Plant Design and Economics

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Lecture No -41
Sequences for Simple Nonintegrated Distillation Columns

Welcome to lecture 41 of plant design and economics. In this module number 9, we will talk about separation system synthesis part 2. In the previous module, we have talked about part 1 of separation system synthesis and towards the end we started sequencing of ordinary distillation column.

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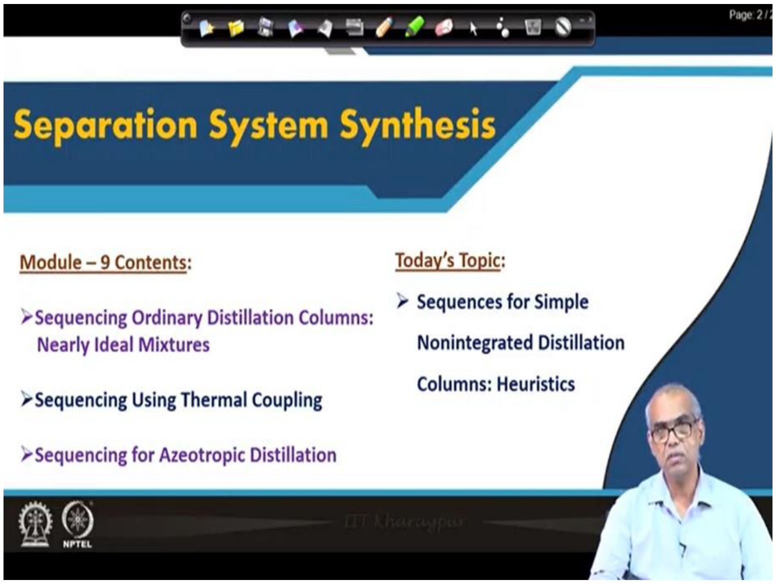

Separation System Synthesis

Module – 9 Contents:

- Sequencing Ordinary Distillation Columns: Nearly Ideal Mixtures
- Sequencing Using Thermal Coupling
- Sequencing for Azeotropic Distillation

Today's Topic:

- Sequences for Simple Nonintegrated Distillation Columns: Heuristics

So we will continue with that discussion in this module and also talk about sequencing using thermal coupling, also sequencing for Azeotropic distillation. So today we will talk about sequences of simple non-integrated distillation columns. We will also talk about some of the heuristics that are commonly used to determine the favorable sequences that can be formed for a separation process using ordinary distillation column without any heat integration.

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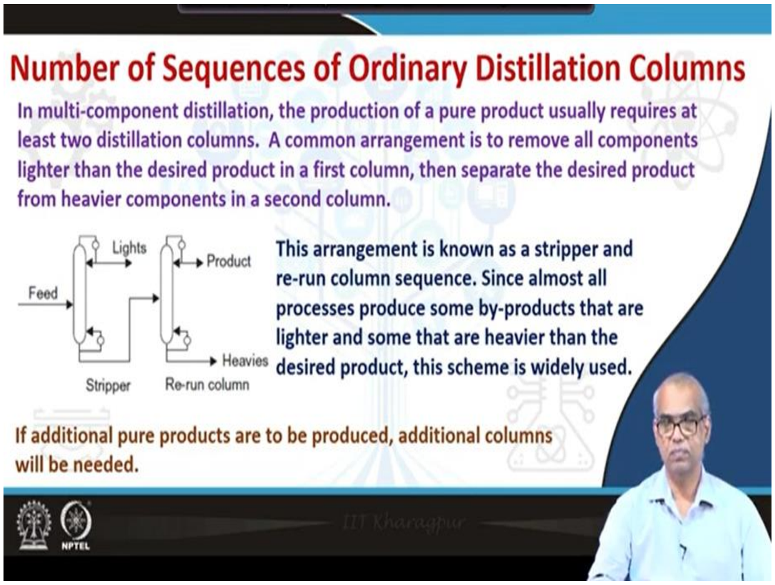

Number of Sequences of Ordinary Distillation Columns

In multi-component distillation, the production of a pure product usually requires at least two distillation columns. A common arrangement is to remove all components lighter than the desired product in a first column, then separate the desired product from heavier components in a second column.

This arrangement is known as a stripper and re-run column sequence. Since almost all processes produce some by-products that are lighter and some that are heavier than the desired product, this scheme is widely used.

If additional pure products are to be produced, additional columns will be needed.

So let us take a quick review of what we learned in the previous module. In multi-component distillation, the production of a pure product usually requires at least two distillation columns. A common arrangement is to remove all components lighter than the desired product in a first distillation column. Look at the figure then separate the desired product from the heavier components in a second column.

So the common practice for separation is to use two distillation columns. And in the first column you remove all components lighter than the desired product so the desired product and all heavier components go to the second distillation column where you take out the desired product as top product and the heavy components as bottom product. So this is often used in industry and this arrangement is known as stripper and re-run column sequence.

Where the first column is known as stripper and the second column is known as re-run. It is commonly used in industry because almost all processes produce some by-products that are lighter and some that are heavier than the desired products. So, this makes this scheme applicable to many practical instances. However if you want additional pure products we must need additional distillation columns.

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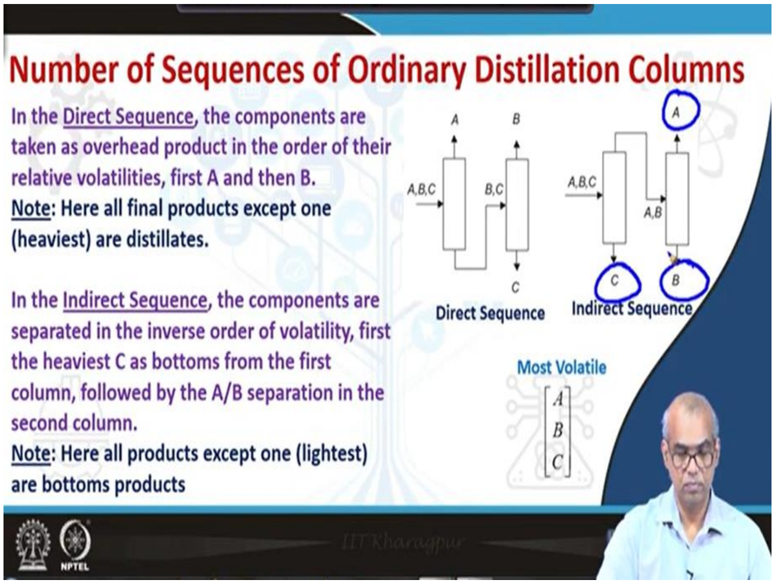

Number of Sequences of Ordinary Distillation Columns

In the Direct Sequence, the components are taken as overhead product in the order of their relative volatilities, first A and then B.
Note: Here all final products except one (heaviest) are distillates.

