DISTILLATION TOWER

Presented by

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1. Fundamentals of Separation in Towers

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1.1 Distillation

- Distillation is a separation process requires differences to be recognized and utilized.
- Separation by distillation implies a difference in boiling points of two or more materials.
- We separate many things by detecting a difference in a physical properties.

color, size, weight, shape

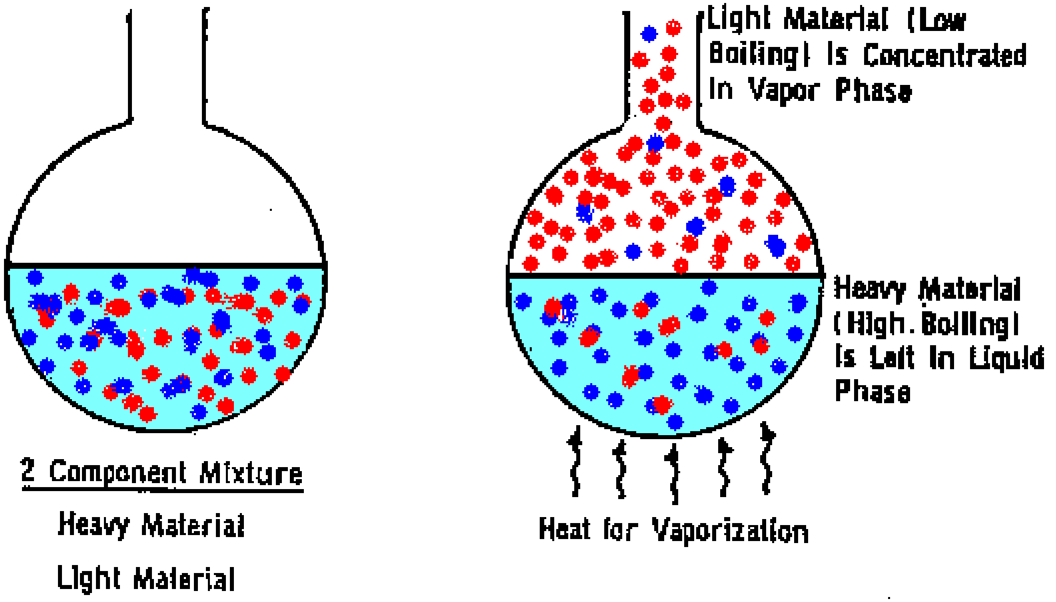
1.1 Distillation

- The components or compounds making up crude oil or natural gas are numbered in thousands.
- Many of these components have similar physical properties including boiling points that may differ by only a few degrees.
- There are other methods of separation used in a refinery for example:
  - Extraction with a solvent,
  - Crystallization, and
  - Absorption.

1.2 Principles of Distillation

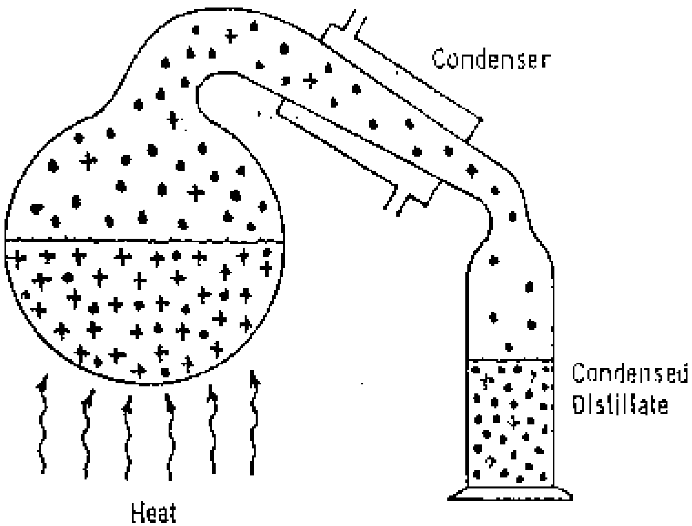
The basic principle of distillation is simple:

1. When a solution of two or more components is boiled,
2. The lighter component vaporizes preferentially.



1.2 Principles of Distillation

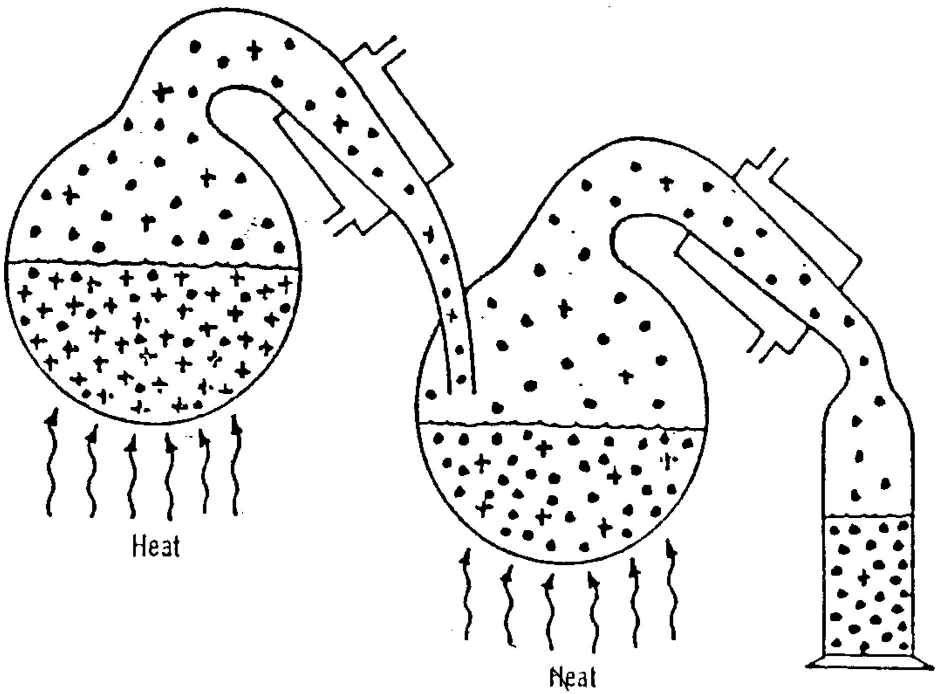
- this simple distillation concept into a practical operation as it is used in the refinery By cooling the over head vapor, we condense and remove it from the original mixture.
- This is a partial separation, because there are a few “+ Heavy Material" in the distillate product.



- • Light Material
- + Heavy Material

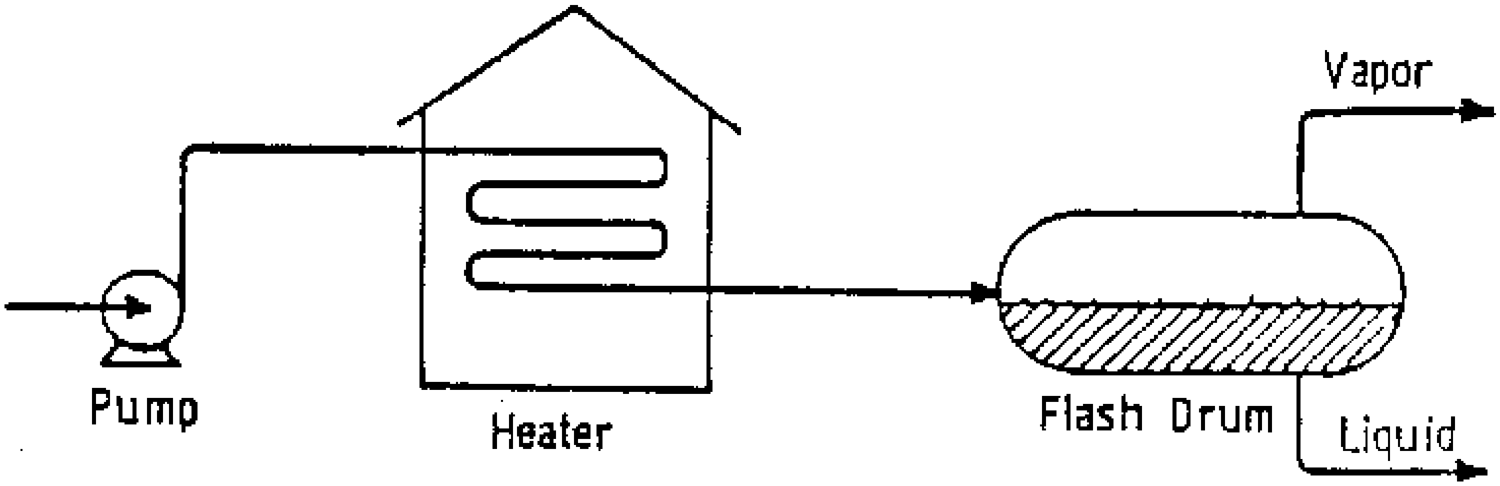
1.2 Principles of Distillation

- Therefore, to purify the distillate product, we may have to conduct a second distillation.
- Obviously, we can continue to cascade these simple distillations until we achieve the desired purity of product.



1.2 Principles of Distillation

- This is called Flash Vaporization.
- The liquid is pumped continuously through a heater and into a drum.

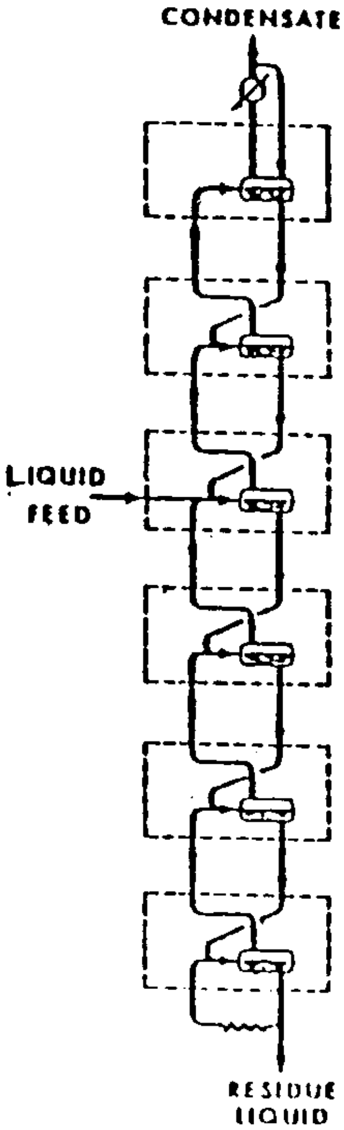


1.2 Principles of Distillation

- Suppose we have 50% of the charge taken overhead.
- And further, suppose the resulting overhead product does not contain the desired concentration of the lighter product.
- As we have seen before, we can increase the purity by adding a stage of distillation.

1.2 Principles of Distillation

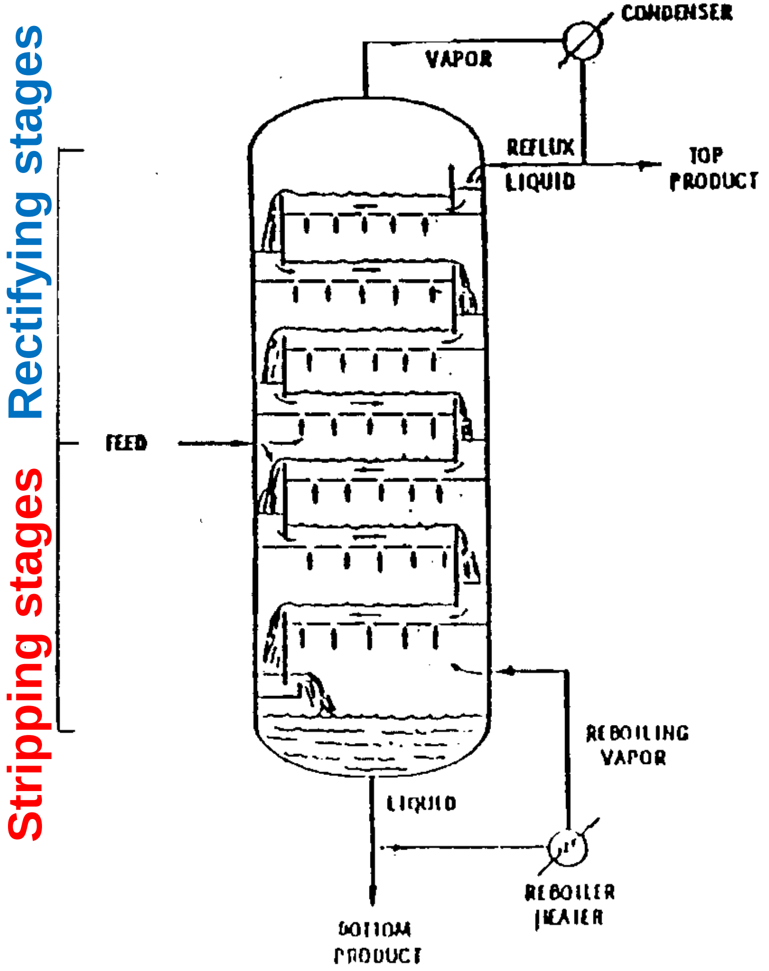
- Although this is accomplishing our goal of increasing the purity of the light friction, we are also making large amounts of the intermediate product, each of which contains the same light friction.



1.2 Principles of Distillation

Tower Sections

- the lighter component in the overhead.
- the heavier component in the bottom product.
- The upper two stages are called rectifying stages.
- These below the feed are called stripping stages.



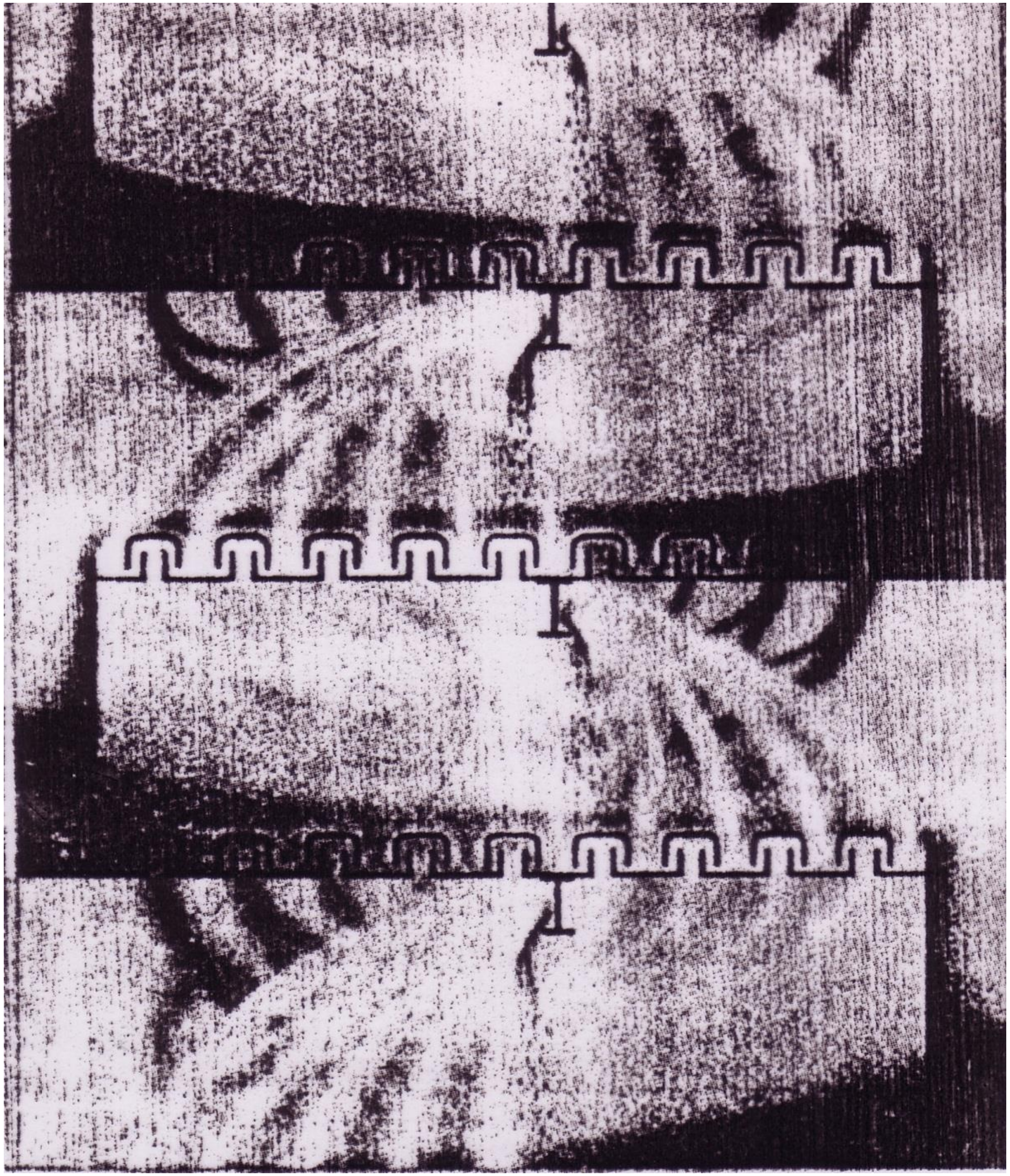
1.2 Principles of Distillation

- The upper rectifying section increases the purity of the overhead product.
- The lower stripping section increases the recovery of the overhead product.
- For the bottom, or heavy, product the rectifying section improves recovery.

