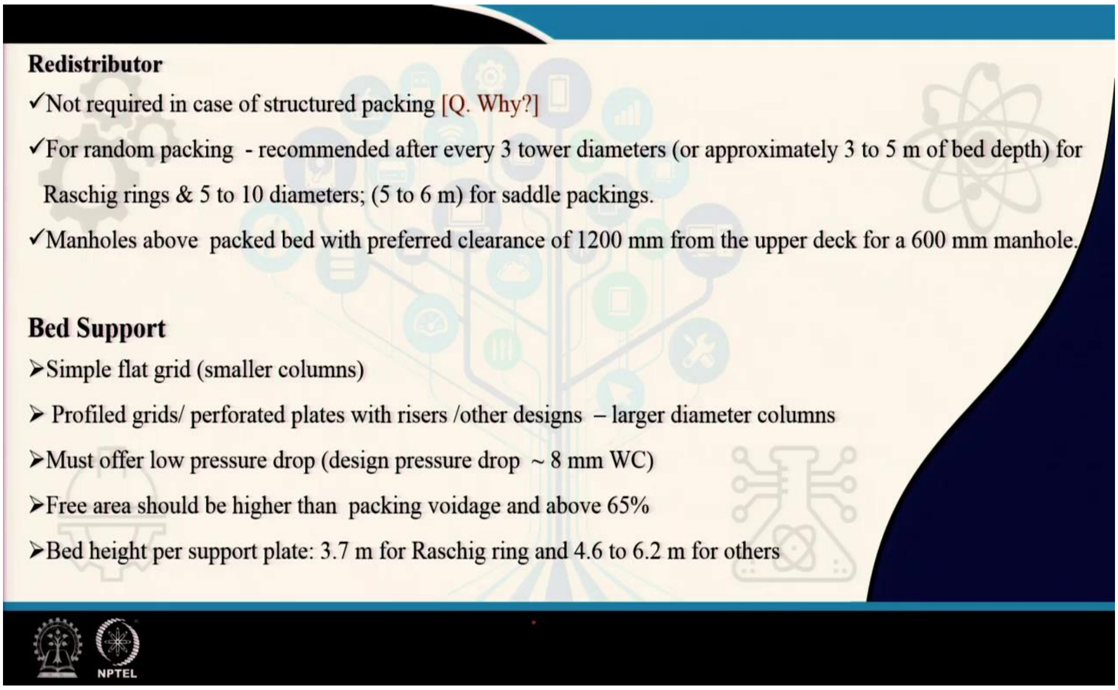

I will stop here with this and continue in the next class.

Thank you.