In the Indirect Sequence, the components are separated in the inverse order of volatility, first the heaviest C as bottoms from the first column, followed by the A/B separation in the second column.
Note: Here all products except one (lightest) are bottoms products

We have defined the direct sequence and indirect sequence. Again consider a three component mixture A, B, C and let us say A is most volatile in the series then comes B and C is the least volatile. So in the direct sequence the components will be taken as over a product in the order of their relative volatilities, that means in the first column will take out A and then B will be taken out as over it in the second column.

So in this direct sequence all final products except one are distillates. And the one that is not distillates is the heaviest component. In case of indirect sequence, the components are separated in the inverse order of relative volatility. So first the heaviest component C as bottom from the first distillation column and then it is followed by separation between component A and B in the second column where A will be taken as over it because it is more volatile compared to B and B will be taken as bottoms.

So note in indirect sequence all products, except one are bottom. So only the lightest component is the distillate and all other products are bottom products.

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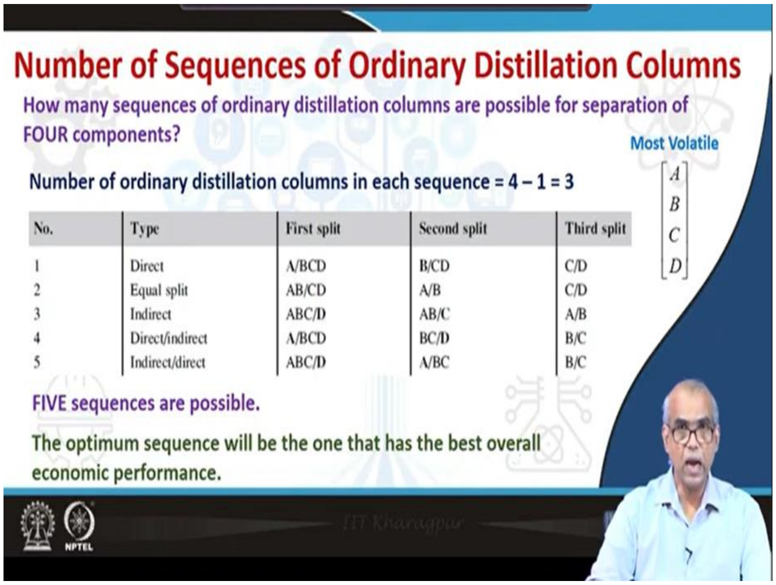

Number of Sequences of Ordinary Distillation Columns

How many sequences of ordinary distillation columns are possible for separation of FOUR components?

Most Volatile

$$\begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix}$$

Number of ordinary distillation columns in each sequence = 4 – 1 = 3

No.	Type	First split	Second split	Third split
1	Direct	A/BCD	B/CD	C/D
2	Equal split	AB/CD	A/B	C/D
3	Indirect	ABC/D	AB/C	A/B
4	Direct/indirect	A/BCD	BC/D	B/C
5	Indirect/direct	ABC/D	A/BC	B/C

FIVE sequences are possible.

The optimum sequence will be the one that has the best overall economic performance.

So if I have 4 components how many sequences of ordinary distillation columns are possible? So number of ordinary distillation columns in each sequence will be number of components - 1; so 4 - 1 = 3. So how many sequences are possible with 3 ordinary distillation columns for complete separation of FOUR components? So they can be shown in this table. Let us again consider that I have arranged all the components according to their relative volatility.

Where A is most volatile then comes B then C and D is the least volatile. So, we can have 5 different sequences. One direct sequence where in the first column will have split between A and B because A is most volatile. And then in the second column we will have a split between B and C and in the third column we will have a split between C and D. So that is direct sequence. We can have one indirect sequence where first I will have a split between C and D so that I can take out D as bottoms.

And then I will have a split between B and C. Note that I am doing it in the inverse order of their relative volatility. And finally I will have a split between A and B. So that gives me an indirect sequence. I can have an equal split sequence where I will have the first split here A, B and C, D. Then I will have a split between A and B in the second column and between C and D in the third column.

Now, I can also have two mixed sequences of direct sequence and indirect sequence. What are they? So let me start with one direct indirect mix sequence. So first split I do according to direct sequence that means I will make a split between A and B. Next split in the second column I do according to indirect sequence. So then I split between C and D or either B C and D. And then the third column I do the third split between B and C.

So this gives me a direct indirect mix sequence. I can also have indirect direct mix sequence where I have the first split between A, B, C and D following the indirect sequence. And the next split in the second column I follow the direct sequence so I have a split between A and the remaining. And finally in the third column I have a split between B and C. So, all these 5 sequences are possible.

So what will be the optimum sequence? Obviously the optimum sequence will be the one that gives us the best overall economic performance. Please note that ultimately process economics will govern the choice.

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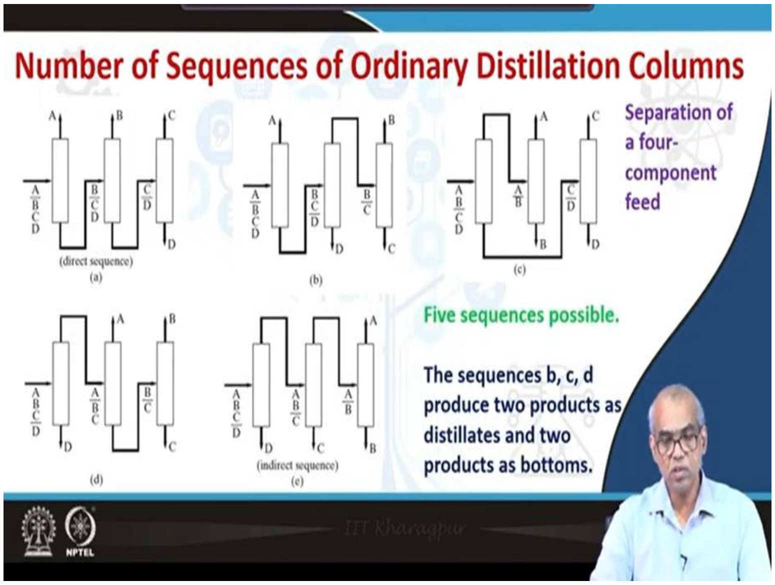

Number of Sequences of Ordinary Distillation Columns

Separation of a four-component feed

Five sequences possible.

The sequences b, c, d produce two products as distillates and two products as bottoms.

So, these are those five sequences. You have a direct sequence, you have indirect sequence and then you have that equals split we talked about between A B and C D and we have one mix sequence here another mix sequence here.