1.2 Principles of Distillation

Equilibrium Stage

- A stage, or more specifically, an equilibrium stage, is defined as:
- Any portion of the distillation column such that the liquid and vapor leaving it have composition in equilibrium with each other.
- By definition, then, a stage should be designed in such a way as to provide intimate contact, or mixing, of the rising vapor and the descending liquid.



1.2 Principles of Distillation

- The design of trays has taken many forms.
- Some common ones are :
  - Valve trays,
  - Bubble cap trays,
  - Sieve trays, and many others.

1.2 Principles of Distillation

- Alternate designs include packing instead of trays.
- Various kinds of packing have used, some of which are :
  - Pall rings,
  - Saddles, and
  - Mesh.

1.2 Principles of Distillation

Mesh

Pall rings

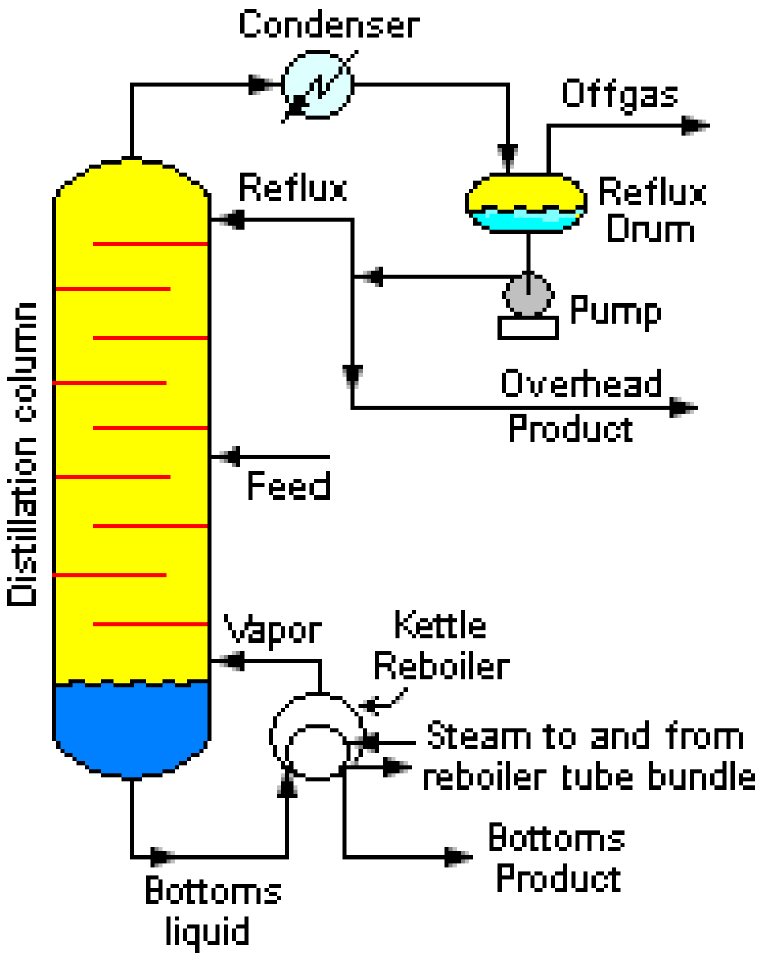
Saddles rings

1.2 Principles of Distillation

- The type of column internal used depends on the application.
- The considerations being :
    - Purity of feed,
    - Efficiency,
    - Capacity,
    - Pressure drop,
    - Liquid holdup, and
    - Cost.

1.2 Principles of Distillation

- The column shown is a simple binary column with trays.
- There is only one feed and two products, the overhead and bottoms.
- More complex columns may have several feed streams.



1.3 Reflux

- The word reflux is defined as: "flowing back“
- reflux is: The liquid flowing back down the tower from each successive stage.
- **Kinds of Reflux**
  - Cold Reflux
  - Hot Reflux
  - Internal Reflux
  - Circulating Reflux
  - Side Reflux

1.3 Reflux

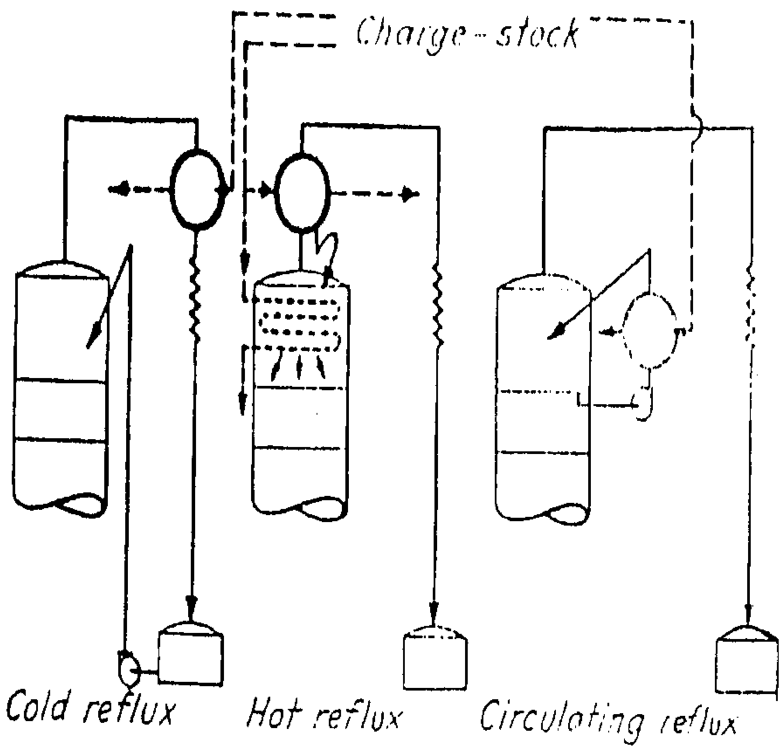
Cold Reflux

- The liquid that is supplied at temperature a little below that at the top of the tower.
- Each pound of this reflux removes a quantity of heat equal to the sum of its: latent and sensible heat

1.3 Reflux

Hot Reflux

- It is the reflux that is admitted to the tower at the same temperature as that maintained at the top of the tower.
- It is capable of removing the latent heat because no difference in temperature is involved.



1.3 Reflux

Internal Reflux

- It is the liquid that overflow from one plate to another in the tower, and may be called hot reflux because it is always substantially at its boiling point.
- It also capable of removing the latent heat only because no difference in temperature is involved.

1.3 Reflux

Circulating Reflux

- It is able to remove only the sensible heat which is represented by its change in temperature as it circulates.
- The reflux is withdrawn and is returned to the tower after having been cooled.

1.3 Reflux

Side Reflux

- This type of reflux (circulating reflux) may conveniently be used to remove heat at points below the top of the tower.
- If used in this manner, it tends to decrease the volume of vapor the tower handles.

1.3 Reflux

Reflux Ratio

- It is defined as the amount of internal reflux divided by the amount of top product.
- It is denoted by R which equals L/D.
- Since internal hot reflux can be determined only by computation.

1.3 Reflux

The Importance of Reflux Ratio

- In general, increasing the reflux:
  - ✓ Improves overhead purity, and
  - ✓ Increases recovery of the bottom product.
- The number of stages required for a given separation will be dependent upon the reflux ratio used.

1.3 Reflux

Two points to consider

1. A minimum number of plates (stages) required at total reflux.
2. There is a minimum reflux ratio below which it is impossible to obtain the desired enrichment (separation) however many plates are used.

1.3 Reflux

Total Reflux

- Total reflux is the conclusion when all the condensate (distillate) is returned to the tower as reflux, no product is taken off and there is no feed.
- At total reflux, the number of stages required for a given separation is the minimum at which it is theoretically possible to achieve the separation.
- Total reflux is carried out at:
    1. Towers start-up and shutdown.
    2. Testing of the tower.

1.3 Reflux

Minimum Reflux

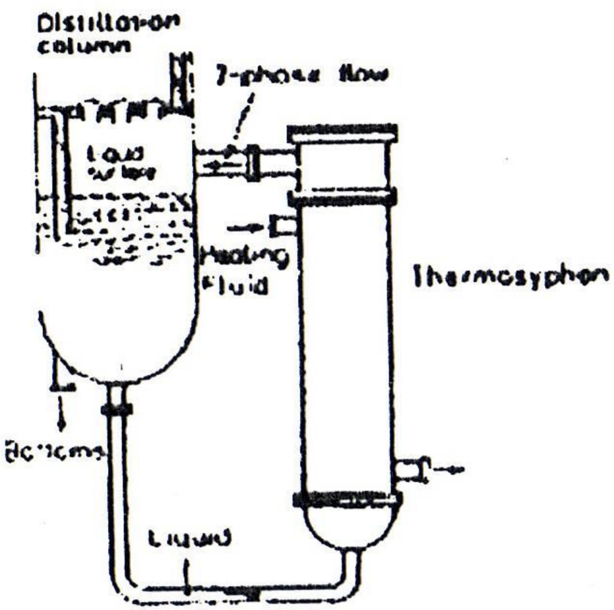
- At minimum reflux, the separation can only be achieved with an infinite number of stages.

Optimum Reflux Ration

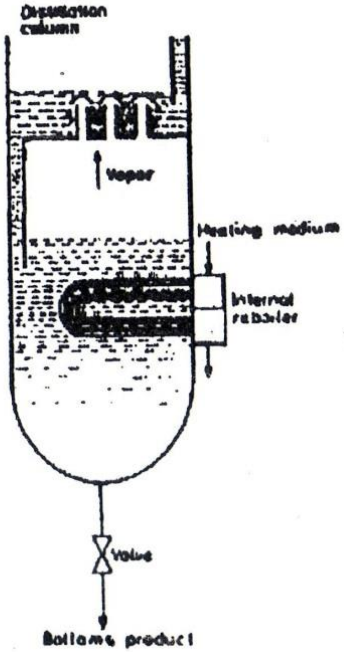
- The optimum value will be the one at which the specified separation is achieved at the lowest annual cost.
- For many systems, it lie between: 1.2 to 1.5 times the minimum reflux ratio

1.4 Reboiling

- In all distillations processes
- Heat being added by:
  - Feed, and
  - Reboiler.
- Heat is transferred to the bottom materials which cause vaporization of the lighter components.
- This vapor travels up the column to provide:
  - The stripping action, and
  - The additional heat necessary to vaporize the down coming reflux.

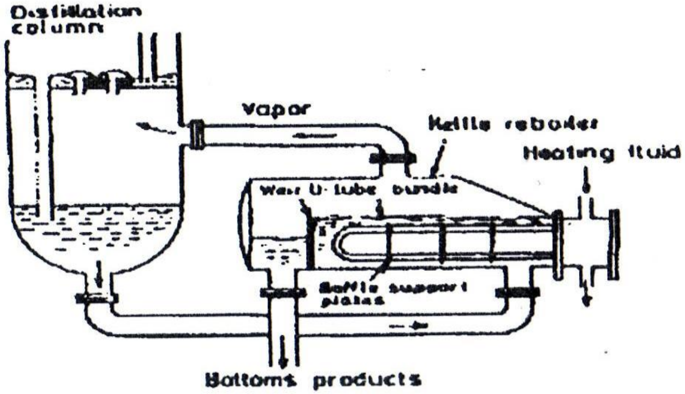


Thermosyphon Reboiler



Internal Reboiler

Kettle reboiler



2.CRUDE DISTILLATION

2.CRUDE DISTILLATION

2.1 Process Description

2.2 Product Specifications

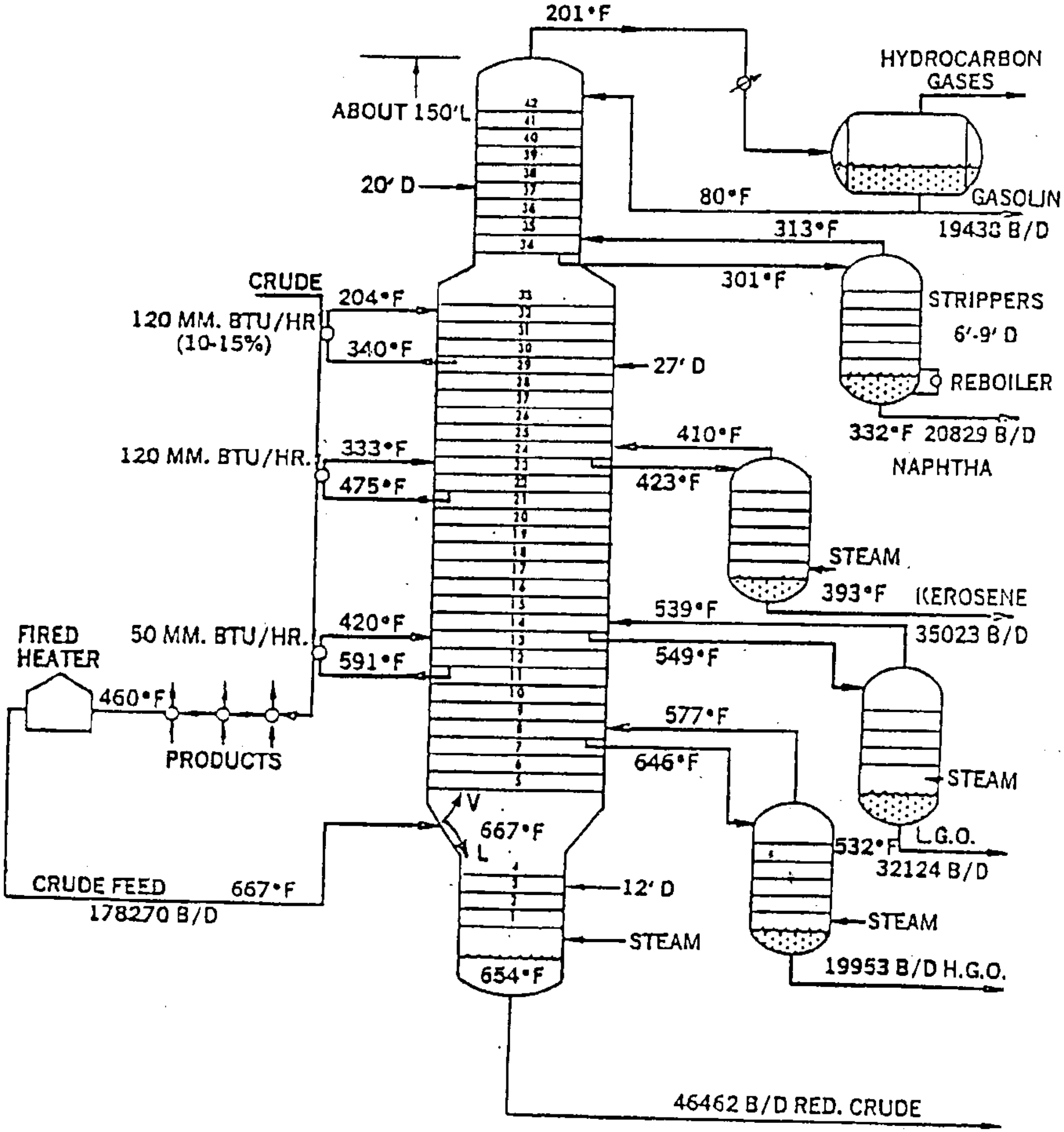
2.CRUDE DISTILLATION

- The purpose of crude oil distillation is primarily to split the crude into several distillate fractions of a certain boiling range.