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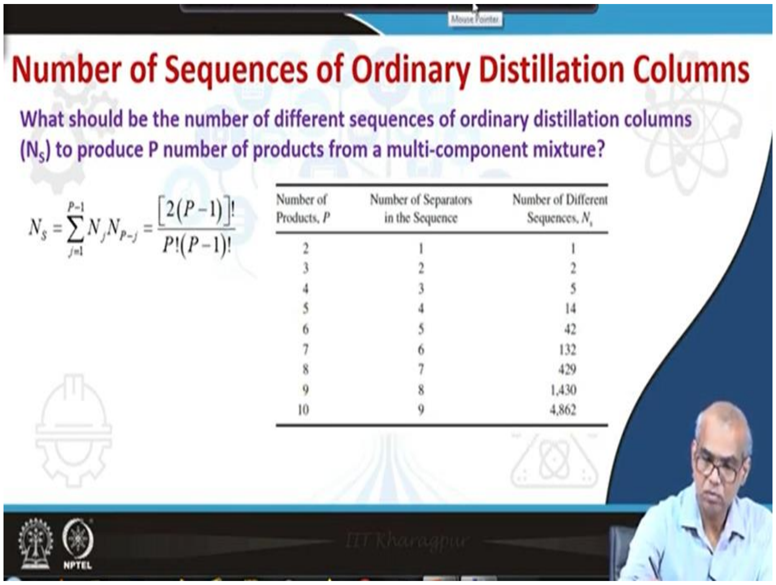

Number of Sequences of Ordinary Distillation Columns

What should be the number of different sequences of ordinary distillation columns (N_S) to produce P number of products from a multi-component mixture?

$$N_S = \sum_{j=1}^{P-1} N_j N_{P-j} = \frac{\left[2(P-1)\right]!}{P!(P-1)!}$$

Number of Products, P	Number of Separators in the Sequence	Number of Different Sequences, N_s
2	1	1
3	2	2
4	3	5
5	4	14
6	5	42
7	6	132
8	7	429
9	8	1,430
10	9	4,862

So in the previous lecture we have seen that the number of different sequences of ordinary distillation columns to produce P number of products from a multi-component mixture can be obtained using this formula. And this formula tells us how the number of different sequences increases with increasing number of products. For example, if I have 5 components I need 4 ordinary distillation columns in the sequence and I can have 14 different sequences.

Note how the number rapidly increases. For example with 10 component mixture and 9 ordinary distillation columns, we can have 4,862 almost 5,000 different possible sequences. Now one way to determine the optimal sequence may be you find out all the sequences, do the design calculations, compute the cost and select the one that gives us best process economics.

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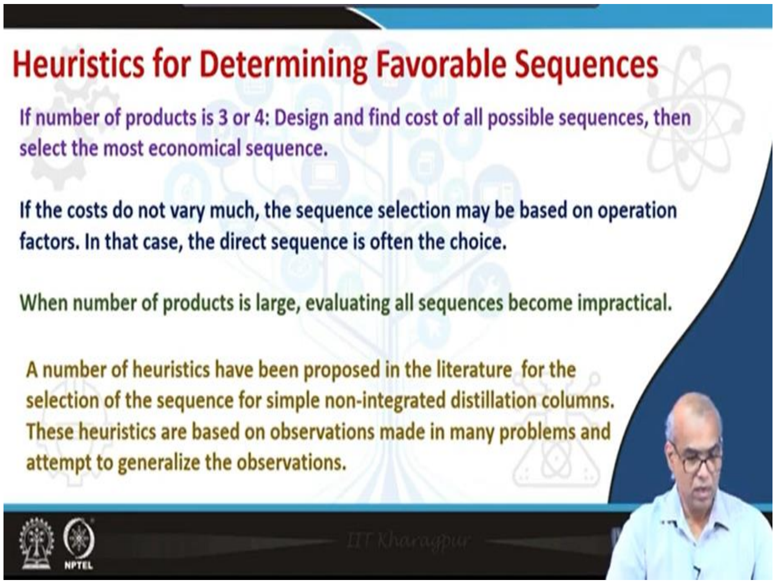
Heuristics for Determining Favorable Sequences

If number of products is 3 or 4: Design and find cost of all possible sequences, then select the most economical sequence.

If the costs do not vary much, the sequence selection may be based on operation factors. In that case, the direct sequence is often the choice.

When number of products is large, evaluating all sequences become impractical.

A number of heuristics have been proposed in the literature for the selection of the sequence for simple non-integrated distillation columns. These heuristics are based on observations made in many problems and attempt to generalize the observations.

Now if the number of products is 3 or 4 that means small we can design and find cost of all possible sequences and then select the most economic sequences. Sometimes the cost may not vary much then the sequence selection has to be based on operation factors. And in such cases often times the direct sequence is chosen. Note that when we choose direct sequence we take all products except one as distillates.

And the displace as products are always favored because they are purer compared to the case where you take out products as bottoms. Now if the number of products is large evaluating all sequences becomes impractical. To help us a number of heuristics have been proposed in the literature. So there is a large number of heuristics that has been proposed in the literature for the selection of the sequence for simple non-integrated distillation columns.

One can make use of this heuristics. These heuristics are based on observations made in many problems over the years and attempt to generalize the observations. So use of such heuristics will make the determination of the sequence easier.

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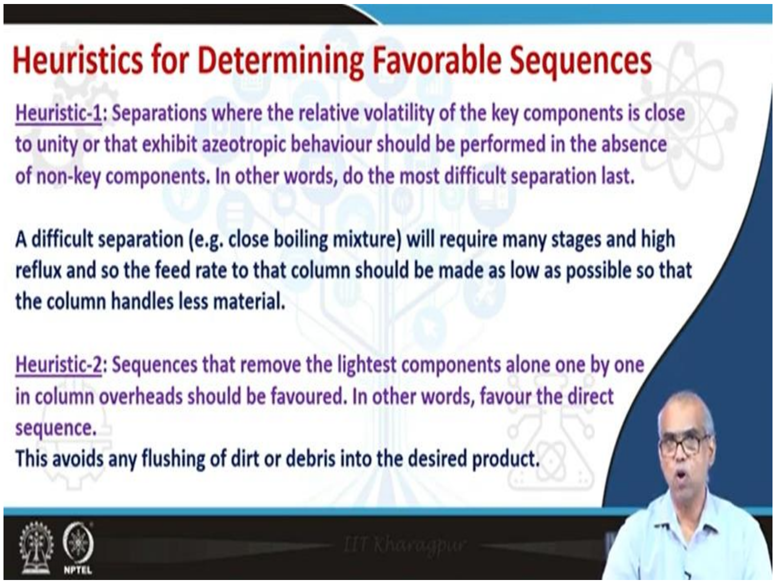

Heuristics for Determining Favorable Sequences

Heuristic-1: Separations where the relative volatility of the key components is close to unity or that exhibit azeotropic behaviour should be performed in the absence of non-key components. In other words, do the most difficult separation last.

A difficult separation (e.g. close boiling mixture) will require many stages and high reflux and so the feed rate to that column should be made as low as possible so that the column handles less material.

Heuristic-2: Sequences that remove the lightest components alone one by one in column overheads should be favoured. In other words, favour the direct sequence.
This avoids any flushing of dirt or debris into the desired product.

So let us first go through some of those more popular or common heuristics. Heuristic 1, separations where the relative volatility of the key components is close to unity for that exhibit azeotropic behavior should be performed in the absence of non-key components. In other words we should do the most difficult separation last. So perform the most difficult separation at the end, why?

A difficult separation such as close boiling mixture will require many stages, high reflux ratio and show the feed rate to the column should be made as low as possible so that the column has to handle less material. Heuristic number 2, sequences that remove the lightest components alone one by one in column over it is should be favored. In other words we should favor the direct sequences.

This will avoid any flushing of dirt or debris into the desired products, that means when you take out products as top products or overhead products the purity of these products generally become higher.

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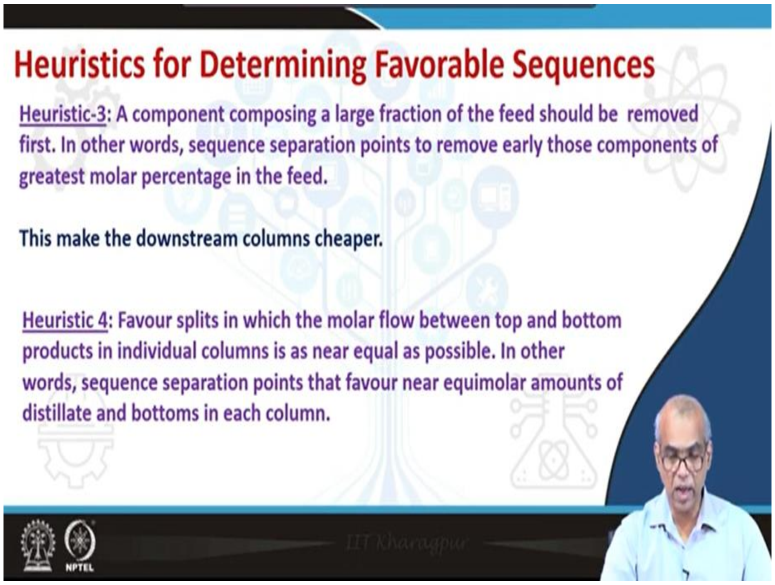

Heuristics for Determining Favorable Sequences

Heuristic-3: A component composing a large fraction of the feed should be removed first. In other words, sequence separation points to remove early those components of greatest molar percentage in the feed.

This make the downstream columns cheaper.

Heuristic 4: Favour splits in which the molar flow between top and bottom products in individual columns is as near equal as possible. In other words, sequence separation points that favour near equimolar amounts of distillate and bottoms in each column.

Heuristic number 3, a component composing a large fraction of the feed should be removed first. In other words sequence separation points to remove early those components of greatest molar percentage in the feed. That means if you have a component in large quantity try to separate that first. What is the advantage? This will make the downstream columns cheaper. Heuristic number 4, favors splits in which the molar flow between top and bottom products in individual columns is as near equal as possible.

In other words sequence separation points that favor near equimolar amounts of distillate and bottoms in each column. So we try to separate such that we have equimolar amounts of distillate and bottoms in each column to the extent possible.

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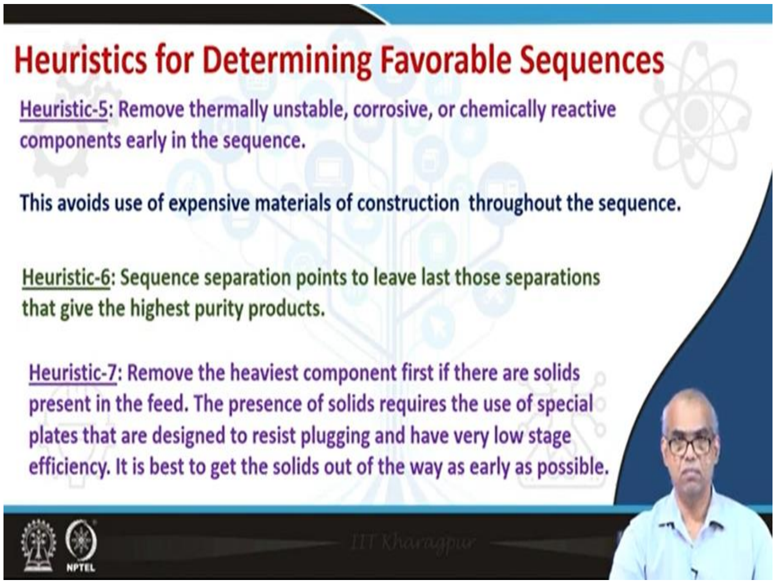

Heuristics for Determining Favorable Sequences

Heuristic-5: Remove thermally unstable, corrosive, or chemically reactive components early in the sequence.

This avoids use of expensive materials of construction throughout the sequence.

Heuristic-6: Sequence separation points to leave last those separations that give the highest purity products.

Heuristic-7: Remove the heaviest component first if there are solids present in the feed. The presence of solids requires the use of special plates that are designed to resist plugging and have very low stage efficiency. It is best to get the solids out of the way as early as possible.

So these four heuristics are more popular and widely used. We will now talk about few more heuristics. Heuristic number 5, remove thermally unstable corrosive or chemically reactive components early in the sequence. This avoids use of expensive material of construction throughout the sequence. Heuristics number 6, sequence separation points to leave last those separations that give the highest priority products.

Heuristic number 7, remove the heaviest component, first if there are solids present in the feed. The presence of solids requires the use of special plates or special trays that are designed to resist plugging and have very low stage efficiency. Therefore it is advisable to get the solids out of the way as early as possible.