- A crude distillation tower, producing 6 fractions has 40 to 50 trays.

2.CRUDE DISTILLATION

- By distillation at atmospheric pressure, crude oil can be separated into:
  - Fuel Gases
  - Gasoline,
  - Kerosene,
  - Gas oil,
  - Diesel oil, and
  - Residue (Fuel Oil)


201°F
HYDROCARBON GASES
ABOUT 150'L
20' D
80°F
GASOLIN
19430 B/D
313°F
301°F
STRIPPERS
6'-9' D
REBOILER
332°F 20829 B/D
NAPHTHA
CRUDE
120 MM. BTU/HR
(10-15%)
204°F
340°F
27' D
120 MM. BTU/HR.
333°F
475°F
410°F
423°F
STEAM
393°F
KEROSENE
35023 B/D
FIRED HEATER
50 MM. BTU/HR.
420°F
591°F
539°F
549°F
460°F
PRODUCTS
577°F
646°F
STEAM
L.G.O.
32124 B/D
V
667°F
L
532°F
CRUDE FEED
178270 B/D
667°F
12' D
STEAM
STEAM
654°F
19953 B/D H.G.O.
46462 B/D RED. CRUDE

2.CRUDE DISTILLATION

- Crude is generally pumped to the unit directly from a storage tank, and it is important that charge tanks be drained completely free from water before charging to the unit.
- If water is entrained in the charge It will vaporize in the exchangers and in the heater, and cause a high pressure drop through that equipment.
- Water expands in volume 1600 times upon vaporization at 100ºC at atmospheric pressure.

2.1 Process Description

Heat Exchange

- In order to reduce the cost of operating a crude unit.
- As much heat as possible is recovered from the hot streams by heat exchanging them with the cold crude charge.
- A record should be kept of heat exchanger outlet temperatures so that fouling can be detected and possibly corrected before the capacity of the unit is affected.

2.1 Process Description

Crude Flashing

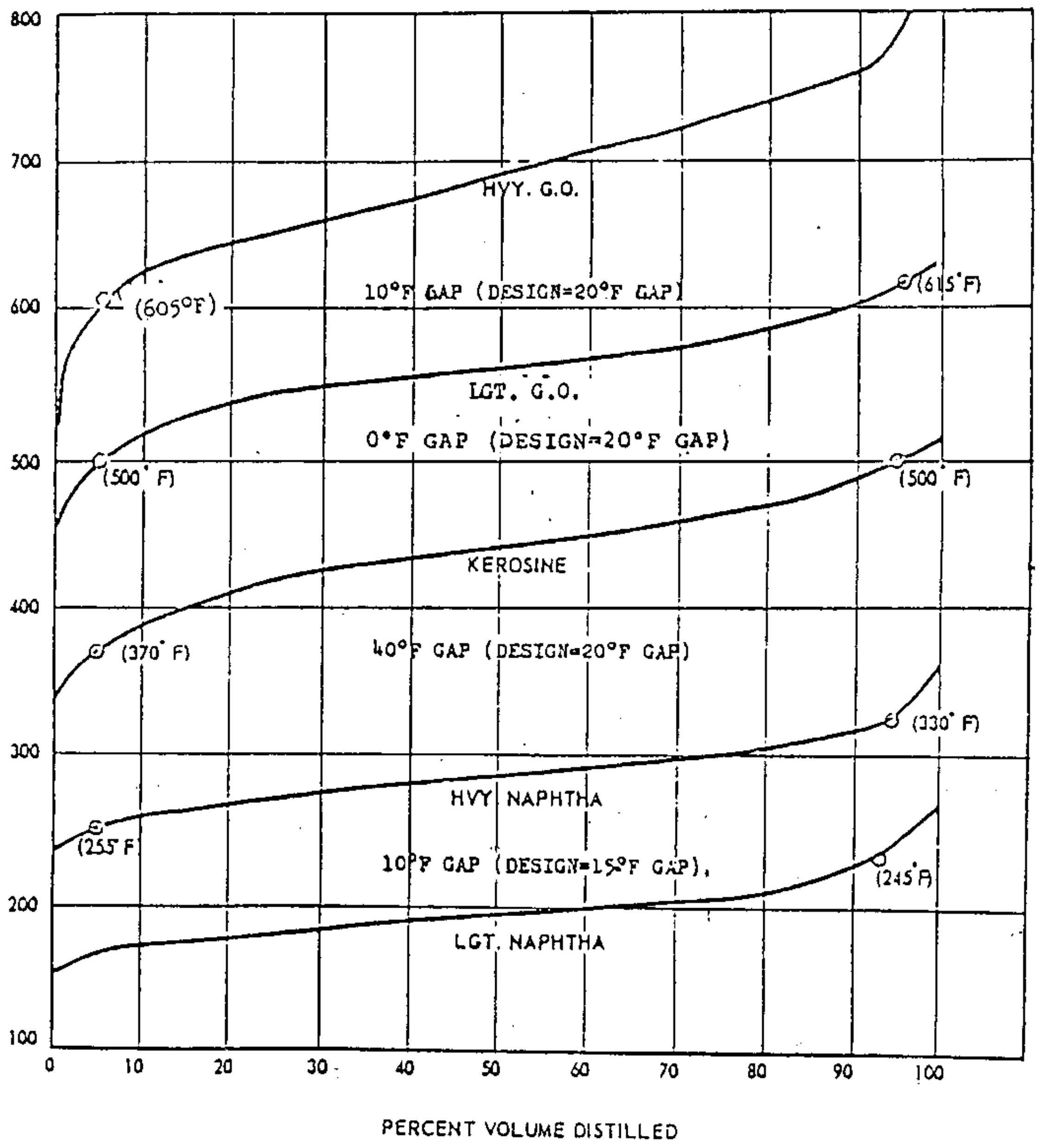
- Desalted crude is heat exchanged against what ever other heat sources are available before it is charged to the heater which has a temperature vary from 325ºC to 430ºC, depending on:
  - ➢ The type of crude, and
  - ➢ The pressure at the bottom of the fractionating tower.

2.1 Process Description

Fractionation

- Crude entering the flash zone of the fractionating column.
- The degree of fractionation between cuts is generally judged by measuring the number of degrees centigrade between the 95% point of the lighter product and the 5% point of the heaving product.
- Some people use IBP and FBP But the IBP varies with stripping.

Recommended Gab between products



2.1 Process Description

- Sometimes fractionators will be “pulled dry.”

- The rate at which a product is being withdrawn is greater than the quantity of internal reflux in the fractionators.

- at the same time there is insufficient material to maintain the level in the stripper.
- the product pump will tend to lose suction.

2.1 Process Description

Product Stripping

- the sidecut products have been in contact with lighter boiling vapors that must be removed to meet flash point specifications.
- Steam (usually superheated steam) is used to strip these light ends.
- While further increases in the quantity of steam may raise the IBP of the product slightly.
- increasing the IBP of one product is to increases the yield of the next light product.

2.1 Process Description

- All the stripping steam is condensed in the overhead receiver and must be drained off.
- Refluxing water will upset the fractionators
- If the endpoint of the overhead product is very low, water may not pass overhead, and will accumulate on the upper trays and cause the tower to flood.

2.1 Process Description

The effect of steam

- Steam is frequently used in fractionating columns, strippers and sometimes in furnaces.
- The partial pressure of steam is subtracted from the total system pressure resulting lower pressure.
- In other words steam has the same effect as lowering the pressure.

2.1 Process Description

Example

- Calculate the top temperature when the top product contains, in addition to H.C components, 4% by wt of steam. Total pressure at the top is 20 psia.

	lbs/hr.	Mol. wt.	Moles
C_3	200	44	4.55
iC_4	300	58	5.17
nC_4	500	58	8.62
iC_5	200	72	2.78
nC_5	1,000	72	13.89
C_6-C_9	37,800	110	343.64
	40,000		378.65
H_2O	1,600	18	88.89

2.1 Process Description

- The mole percentage steam amounts to

$$\frac{88.89}{378.65+88.89}\times 100\% = 19.0\%$$

- the steam partial pressure amounts to

19.0% of 20 psia = 3.80 psia

- The hydrocarbon partial pressure equals,

20–3.80 = 16.20 psia.

- The dew point calculation as described is carried out at a pressure of 16.20 psia.

2.1 Process Description

Desalting

- Most crude contain traces of salt which can decompose in the heater to from hydrochloric acid and cause corrosion of the fractionator's overhead equipment.
- In order to remove the salt, water is injected into the partially preheated crude and the stream is thoroughly mixed so that the water extracts practically all the salt from the oil.

2.1 Process Description

- The mixture of oil and water is separated in a desalter, which is a large vessel in which may be accelerated by the addition of chemicals or by electrical devices.
- If the oil entering the desalter is not enough heated, it may be too viscous to permit proper mixing and complete separation of the water and the oil, and some of the water may be carried into the fractionators.

2.1 Process Description

- If the oil is too hot, some vaporization may occur, and the resulting turbulence can result in improper separation of oil and water.
- The optimum temperature depends upon:
  - ➢ The desalter pressure, and
  - ➢ The quantity of light material in the crude.
- but is normally about 120ºC ± 10ºC being lower for low pressure and light crudes.
- The average water injection rate is 3 – 5% of the charge

2.1 Process Description

- Good desalter control is indicated by the chloride content of the overhead receiver water.

  This should be : 10 – 30 ppm chlorides
- If the desalter operation appears to be satisfactory but the chloride is greater than 30 ppm, then caustic should be injected at the rate of 1 to 3 lbs. per 1000 barrels of charge.
- Thus pH should be controlled between 6.5 and 7.5 and ammonia injection can be used to control this.

2.1 Process Description

Product Disposal

- All products are cooled before being sent to storage.
- Light products should be below 60ºC to reduce vapor losses in storage, but
- Heavier products need not be as cold.

2.1 Process Description

- If a product is being charged to another unit, there may be an advantage in sending it out hot.
- A product must never leave a unit at over 100ºC.
- If there is any possibility of it entering a tank with water bottoms.
- The hot oil could readily boil the water and blow the roof off.

2.2 Product Specifications

- The composition of a distillation product is determined by performing laboratory tests. then the results are compared with product specifications or standards that have been set for the product.
- If the product is meeting specifications, column operations do not have to be adjusted.
- But, if the products are off-specification, a change in column operations must be made.

2.2 Product Specifications

Initial Boiling Point (IBP)

- Is the temperature at which the first drop of condensate is collected during a laboratory distillation test.
- In a mixture of hydrocarbons, the first molecules to vaporize are the light ones.
- So, the IBP test is used to check for light hydrocarbons that are present in a product.

2.2 Product Specifications

- Suppose specifications on the bottom product call for an IBP between 100 – 110°F.
- Lab tests show an IBP of 95°F.
- So, the bottom product in this example contains material that is too light.
- One way is to strip some light components off with steam.
- Another way is to increase the temperature of the feed or the reboiler temperature so more light components are vaporized.

2.2 Product Specifications

End Boiling Point (EP)

- Is the temperature at which the last drop of liquid vaporizes during the test.
- In a mixture of hydrocarbons, the last molecules to vaporize are the heavy ones.
- So, the EBP (EP) test is used to check for heavy hydrocarbons that are present in a product.

2.2 Product Specifications

- Specifications call for an overhead product with an EP between 150 – 160° F.
- Lab results indicate an EP of 170° F.
- So, the top product does not meet specifications because it contains material that is too heavy.
- One way is to decrease the feed or reboiler temperature so that fewer heavy components vaporize.
- Another way is to lower the top temperature by increasing the reflux rate.

2.2 Product Specifications

Flash Point

- Is the temperature at which a petroleum product generates ignitable vapors.
- Light hydrocarbons tend to flash more easily than heavy hydrocarbons.
- A sample that contains traces of light hydrocarbons flashes at a lower temperature than a sample without these traces.

2.2 Product Specifications

- A side draw product carries flash point specifications of 125 – 130° F.
- The lab test shows a flash point of 110° F.
- The sample contains material that is too light. We can bring the product back to specification by:
  - Decreasing the reflux rate, or
  - Using more stripping steam, or
  - Increasing the reboiler temperature.

2.2 Product Specifications

API Gravity

- Is used to designate the "heaviness" or "lightness" of products.
  - Kerosene is measured at about 42° API
  - Gasoline is measured at about 60° API
- The lighter the oil, the higher API gravity.

2.2 Product Specifications

Color

- Light hydrocarbons are light colored while Heavy hydrocarbons are dark in color.
- A light hydrocarbon product that is dark colored probably contains too many heavy molecules.