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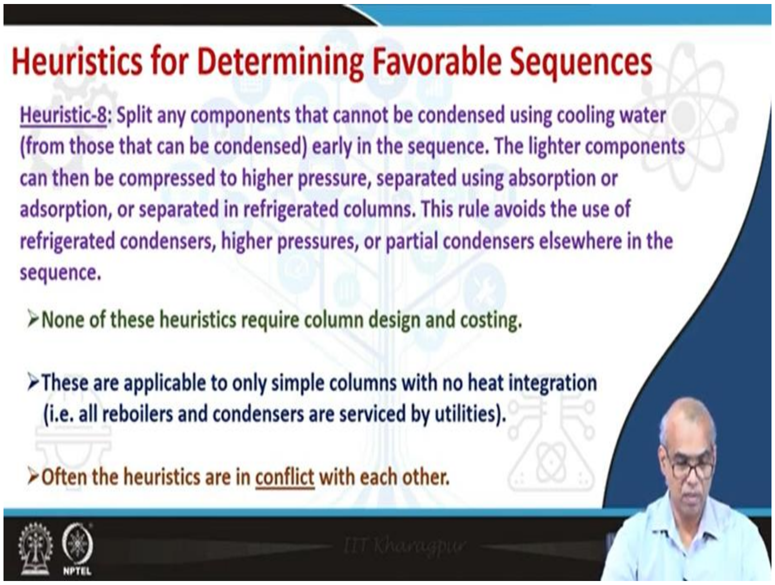

Heuristics for Determining Favorable Sequences

Heuristic-8: Split any components that cannot be condensed using cooling water (from those that can be condensed) early in the sequence. The lighter components can then be compressed to higher pressure, separated using absorption or adsorption, or separated in refrigerated columns. This rule avoids the use of refrigerated condensers, higher pressures, or partial condensers elsewhere in the sequence.

- None of these heuristics require column design and costing.
- These are applicable to only simple columns with no heat integration (i.e. all reboilers and condensers are serviced by utilities).
- Often the heuristics are in conflict with each other.

Heuristic number 8, split any components that cannot be condensed using cooling water from those that can be condensed early in the sequence. The lighter components can then be compressed to higher pressure, separated using absorption or adsorption or separated in refrigerated columns. This rule avoids the use of refrigerated condensers, higher pressures or partial condensers elsewhere in the sequence.

Now, if you note all these heuristics none of these heuristics use column design and costing. These heuristics are applicable to only simple columns with no heat integration that means that all the reboiler loads are serviced by utilities similarly all the condensers are serviced by utilities cooling utilities for condensers hot utilities for the reboilers. There is no heat integration in the distillation columns.

Many times will be able to determine a favorable sequence by making use of these heuristics. However, sometimes these heuristics are in conflict with each other. And then of course the process economics will take the lead role in determining the optimum sequence.

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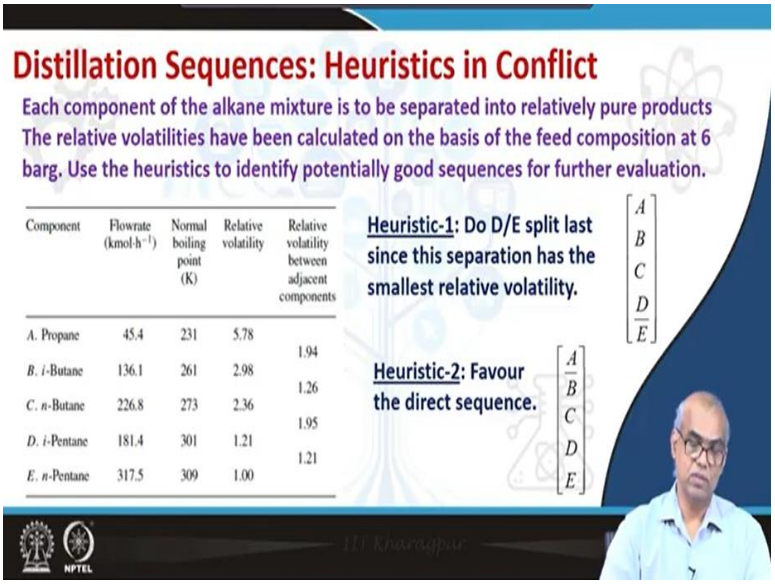

Distillation Sequences: Heuristics in Conflict

Each component of the alkane mixture is to be separated into relatively pure products The relative volatilities have been calculated on the basis of the feed composition at 6 barg. Use the heuristics to identify potentially good sequences for further evaluation.

Component	Flowrate (kmol·h^{-1})	Normal boiling point (K)	Relative volatility	Relative volatility between adjacent components
A. Propane	45.4	231	5.78	1.94
B. i-Butane	136.1	261	2.98	1.26
C. n-Butane	226.8	273	2.36	1.95
D. i-Pentane	181.4	301	1.21	1.21
E. n-Pentane	317.5	309	1.00	

Heuristic-1: Do D/E split last since this separation has the smallest relative volatility.

$$\begin{bmatrix} A \\ B \\ C \\ D \\ \hline E \end{bmatrix}$$

Heuristic-2: Favour the direct sequence.

$$\begin{bmatrix} A \\ \hline B \\ C \\ D \\ E \end{bmatrix}$$

However by making use of this heuristics we can always select certain promising sequences and then we can make detailed cost analysis to select the best one. Now, let us look at the separation of mixtures of alkanes where we have propane, isobutane, n-butane, isopentane and n-pentane. Each component of the alkane mixture is to be separated into relatively pure components. The relative volatilities have been calculated on the basis of feed composition at pressure of 6 barg.

Use the heuristics to identify potentially good sequences for further evaluation. Further evaluation usually by economic consideration. Note that there may also be some other considerations in terms of flexibility and operation safety, etcetera. Now let us make use of those first 4 heuristics that we talked about which are more common and popular. According to heuristic number 1 we should do the DE split last since the separation has the smallest relative volatility.

Note the relative volatility of D that is isopentane is 1.21 and that of E that is n pentane is 1. And these are arranged in the decreasing order of relative volatility. So according to heuristic 1 we will do the D split last because this separation has the smallest relative volatility. According to heuristic 2 we will favor direct sequence and then of course we will have split here.

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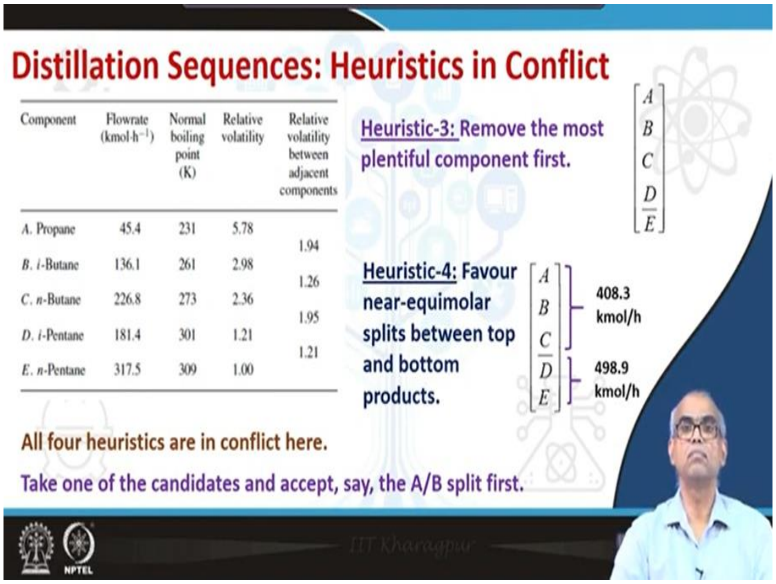

Distillation Sequences: Heuristics in Conflict

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Heuristic-3: Remove the most plentiful component first.

Heuristic-4: Favour near-equimolar splits between top and bottom products.

All four heuristics are in conflict here.

Take one of the candidates and accept, say, the A/B split first.

According to Heuristic 3 we will remove the most plentiful component first. Now, which one is most plentiful component among all? The E: n-pentane note that the flow rate in kilo mole per hour is 317.5 which is higher than all other components. So according to Heuristic 3 we will remove the most plentiful component first. So, it will make a split between D and E. According to Heuristic number 4 we will favor near-equimolar splits between top and bottom products.

So this gives us a split between ABC and D if you sum up this 3 and this 3, flow rates what you get is 408.3 kilo mole per hour for ABC and D is 498.9 kilo mole per hour. So, they are not exactly equivalent, but they are close. So now if you look at these four heuristics, we see that one heuristic says between A and B one says between D and E another says between ABC and D.

So there all in conflict, so all four heuristics are in conflict here. Let us do one thing let us take any of these candidates. Let us say I consider ABC split.

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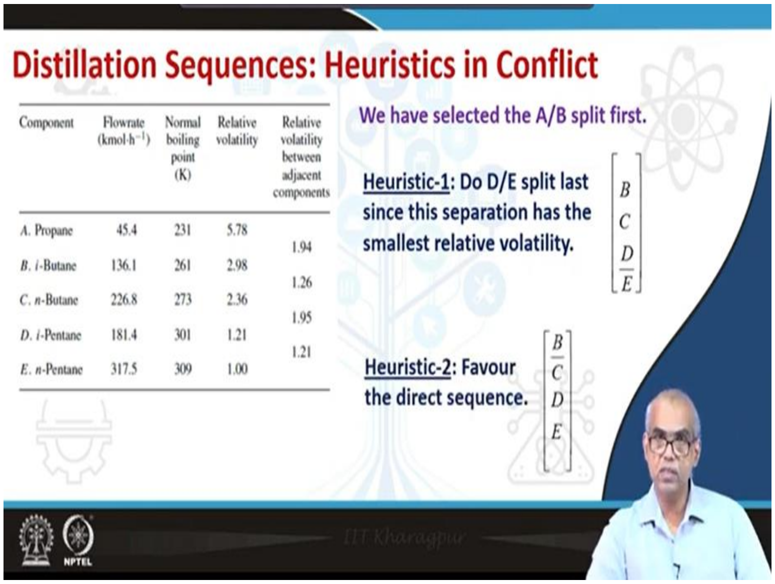

Distillation Sequences: Heuristics in Conflict

Component	Flowrate (kmol·h⁻¹)	Normal boiling point (K)	Relative volatility	Relative volatility between adjacent components
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				1.95
D. *i*-Pentane	181.4	301	1.21	
				1.21
E. *n*-Pentane	317.5	309	1.00	

We have selected the A/B split first.

Heuristic-1: Do D/E split last since this separation has the smallest relative volatility.

$\left[\frac{\begin{matrix}B\\C\\D\end{matrix}}{E}\right]$

Heuristic-2: Favour the direct sequence.

$\left[\frac{B}{\begin{matrix}C\\D\\E\end{matrix}}\right]$

So you consider split between A and B first. One of the Heuristic say that direct sequence according to direct sequence Heuristics will have the split between A and B because A is the most volatile. Now, what about split of the remaining components BCDE? So again Heuristic 1 will do the split between D and E last because of the smallest relative volatility. Heuristic number 2 will favor the direct sequence.

So we will have the split between B and C because among the remaining components I have B as the most volatile component.

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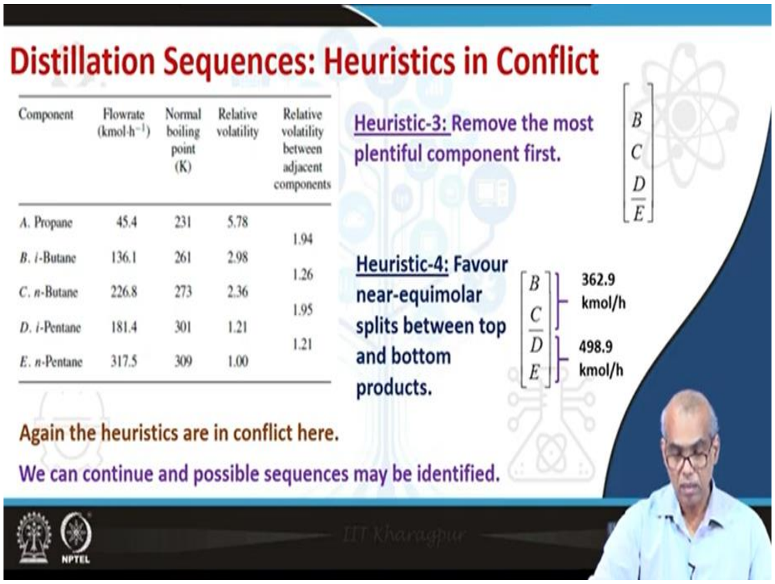

Distillation Sequences: Heuristics in Conflict

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E. *n*-Pentane	317.5	309	1.00	

Heuristic-3: Remove the most plentiful component first.

$\left[\frac{\begin{matrix}B\\C\\D\end{matrix}}{E}\right]$

Heuristic-4: Favour near-equimolar splits between top and bottom products.

$\left[\frac{\begin{matrix}B\\C\end{matrix}}{\begin{matrix}D\\E\end{matrix}}\right]$

362.9 kmol/h

498.9 kmol/h

Again the heuristics are in conflict here.

We can continue and possible sequences may be identified.

What about Heuristic 3? Heuristic 3 says remove the most plentiful component first. So again between D and E is suggested because E is most plentiful. What about the fourth Heuristic, which says favor never near-equimolar splits between top and bottom products. So, please look at B C and D E. They are kind of equimolar not exactly equimolar but close. So we have B C and D again all the heuristics are in conflict here. So we can continue and perhaps we can identify the possible sequences.