7. TOWER HARDWARE

7. TOWER HARDWARE

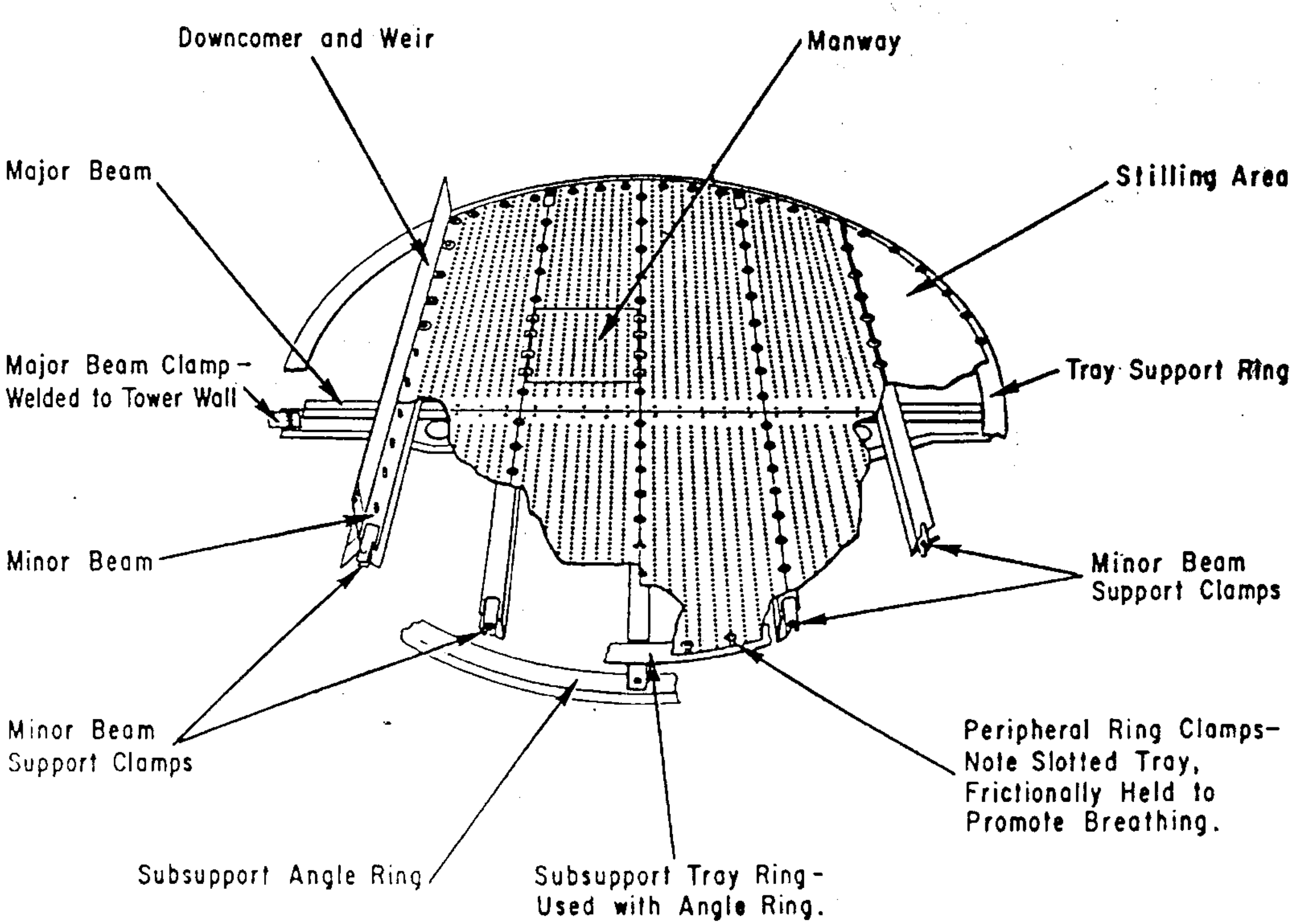
7.1 Trays

7.2 Bottom Strainer

7.3 Reflux distributor

7.4Top Tower Demister

7.1 Trays

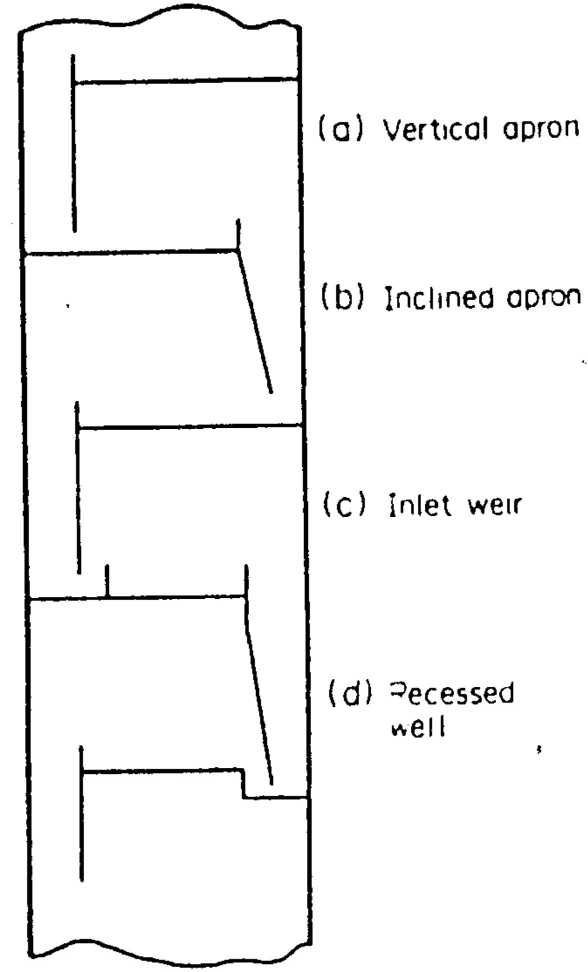


Downcomer and Weir
Manway
Major Beam
Stilling Area
Major Beam Clamp - Welded to Tower Wall
Tray Support Ring
Minor Beam
Minor Beam Support Clamps
Minor Beam Support Clamps
Peripheral Ring Clamps- Note Slotted Tray, Frictionally Held to Promote Breathing.
Subsupport Angle Ring
Subsupport Tray Ring - Used with Angle Ring.

7.1 Trays

Downcomers

- Reflux flows down from one tray to the next through downcomers.
- Downcomers must be large enough to allow for drainage from one tray to the next or flooding might occur on some of the trays.

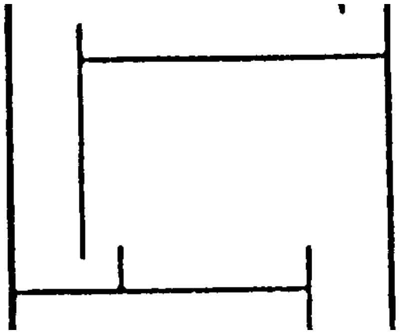


7.1 Trays

Inlet Weirs

- These contribute to the uniform distribution of liquid as it enters the tray from the down comer.

- It is not recommended for fluids that are dirty or tend to foul surfaces.

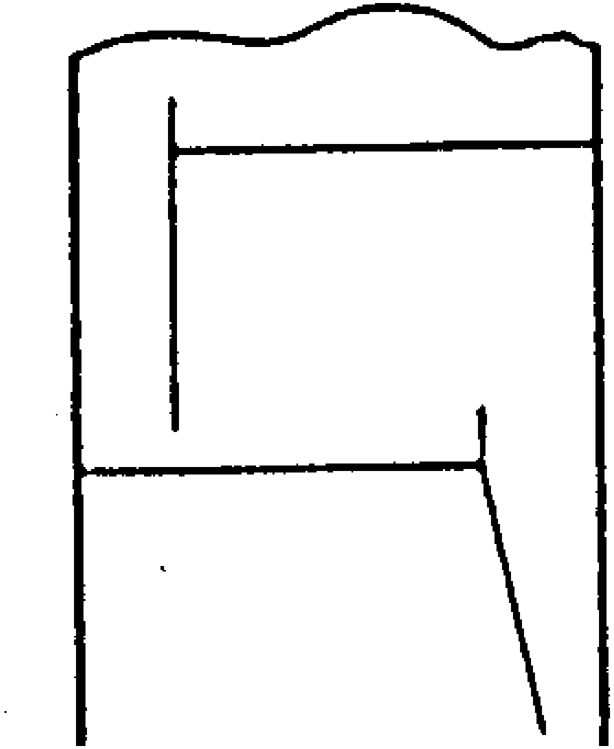


(c) Inlet weir

7.1 Trays

Outlet Weirs

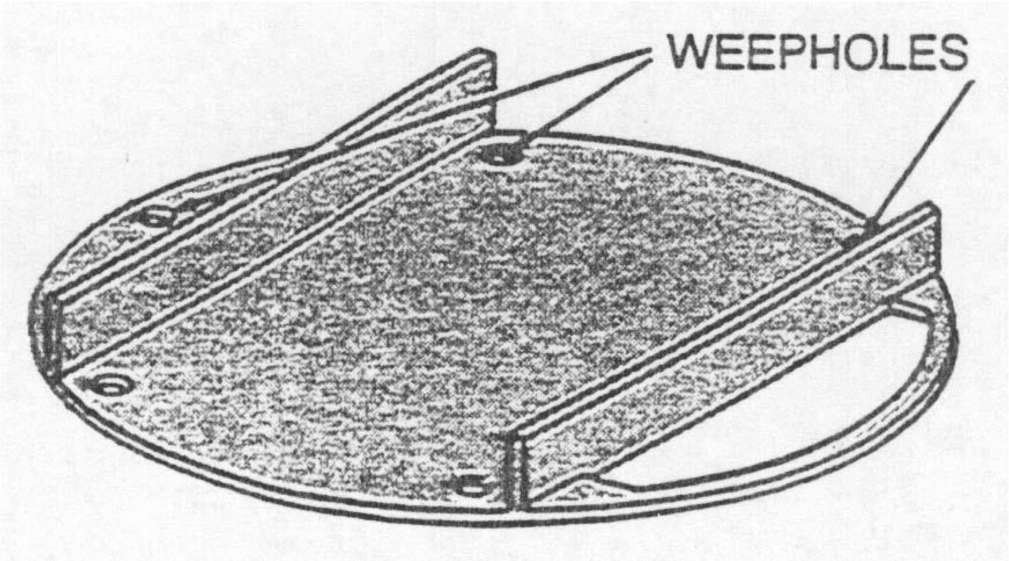
- These are necessary to maintain seal on the tray, thus insuring bubbling of vapors through liquid.



7.1 Trays

Weep Holes

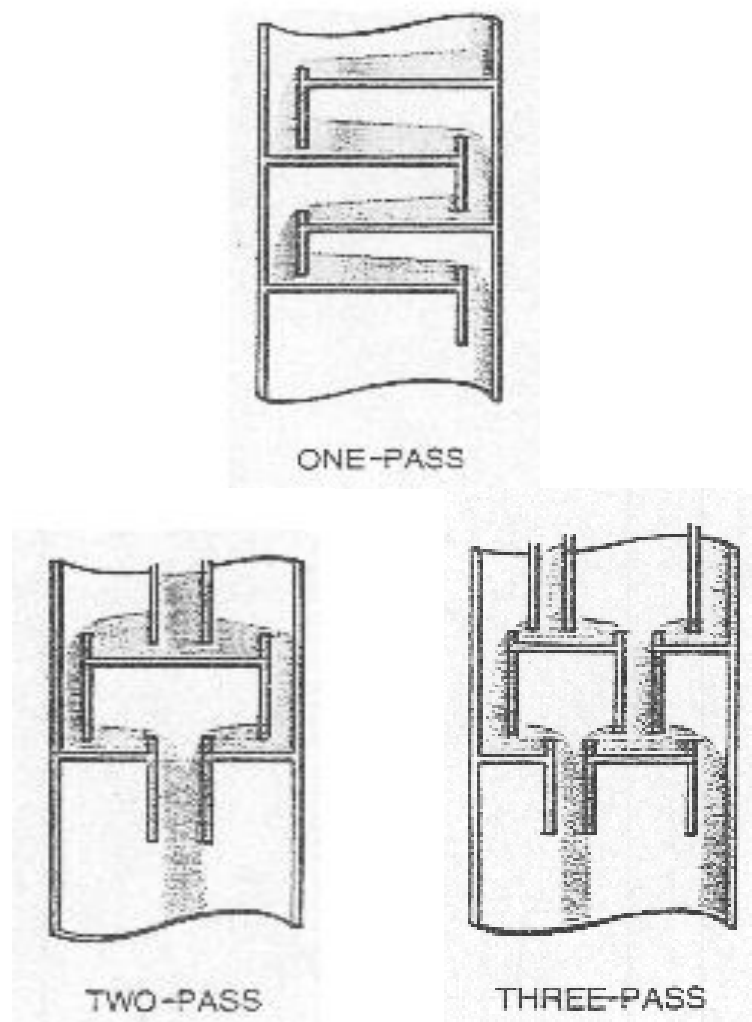
- Holes for drainage must be adequate to drain the tower in a reasonable time, yet not too large to interfere with tray action.



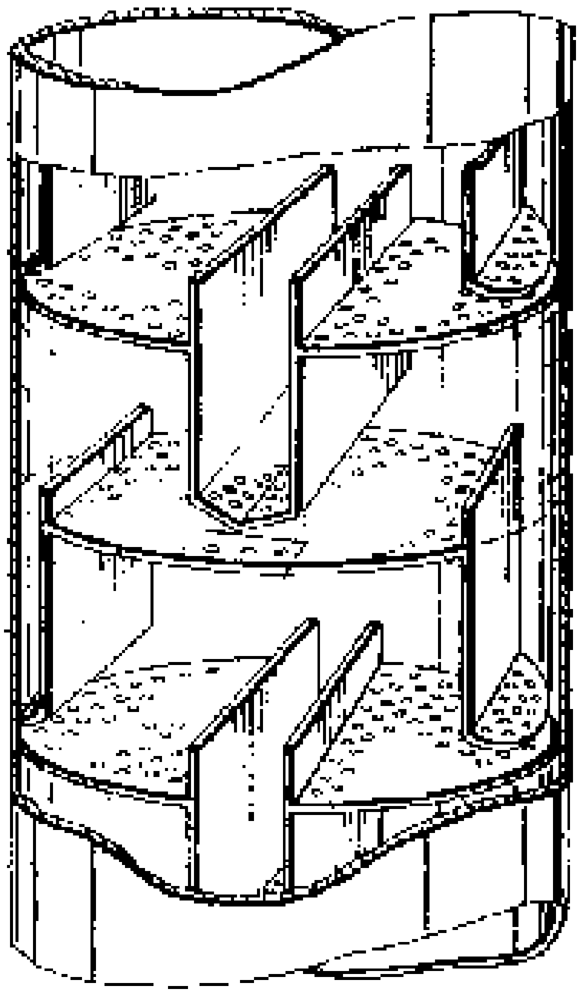
7.1 Trays

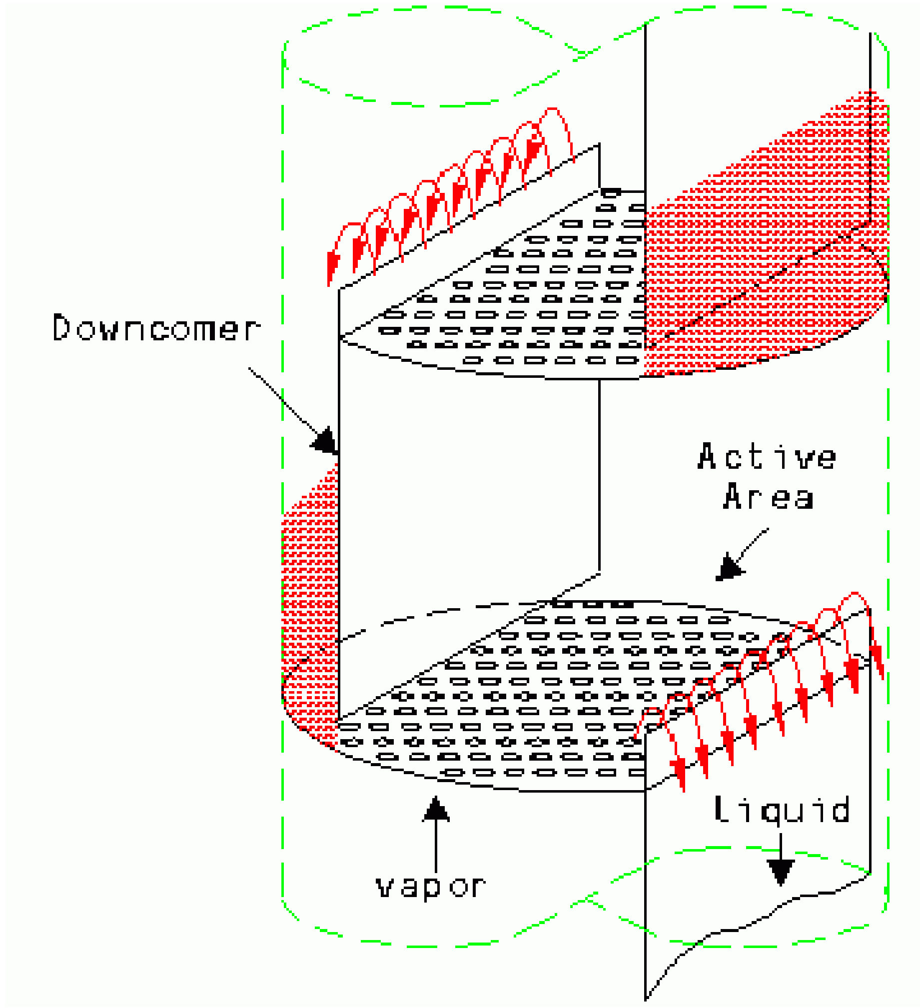
Flow Pass

- In a one-pass system, liquid flows completely across each tray.
- In the two-and three-pass systems, liquid flows across the trays in different direction(s).