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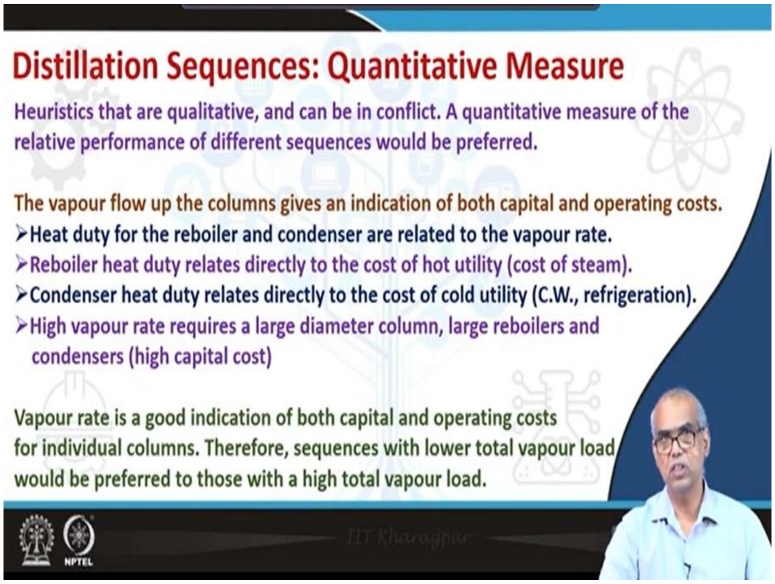

Distillation Sequences: Quantitative Measure

Heuristics that are qualitative, and can be in conflict. A quantitative measure of the relative performance of different sequences would be preferred.

The vapour flow up the columns gives an indication of both capital and operating costs.

- Heat duty for the reboiler and condenser are related to the vapour rate.
- Reboiler heat duty relates directly to the cost of hot utility (cost of steam).
- Condenser heat duty relates directly to the cost of cold utility (C.W., refrigeration).
- High vapour rate requires a large diameter column, large reboilers and condensers (high capital cost)

Vapour rate is a good indication of both capital and operating costs for individual columns. Therefore, sequences with lower total vapour load would be preferred to those with a high total vapour load.

Now often cases often times will be able to identify the favorable sequence by making use of this heuristics. In this particular case, we saw an example where they are in conflict with each other. Heuristics are qualitative. The heuristics we talked about our qualitative and they can be in conflict. So, quantitative measure of the relative performance of difference sequence would be preferred.

The vapour flow of the columns gives an indication of both capital and operating cost. Note that the process economics is ultimately the most important governing factor. So quantitative measure, which has a relation with the process economics will be the preferred one. The vapour flow of the columns gives an indication of both capital and operating cost. So, directly linked with process economics.

Heat duty for the reboiler and condenser are related to the vapor rate. Reboiler heat duty relates directly to the cost of hot utility such as cost of steam. Similarly condenser heat duty is directly related to the cost of cold utility that is cooling water, cost of refrigeration etcetera. High vapour rate requires a large diameter column, large reboiler and also large condenser. So it increase in vapour flow rate capital cost increases.

So vapour rate is a good indication of both capital and operating cost for individual columns. Therefore a sequence with lower total vapour load would be preferred to those with a high total vapour load. So vapour rate is a good indication of both capital and operating cost and will prefer a distillation sequence with lower total vapour load.

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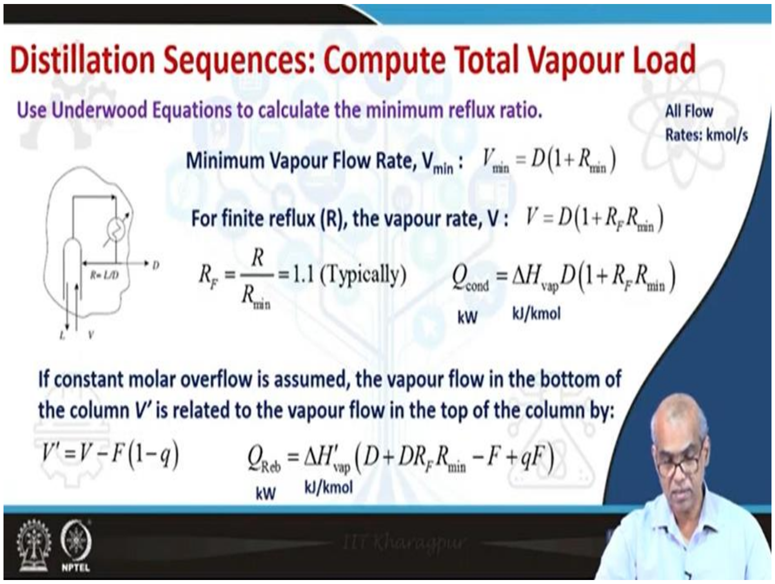

Distillation Sequences: Compute Total Vapour Load

Use Underwood Equations to calculate the minimum reflux ratio.

All Flow Rates: kmol/s

Minimum Vapour Flow Rate, $V_{\min}$: $V_{\min} = D(1+R_{\min})$

For finite reflux (R), the vapour rate, V : $V = D(1+R_F R_{\min})$

$R_F = \frac{R}{R_{\min}} = 1.1$ (Typically)

$Q_{\mathrm{cond}} = \Delta H_{\mathrm{vap}} D(1+R_F R_{\min})$

kW kJ/kmol

If constant molar overflow is assumed, the vapour flow in the bottom of the column V' is related to the vapour flow in the top of the column by:

$V' = V - F(1-q)$

$Q_{\mathrm{Reb}} = \Delta H'_{\mathrm{vap}}(D + DR_F R_{\min} - F + qF)$

kW kJ/kmol

So; how to compute the total vapour load? First, let us make use of Underwood equation to calculate the minimum reflux ratio. Now if you consider a section of the top of the distillation column the minimum vapour flow rate can be obtained as D into 1 + Minimum reflux rate R, minimum reflux ratio R. This is obtained from the mass balance equation around this envelope. Now if you take finite reflux, R the vapour rate will be V into wherever V will be equal to D into 1 + R.

Now if I consider a factor RF = R by R minimum, which is typically taken as 1.1 we see that R = RF into R minimum, so RF into R minimum. So this way for finite reflux, we can find vapour rate V is we equal to D into 1 + RF into R minimum where RF is the ratio of actual reflux ratio to minimum reflux ration, which is typically considered as 1.1. Now, we can also find out now condenser heat duty as Q = Heat of vaporization into D into 1 + RF into R minimum.

So heat of vaporization for the vapour at that top of the distillation column, D is the distillate rate in kilo mole per second all flow rates are in kilo mole per second and the condenser heat duty is in kilo watt. Now if constant molar overflow is assumed the vapour flow in the bottom of the column will be related to the vapour flow in the top of the column and the feed condition, which is q.

And they are related by the equation V prime which represents the vapour flow in the bottom of the column = V into F into 1- q, where F is the feed flow rate in kilo mole per second and q is the feed condition. So q equal to feed condition which equal to heat required to vaporize one mole of it divided by molar rate of vaporization. We can also find out the reboiler heat load as heat of vaporization of the liquid at the bottom and then this factor D + DRF R minimum - F+ q into F.

Note that heat of vaporization is in kilo joule per kilomole, reboiler heat load is kilo watt, all flow rates are in kilo mole per second and Q is in heat condition which does not have any unit.

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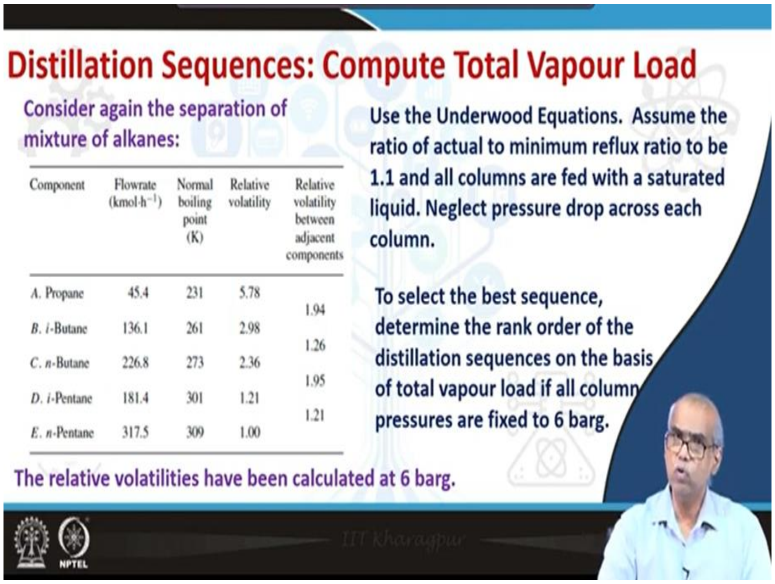

Distillation Sequences: Compute Total Vapour Load

Consider again the separation of mixture of alkanes:

Component	Flowrate (kmol·h^{-1})	Normal boiling point (K)	Relative volatility	Relative volatility between adjacent components
A. Propane	45.4	231	5.78	
				1.94
B. *i*-Butane	136.1	261	2.98	
				1.26
C. *n*-Butane	226.8	273	2.36	
				1.95
D. *i*-Pentane	181.4	301	1.21	
				1.21
E. *n*-Pentane	317.5	309	1.00	

The relative volatilities have been calculated at 6 barg.

Use the Underwood Equations. Assume the ratio of actual to minimum reflux ratio to be 1.1 and all columns are fed with a saturated liquid. Neglect pressure drop across each column.

To select the best sequence, determine the rank order of the distillation sequences on the basis of total vapour load if all column pressures are fixed to 6 barg.

Now for an example again consider the separation of mixtures of alkane. The relative volatility is having calculated at a fixed pressure of 6 barg. Use the underwood equation to find out minimum reflux ratio. Assume the ratio of actual to minimum reflux ratio to be 1.1 and all the columns are fed with a saturated liquid. So value of the q equal to 1 fixed. Neglect pressure drop across each column.

Now in order to select the best sequence what we will do is we will determine the rank order of the distillation sequences on the basis of total vapour load if all column pressures are fixed to 6 barg. So I have these 5 components and you know for 5 components 14 sequences are possible. So find out all 14 sequences. I am assuming that the pressure in each column is fixed at 6 barg. Relative volatility is our computed at this 6 barg.

To select the best sequence we determine the vapour load for all 14 sequences and rank them in the order on the basis of total vapour load. The lowest vapour load is the favoured sequence.

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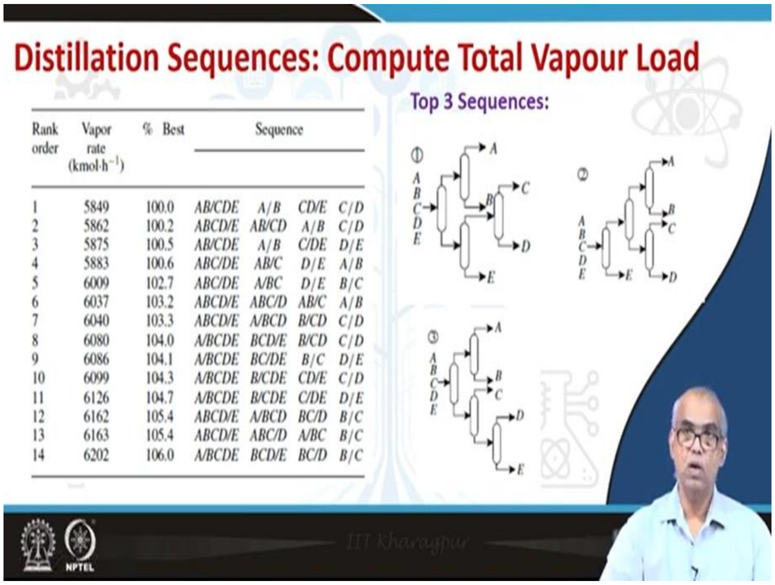

Distillation Sequences: Compute Total Vapour Load

Rank order	Vapor rate (kmol·h^{-1})	% Best	Sequence			
1	5849	100.0	AB/CDE	A/B	CD/E	C/D
2	5862	100.2	ABCD/E	AB/CD	A/B	C/D
3	5875	100.5	AB/CDE	A/B	C/DE	D/E
4	5883	100.6	ABC/DE	AB/C	D/E	A/B
5	6009	102.7	ABC/DE	A/BC	D/E	B/C
6	6037	103.2	ABCD/E	ABC/D	AB/C	A/B
7	6040	103.3	ABCD/E	A/BCD	B/CD	C/D
8	6080	104.0	A/BCDE	BCD/E	B/CD	C/D
9	6086	104.1	A/BCDE	BC/DE	B/C	D/E
10	6099	104.3	A/BCDE	B/CDE	CD/E	C/D
11	6126	104.7	A/BCDE	B/CDE	C/DE	D/E
12	6162	105.4	ABCD/E	A/BCD	BC/D	B/C
13	6163	105.4	ABCD/E	ABC/D	A/BC	B/C
14	6202	106.0	A/BCDE	BCD/E	BC/D	B/C

Top 3 Sequences:

See if I do that you will get this. So note that the rank 1 has vapour rate as 5849 kilo mole per hour. And the vapour rate increases as I go from sequence 1 to 2 to 3 and so on and so forth. So they have been ordered or they have been ranked according to their vapor rate in kilo mole per hour with the lowest vapor rate, given rank number 1. So all 14 sequences are given ranks and you can now select the sequence with lowest vapor rate.

So, these are the top 3 sequences. Note that this one AB and CD is split is done in the first column. This one is second. And this is the third. So these are the top three performers. So this way making use of total vapor rate in the distillation column as a quantitative measure. We can be able to find out the favorable sequence. With this we stop our discussion here.