7.1 Trays

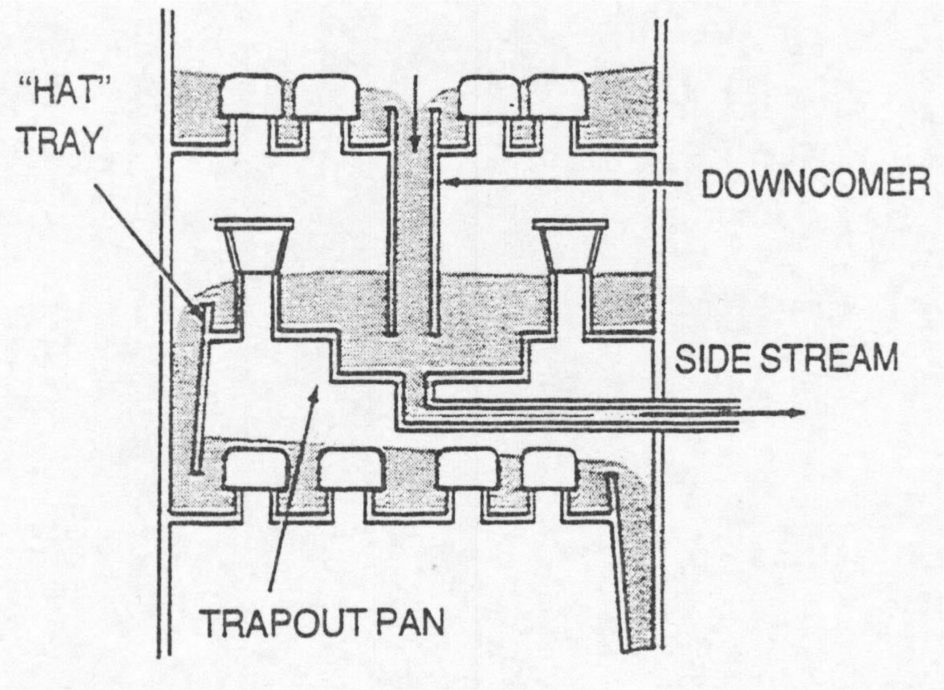




7.1 Trays

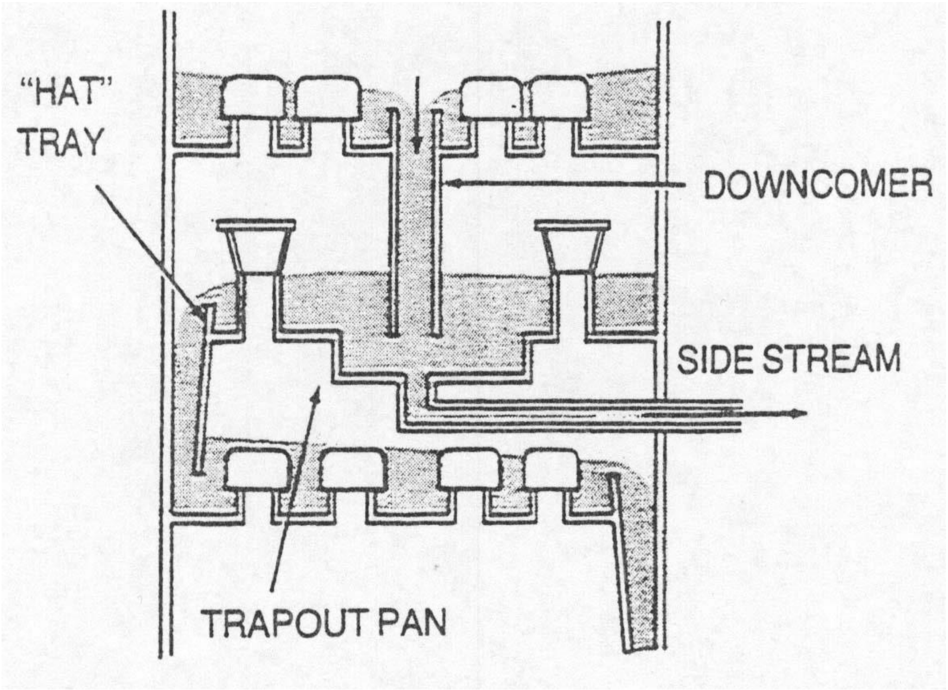
Drawoff Pan (trapout pans)

- trays where a side stream is being drawn off.
- These low areas on trays are called trapout pans.



7.1 Trays

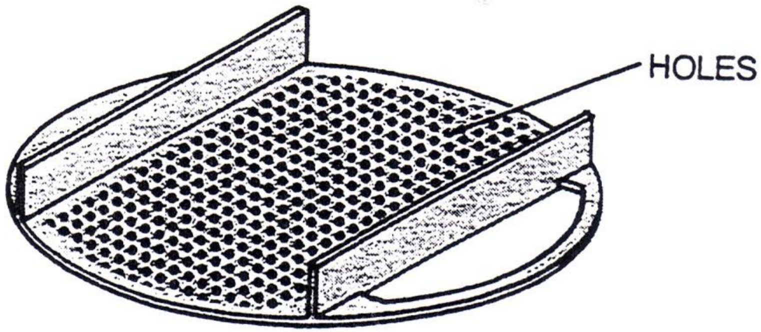
- The risers on a tray where a side stream is being drawn off are much taller than normal to prevent vapor-liquid contact on this tray.
- Because the tall risers and caps look something like a "top hat", this type of tray is often called a hat tray.



7.1 Trays Sieve Deck

Sieve Deck Tray

- This tray is a sheet of light metal with a large number of holes drilled through it.
- Vapor rising through the holes keeps the liquid on the tray and bubbles up through it.



- The overflow weir keeps a constant depth of liquid on the tray.

7.1 Trays Sieve Deck

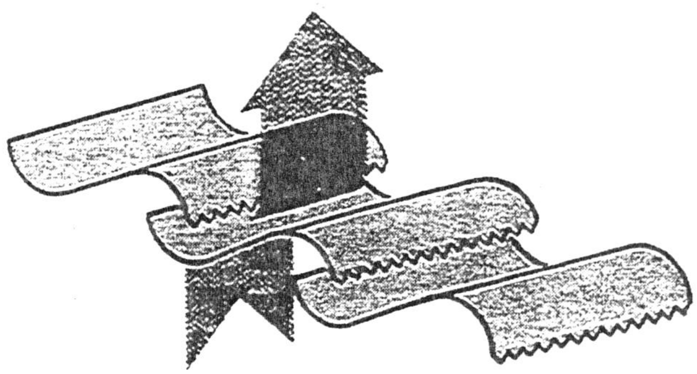
- A sieve deck tray is:
  - Inexpensive,
  - Easy to clean, and
  - Maintains good liquid and vapor contact as long as it is operated at its design load.

- Because the sieve deck tray has fixed openings and does not have covers over the holes, it does not perform well if tower loads are constantly changing.

7.1 Trays S-section

S-section tray

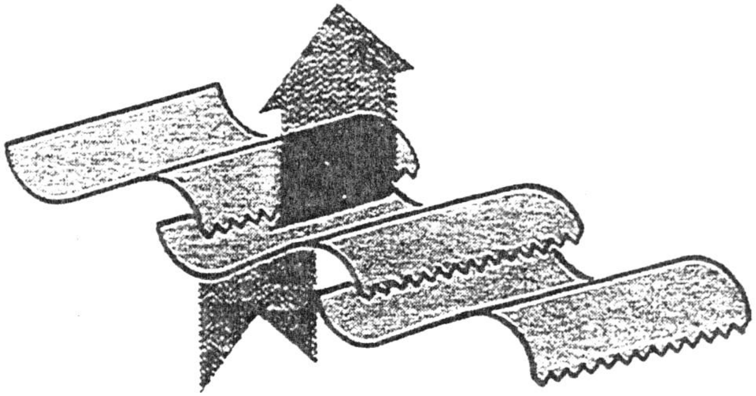
- The S-section tray is also inexpensive to construct.
- It is made of overlapping S-shaped sections



- which form:
  - Long,
  - Continuous bubble caps, and
  - Troughs for the liquid and the vapor.

7.1 Trays S-section

- Each long cap has slots cut in its lower edge which act like bubble cap teeth, forcing vapor to bubble, or flow through the liquid on the troughs.
- The S-section tray must be put together exactly in order to work well.

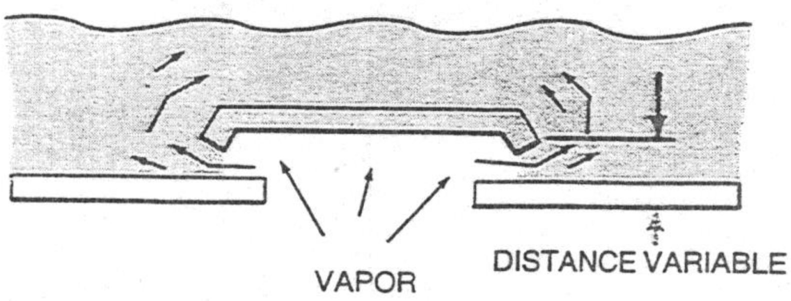


- Small differences in the position or leveling of the S-sections affect the efficiency of vapor-liquid contact.

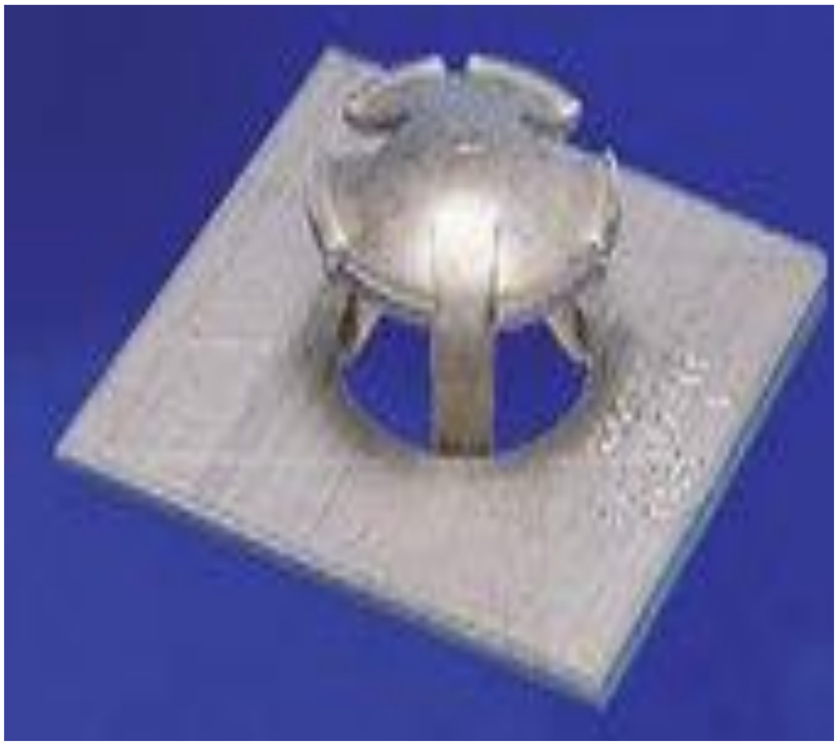
7.1 Trays Valve

Valve Tray

- A valve tray has a variable opening for vapors to flow through.
- The hole has a cover that consists of a cap held in place by guides which go down through the plate, or tray and hook underneath it.



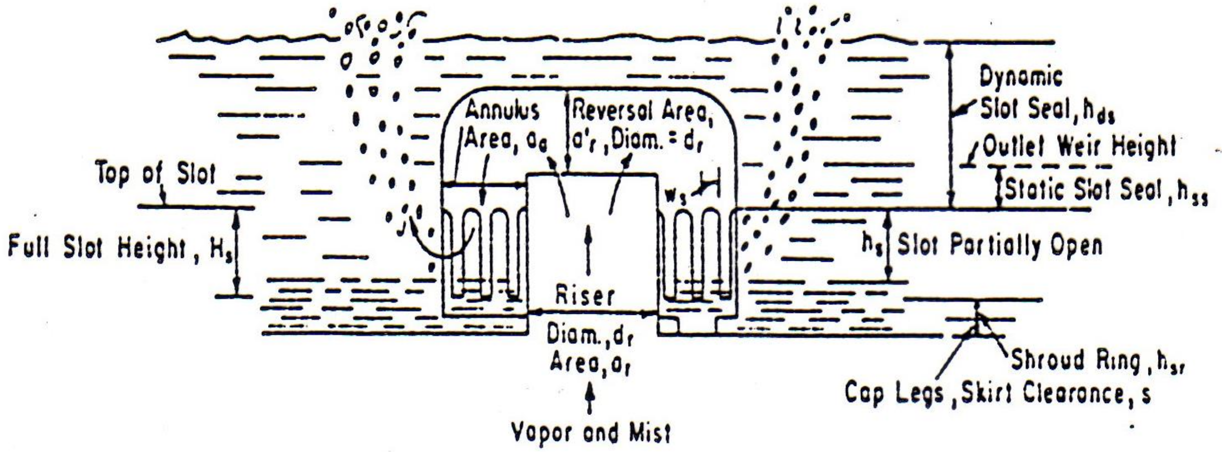
7.1 Trays Valve

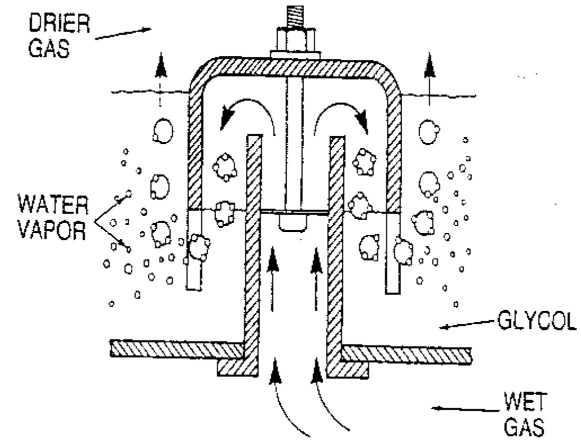


7.1 Trays Bubble Cap

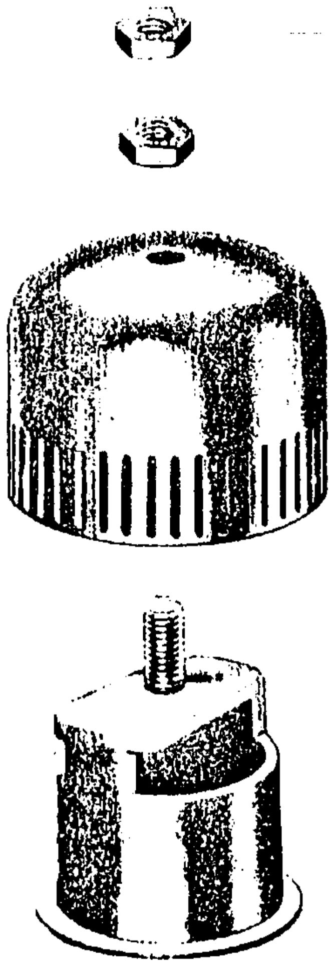
Bubble Cap Tray

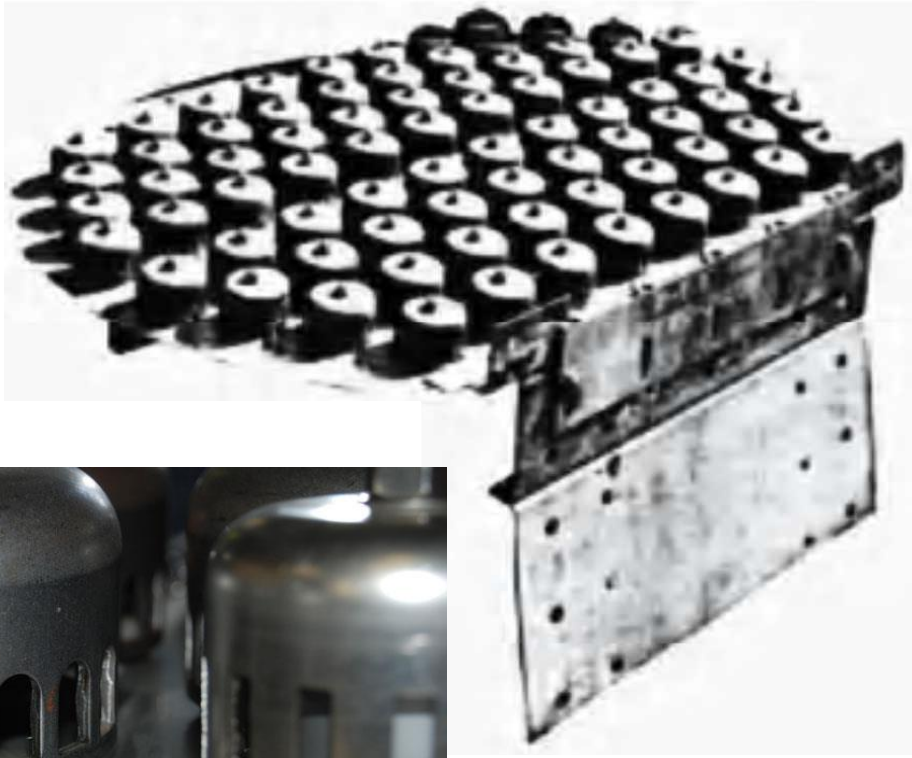
- The vapor is broken into small bubbles which increases the surface area for vapor-liquid contact.
- The bubble cap sits on top of a riser.
- The riser channels vapors into the bubble cap.





7.1 Trays Bubble Cap





7.1 Trays

Selection of Tray Type

- The principal factors to consider when comparing the performance of bubble-cap, sieve and valve trays are:
  - Cost,
  - Capacity,
  - Operating range,
  - Efficiency, and
  - Pressure drop.

7.1 Trays

Cost:

- Bubble-cap trays are appreciably more expensive than sieve or valve trays.
- The relative cost will depend on the material of construction used;
- For mild steel the ratios, bubble-cap: valve: sieve, are approximately
- 3.0 : 1.5 : 1.0

7.1 Trays

Capacity:

- There is little difference in the capacity rating for the three types (the diameter of the column required for a given flow-rate).
- The ranking is:
    - sieve, valve, and bubble-cap

7.1 Trays

Operating range:

- This is the most significant factor.
- By operating range is meant the range of vapour and liquid rates over which the plate will operate satisfactorily (the stable operating range).
- Some flexibility will always be required in an operating plant to:
  - Allow for changes in production rate, and
  - Cover start-up and shut-down conditions.

7.1 Trays

Turn-down Ratio

- The ratio of the highest to the lowest flow rates.
- Bubble-cap trays have a positive liquid seal and can therefore operate efficiently at very low vapour rates.

7.1 Trays

Turn-down Ratio

- Sieve trays rely on the flow of vapour through the holes to hold the liquid on the tray and cannot operate at very low vapour rates, but, with good design, sieve trays can be designed to give a satisfactory operating range; Typically, from 50 to 120 % of design capacity.
- Valve trays are intended to give greater flexibility than sieve trays at a lower cost than bubble-caps.

7.1 Trays

Efficiency:

- The Murphree efficiency of the three types of trays will be virtually the same when operating:
  - Over their design flow range, and
  - No real distinction can be made between them.

7.1 Trays

Pressure Drop:

- The pressure drop over the trays can be an important design consideration, particularly for vacuum columns.
- The trays pressure drop will depend on the detailed design of the tray but.
- sieve plates give the lowest pressure drop, followed by valves, with bubble-caps giving the highest.

7.1 Trays

Summary

- Sieve trays are the cheapest and are satisfactory for most applications.
- Valve trays should be considered if the specified turn-down cannot be met with sieve trays.
- Bubble-caps should only be used where:
  - Very low vapour (gas) rates have to be handled and
  - A positive liquid seal is essential at all flow-rates.

7.1 Trays

Comparison between Common Conventional Trays.				
No.	**Factors**	**Sieve Tray**	**Valve Tray**	**Bubble-Cap Tray**
1	Capacity	High	medium	medium
2	Efficiency	High	medium	medium
3	Turndown	~50%	~25-30%	10%
4	Entrainment	Low	medium	High
5	Pressure Drop	Low	medium	High
6	Cost	Low	~1.2 times	~ 2-3 times
7	Maintenance	Low	medium	High
8	Fouling	Low	medium	High
9	Effects of Corrosion	Low	medium	High

7.2 Bottom Strainer

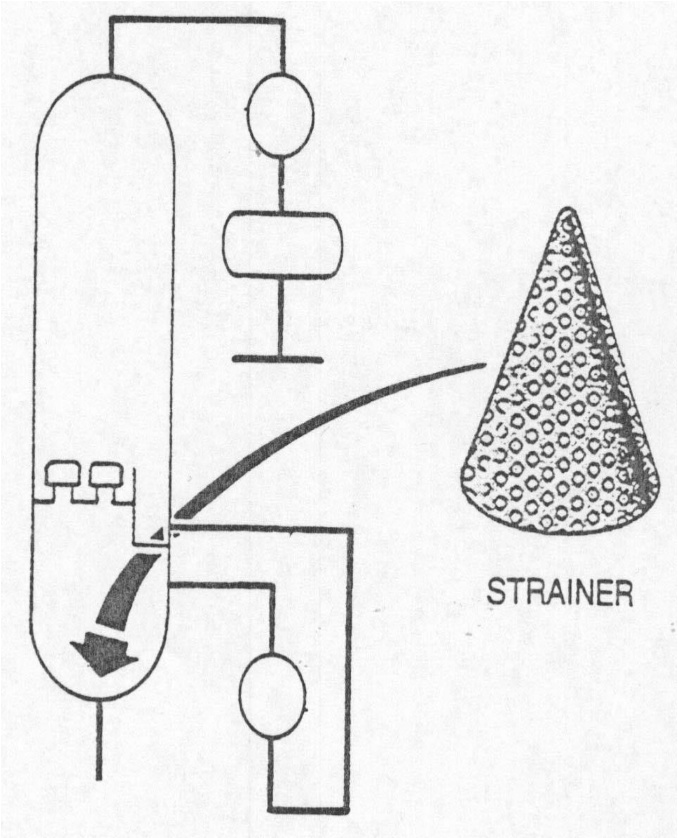
- During the operation of a tower:
  - The bubble caps,
  - Bolts, and
  - Other foreign objects

- may be dislodged and carried along with bottom stream.

7.2 Bottom Strainer

- To prevent these objects leaving the tower and damaging pumps, a strainer is installed in the bottom outlet line.

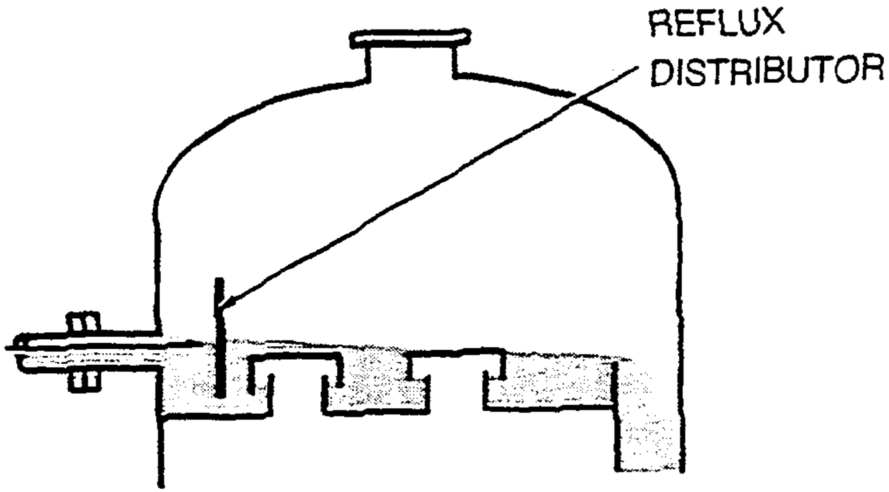
- The holes in the strainers must be kept open so that the flow of liquid out of the tower will not be stopped, or hindered.



7.3 Reflux distributor

- Reflux entering the top of the tower should be spread evenly across the top tray to avoid dead spots.

- One way to disperse reflux is to place a reflux distributor in front of the inlet line.



7.3 Reflux distributor

- A reflux distributor is simply a plate or baffle that prevents liquid from spraying across the tray.

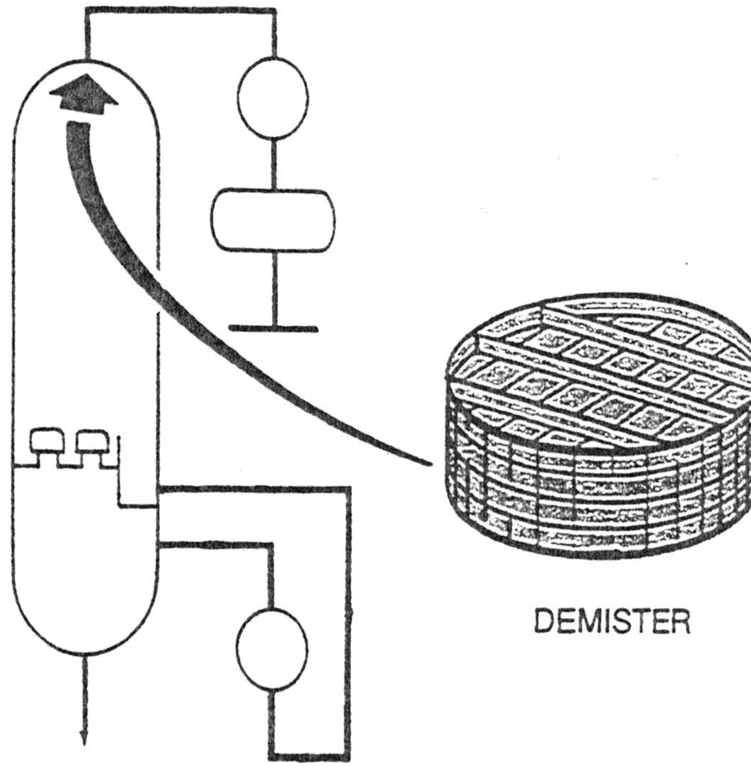
- Reflux entering the tower is forced to flow under the baffle so that the liquid is distributed evenly across the tray.

7.4 Top Tower Demister

- Sometimes small drops of liquid suspended in vapor are carried up from one tray to the next or into the overhead vapor line.
- This is called entrainrnent.
- When the overhead product must be a dry vapor or gas, entrainment is a more serious problem.
- Entrainment between trays can usually be prevented by controlling vapor velocity.

7.4 Top Tower Demister

- Entrainment at the top of a tower can be cut down by placing a demister on the vapor outlet line.
- Demisters are constructed of fine-gauge wire knitted into mesh.



3. CRUDE DISTILLATION OPERATION

3. CRUDE DISTILLATION OPERATION

3.1 Reflux Rate Changing

3.2 Feed Temperature Changing

3.3 Side Product (Draw off) Rate Changing

3.1 Reflux Rate Changing

- Reflux as a "coolant" that removes heavy fractions by condensing them.
- Suppose the reflux rate is increased from 1,000 to 1,200 barrels per hour, and the other tower operating conditions are held constant.
- the temperature on each tray to decrease then :
  - Lighter overhead,
  - Lighter bottom, and
  - Lighter side draw products are produced.

3.1 Reflux Rate Changing

- If we decrease the reflux rate from 1,000 barrels to 800 barrels, the cut point changes are reversed.
- The temperature on each of the trays increases.
- overhead, bottom, and side draw products become heavier.
- The amount of overhead product produced increases and the amount of bottom product formed decreases.

3.2 Feed Temperature Changing

- Suppose we raise the temperature of the feed and hold the reflux rate and other tower variables constant.
- more of the feed is vaporized.
- the amount of top product formed increases.
- the amount of bottom product formed decreases.
- By increasing the feed temperature: Heavier overhead, Heavier bottom, and Heavier side draw products are produced.

3.2 Feed Temperature Changing

- If we reduce the temperature of the feed, the cut point changes will again reverse.
- the top, side draw and bottom products become lighter.
- the amount of top product produced decreases and the amount of bottom product formed increases.

3.3 Side Product (Draw off) Rate Changing

- Another way to change the cut point in a crude column is to vary the amount of liquid that is drawn to the stripper columns.
- Suppose we increase the kerosene draw by 100 barrels.
- less reflux flows to the trays below the draw-off tray.

3.3 Side Product (Draw off) Rate Changing

- the temperature of trays below the kerosene draw increases.
- more heavy material begins rising up the tower.
- the kerosene draw will be heavier.
- The products formed below the kerosene draw also become heavier.

3.3 Side Product (Draw off) Rate Changing

- Now suppose we want to make the kerosene product heavier without changing the composition of the gas oil and reduced crude products.
- To do this we must increase the kerosene draw and at the same time not change the amount of reflux, and decrease liquid on the gas oil tray.

3.3 Side Product (Draw off) Rate Changing

- Let’s reverse the situation and look at what happens when the kerosene draw is decreased.
- Low temperatures produce light products, so reducing the kerosene draw results in a lighter kerosene product.
- The products formed below the kerosene draw also become lighter.

3.3 Side Product (Draw off) Rate Changing

- Suppose we want a lighter kerosene product but do not want to change the composition of the gas oil and reduced crude products.
- Since there is more reflux flowing down to the gas oil tray, we will have to increase the gas oil draw.
- Another way is decrease kerosene draw and increase gas oil draw.

3.3 Side Product (Draw off) Rate Changing

- The composition of crude distillation products can be changed by changing, or varying the amount of liquid that is drawn to a stripping column.
- Opening a stripper draw makes this product and products formed below this point heavier.
- Closing a stripper draw makes this product and products below this tray lighter.

4. FRACTIONATOR CONTROL

4. FRACTIONATOR CONTROL

4.1 Feed Section Control

4.2 Top Section Control

4.3 Bottom Section Control

4. FRACTIONATOR CONTROL

- The fractionator operates by using:
  - A controlled temperature gradient from top to bottom.
  - The composition of the top product is fixed by its bubble point or dew point.
  - The bottom product is controlled by its bubble point.

4. FRACTIONATOR CONTROL

Older control systems

- Attempt to accomplish these functions by the use of pressure, temperature, level and flow controls on each stream independently.

The next plateau

- was to:
  - Recognize that these streams were not really independent, and
  - Address the interaction between them by means of control loops.

4. FRACTIONATOR CONTROL

The next level of sophistication

- Is to add a chromatograph to sense directly those composition changes that are critical and transmit the proper signal to the controls.
- A simple analog system may be used to accomplish this.

4. FRACTIONATOR CONTROL

The final plateau

- Is reached by "marrying" all of these to a computer which has been properly programmed.
- All streams being sensed feed their information into this computer or programmable logic controller (PLC) which runs through a dynamic simulation and then tells the controls what to do.
- A computer does not solve the control problem; it can only react within the limits imposed on it by its creator.

4. FRACTIONATOR CONTROL

Some of the variables that can be used:

- Tower pressure.
- Feed flow rate.
- Feed composition.
- Feed temperature.
- Heat added (boil-up).
- Bottom product flow rate.
- Heat removed reflux.
- Distillate product flow rate.

4.1 Feed Section Control

Feed Composition

- it is necessary to make change elsewhere to the operation of the column in order to compensate for variations in feed composition.

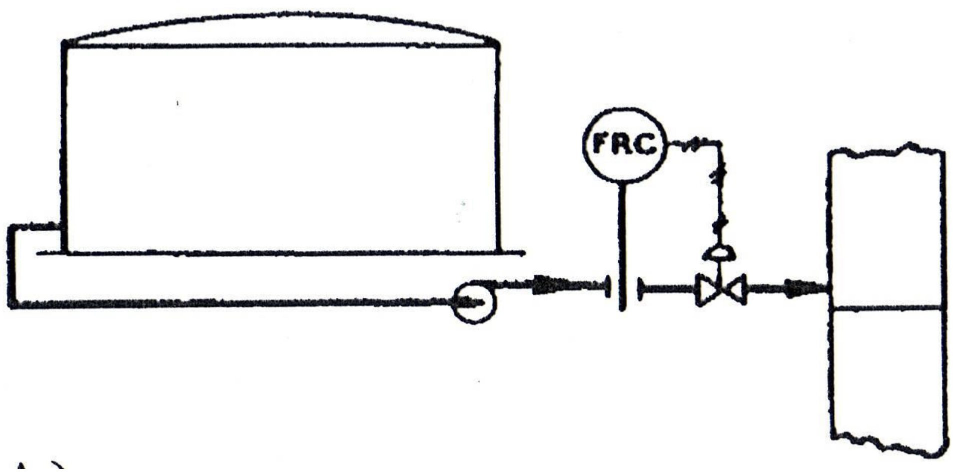
4.1 Feed Section Control

Feed Rate Control

- Regardless of the process used to recover liquid, both flow rate and composition will vary to the first fractionator.
- The following Figures show several possible arrangements.

4.1 Feed Section Control

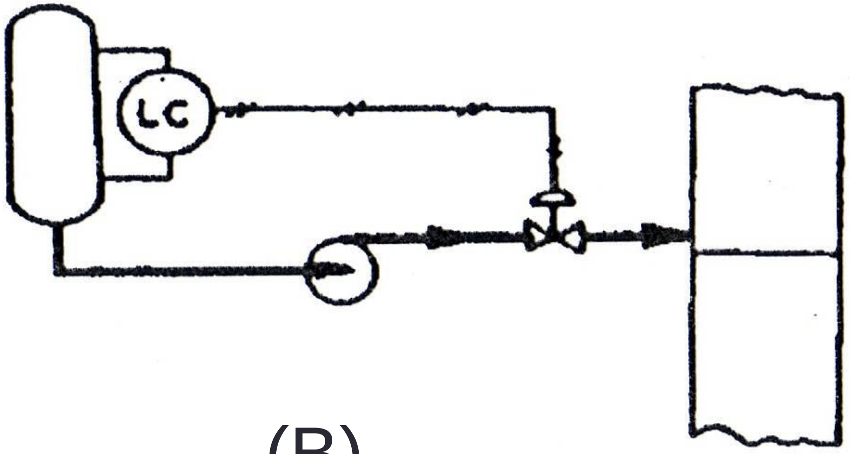
- If the tank is large, method (A) could be used.
- The pump would be eliminated, if the tank is at a high enough pressure.



(A)

4.1 Feed Section Control

- Method shown in Figure (B) would use the wide band with or without the pump.
- A level indicator with level alarms would be required on the tank to guard against low and high levels.

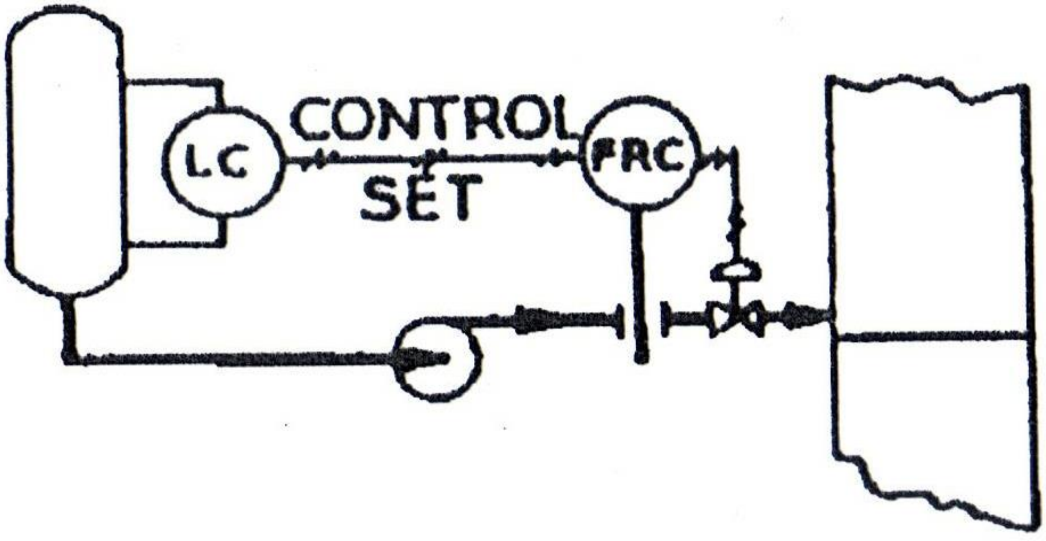


(B)

4.1 Feed Section Control

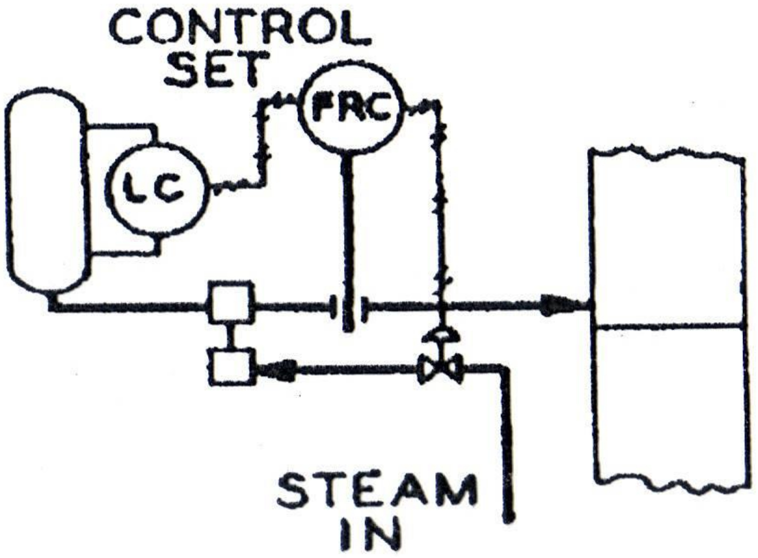
- Method shown in Figure (C) is a further addition that might be necessary when the pressure on the accumulator is not constant.
- The LC resets the flow recording controller (FRC).

(C)



4.1 Feed Section Control

- Figure (D) shows a steam pump layout.
- The level controller sets the control point for flow.
- The flow controller actuate the valve on the steam line.



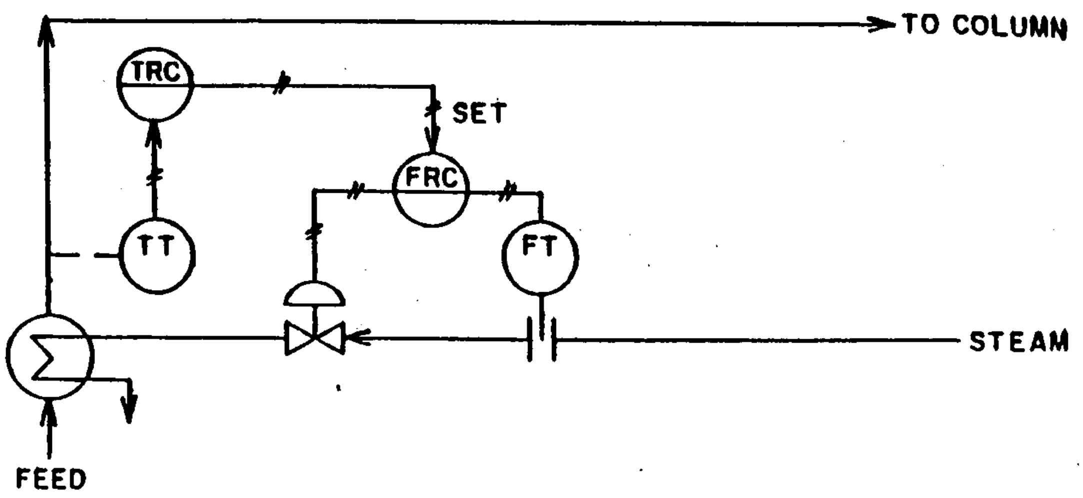
4.1 Feed Section Control

Feed Temperature (Thermal Condition)

- For efficient separation; it is usually desirable to have the feed at its bubble point when it enters the tower, unless the feed comes directly from some preceding distillation step.
- An outside source of heat is required.

4.1 Feed Section Control

- Steam may be used to heat the feed, any change in feed temperature, a corrective adjustment to the supply of steam into the exchanger.
- The use of a cascade loop can provide superior temperature control.



4.1 Feed Section Control

- Constant temperature feed does not necessarily mean constant feed composition (quality).
- If the feed composition varies, its bubble point varies.
- It is common practice to set the temperature control at a point which is equivalent to the bubble point of the heaviest feed.

4.2 Top Section Control

Column Pressure Control

- Most distillation control systems are based upon maintaining the column pressure at some constant value.
- Any variation of the pressure will upset the control system by changing the equilibrium conditions of the material in the column.

4.2 Top Section Control

The set point for pressure is a compromise between two extremes:

1. The pressure must be high enough to cause condensation of the overhead vapor by heat exchange with the cooling medium (usually cooling water).
2. On the other head, the pressure must be low enough to permit vaporization of the bottom liquid by heat exchange with the heating medium (usually steam or hot oil).

4.2 Top Section Control

- Column pressure can be controlled by manipulating:
  - ➢ The material balance (rate of distillate product) or
  - ➢ The condensing temperature (bubble/dewpoint pressure of distillate).

4.2 Top Section Control

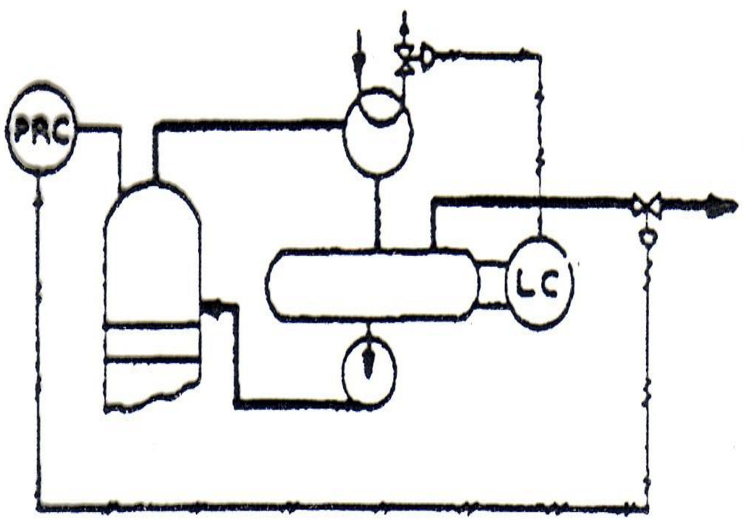
- The optimum pressure is determined by the cost.
- It is usually more economical to select the lowest pressure which will allow satisfactory condensation of the distillate product at cooling water temperature.
- The type of pressure control to be used depends on weather the overhead product is:
  - Vapor,
  - Liquid or
  - Liquid and vapor.

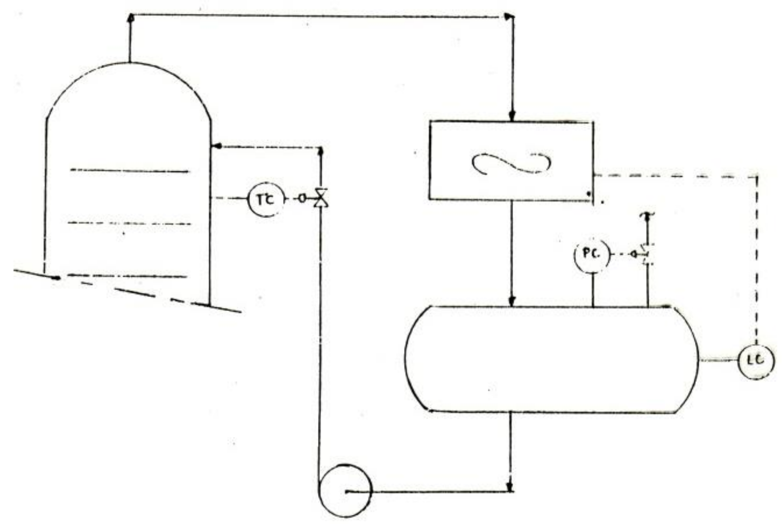
4.2 Top Section Control

Vapor Distillate Product

Partial Condenser

- pressure-controlled by regulating the flow of vapor from the reflux drum.





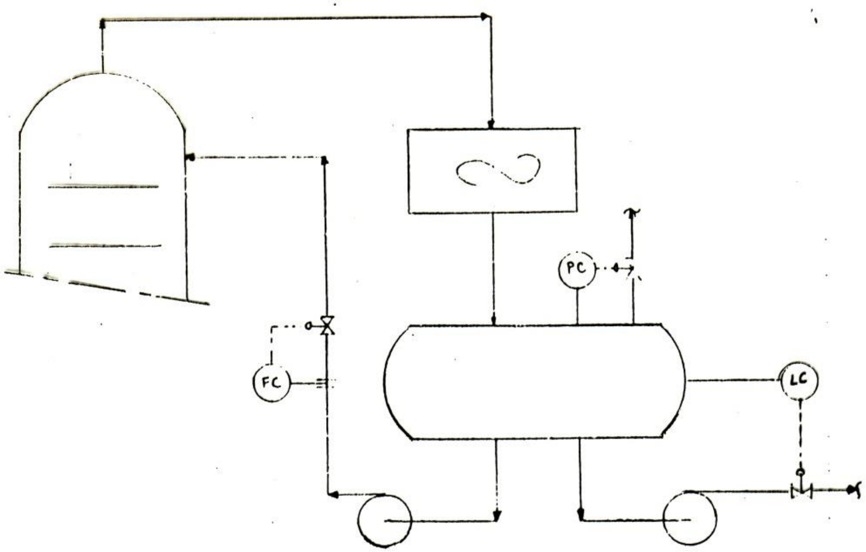
4.2 Top Section Control

Liquid and Vapor Distillate Products

Partially Flooded Condenser

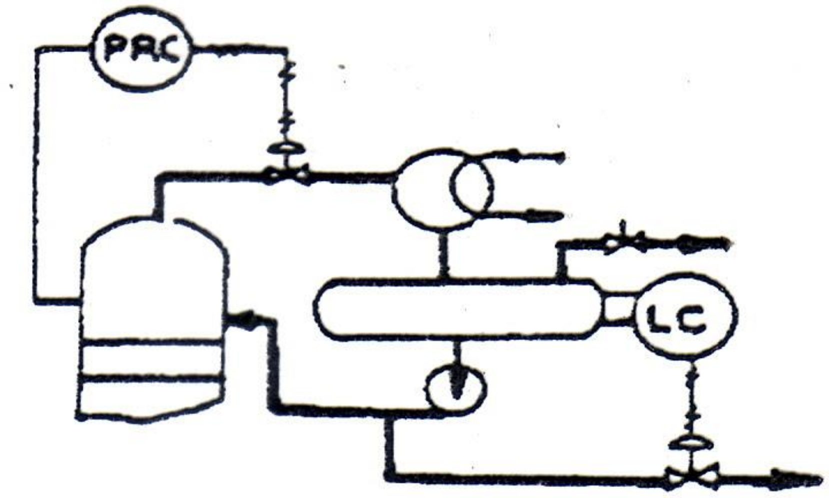
- In this case the level controller regulates the flow of liquid product.

- The reflux is on flow or on temperature control.



4.2 Top Section Control

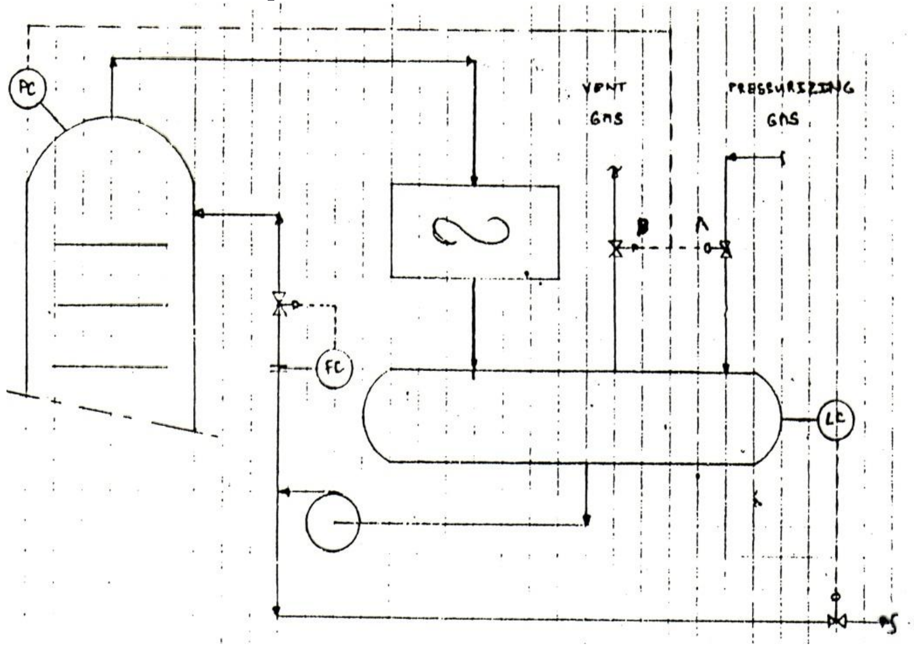
- A system shown for a total condenser is suitable for a narrow boiling range product.
- The disadvantage is that a large control valve must be placed in the overhead line.



4.2 Top Section Control

- When it is desired to operate the tower at a pressure higher than the liquid vapor pressure, gas of sufficiently high pressure should be admitted to the reflux drum on pressure control.

- The controller should be a split range type.



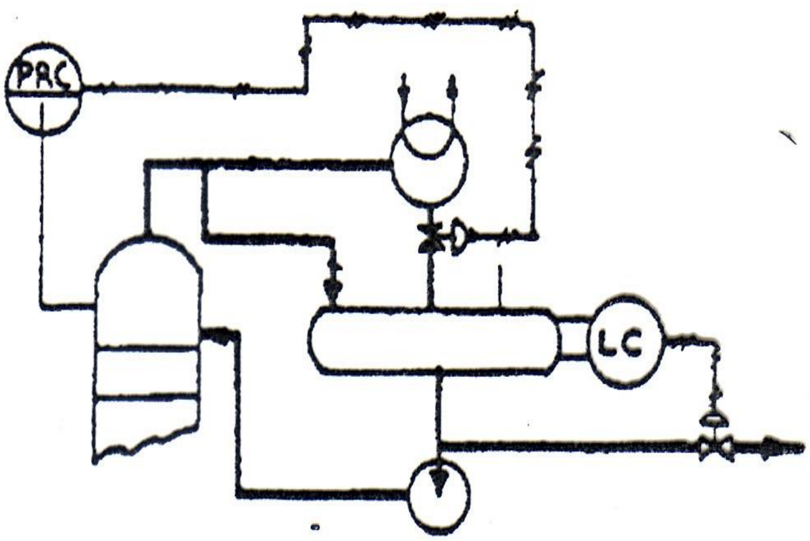
4.2 Top Section Control

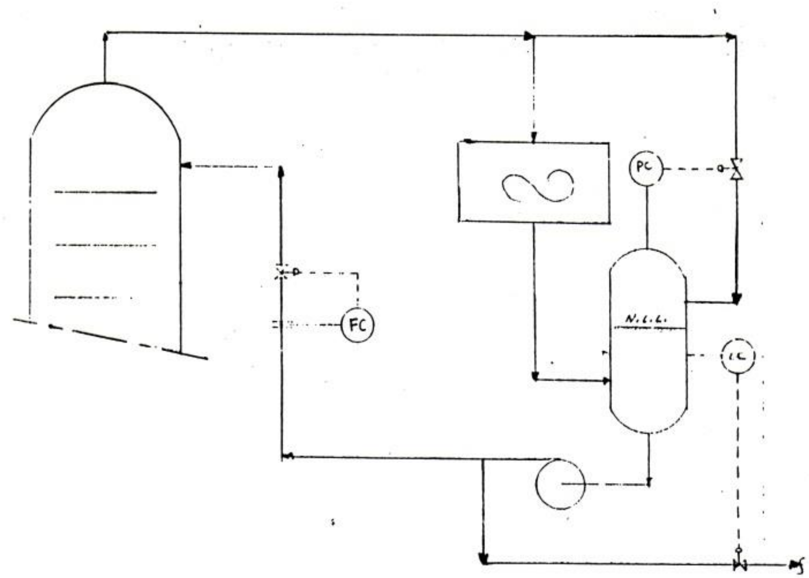
Liquid Distillate Product

Total Condenser

- When the overhead vapor is totally condensed in the condenser, the pressure in the reflux drums is equal to the liquid vapor pressure.
- The pressure is then a function of the condenser outlet temperature.

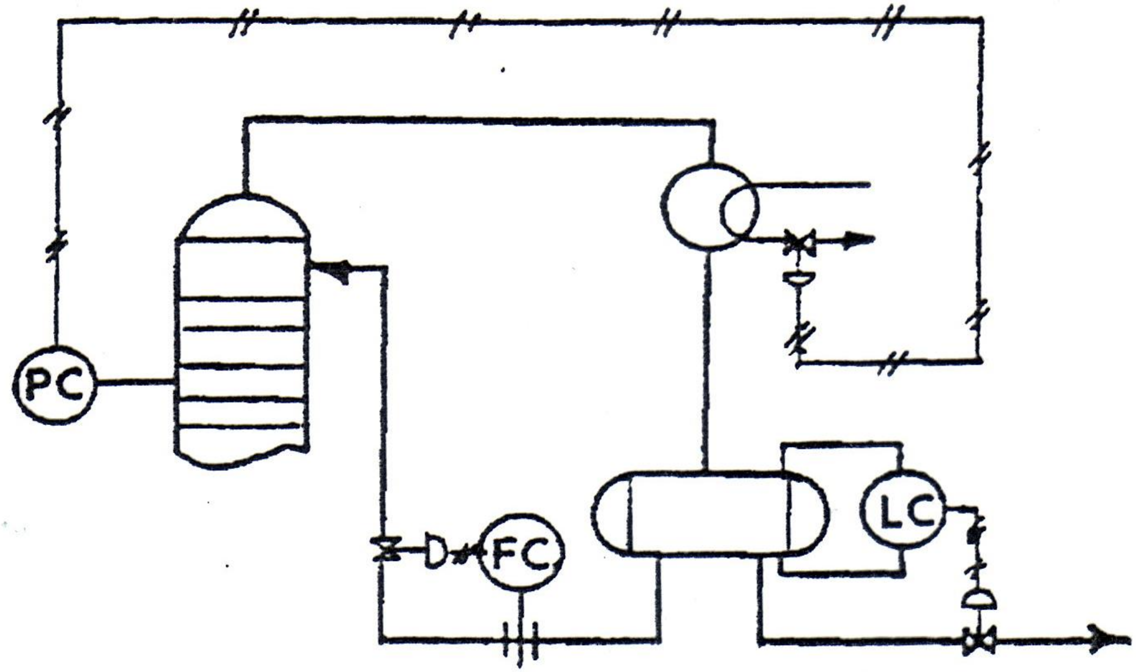
4.2 Top Section Control





4.2 Top Section Control

- The temperature of the condensed product in the accumulator can also be controlled by controlling the cooling medium.

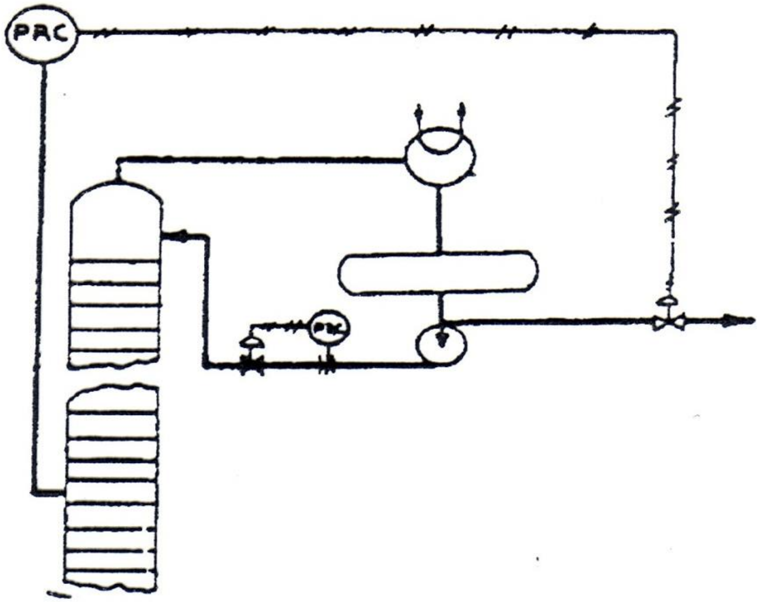


4.2 Top Section Control

- This method is not recommended if the cooling medium is cooling water as it induces fouling and scaling in the condenser.
- If the cooling medium is air, louvers or variable pitch for blades can be used to control air flow.
- Induced draft coolers are preferred because the tube bundle is not exposed to precipitation.

4.2 Top Section Control

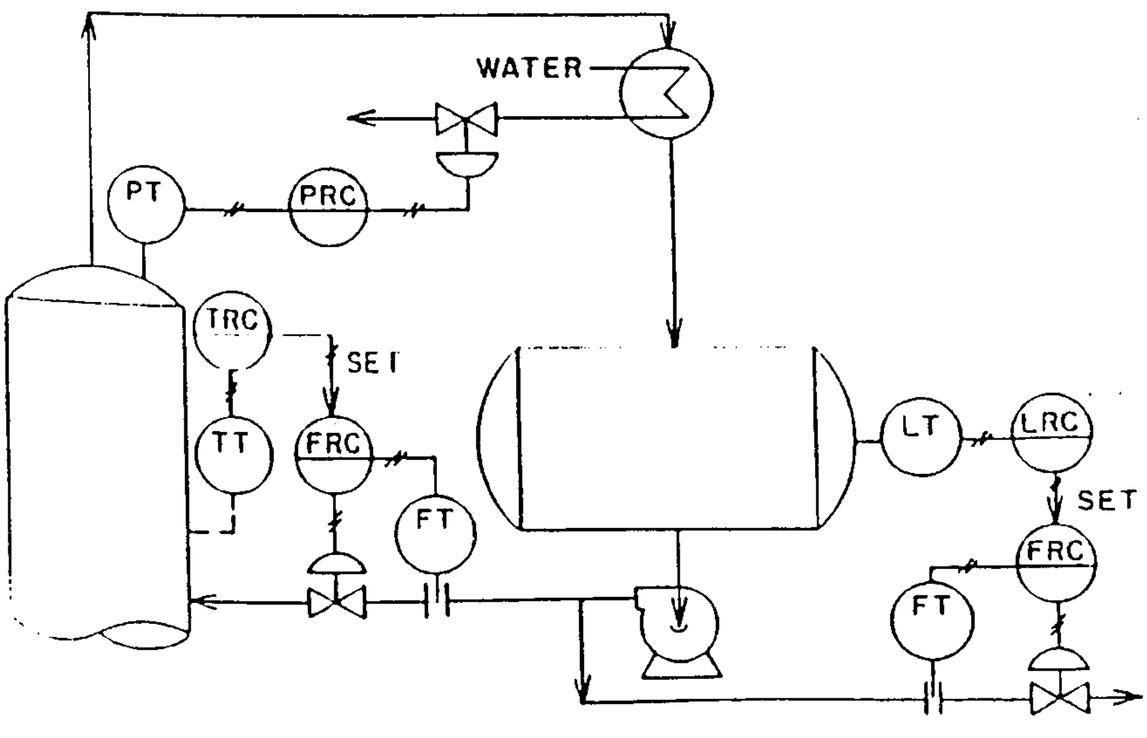
- The Figure shows a flooded condenser system for a total condenser.
- In this system the accumulator runs completely full of liquid and pressure is controlled by manipulating
- This method is commonly used in NGL fractionators.



4.2 Top Section Control

Reflux Controls

- The rate of reflux would be controlled by a flow control set manually or representing a ratio to distillate stream.



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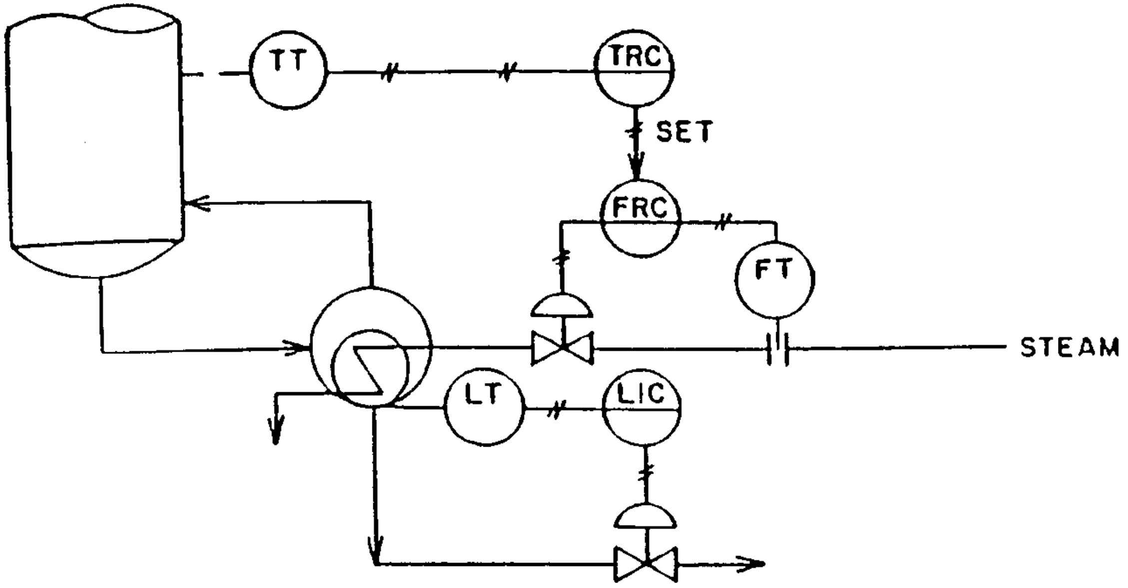
4.2 Top Section Control

- Measuring temperature in a column usually requires that the sensing device be in the liquid on the tray.
- Heat transfer from a liquid medium to the sensing device is much greater than the heat transfer from a gas medium.

4.3 Bottom Section Control

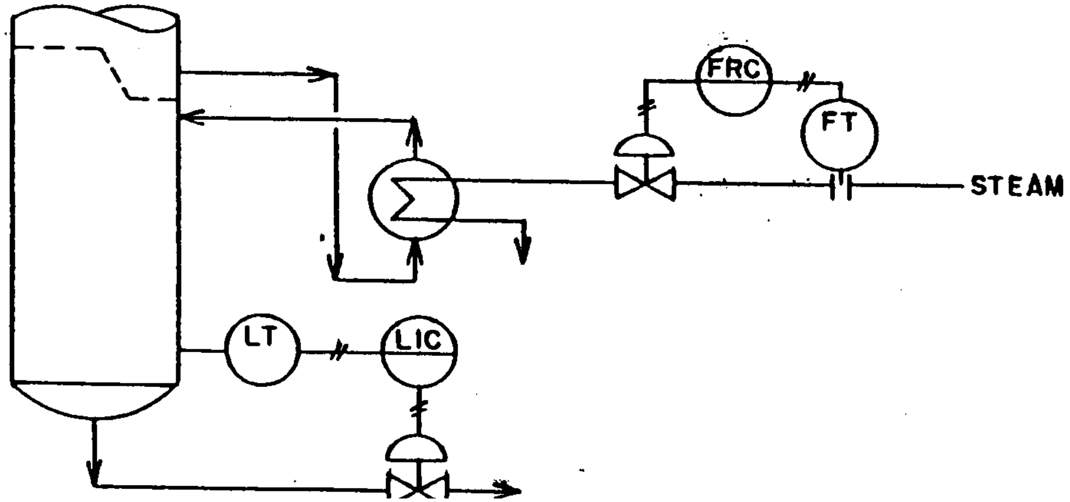
Reboiler Control

- Boil-up rate is controlled by setting the flow of heat to the reboiler.
- A flow controller is placed in the line carrying the heating medium to the reboiler.



4.3 Bottom Section Control

- Other types include thermosyphon reboilers and forced-circulation reboilers.
- For them, the bottom product is withdrawn from the column.



6. TROUBLESHOOTING

6. TROUBLESHOOTING

6.1 Flooding

6.2 Dry Trays

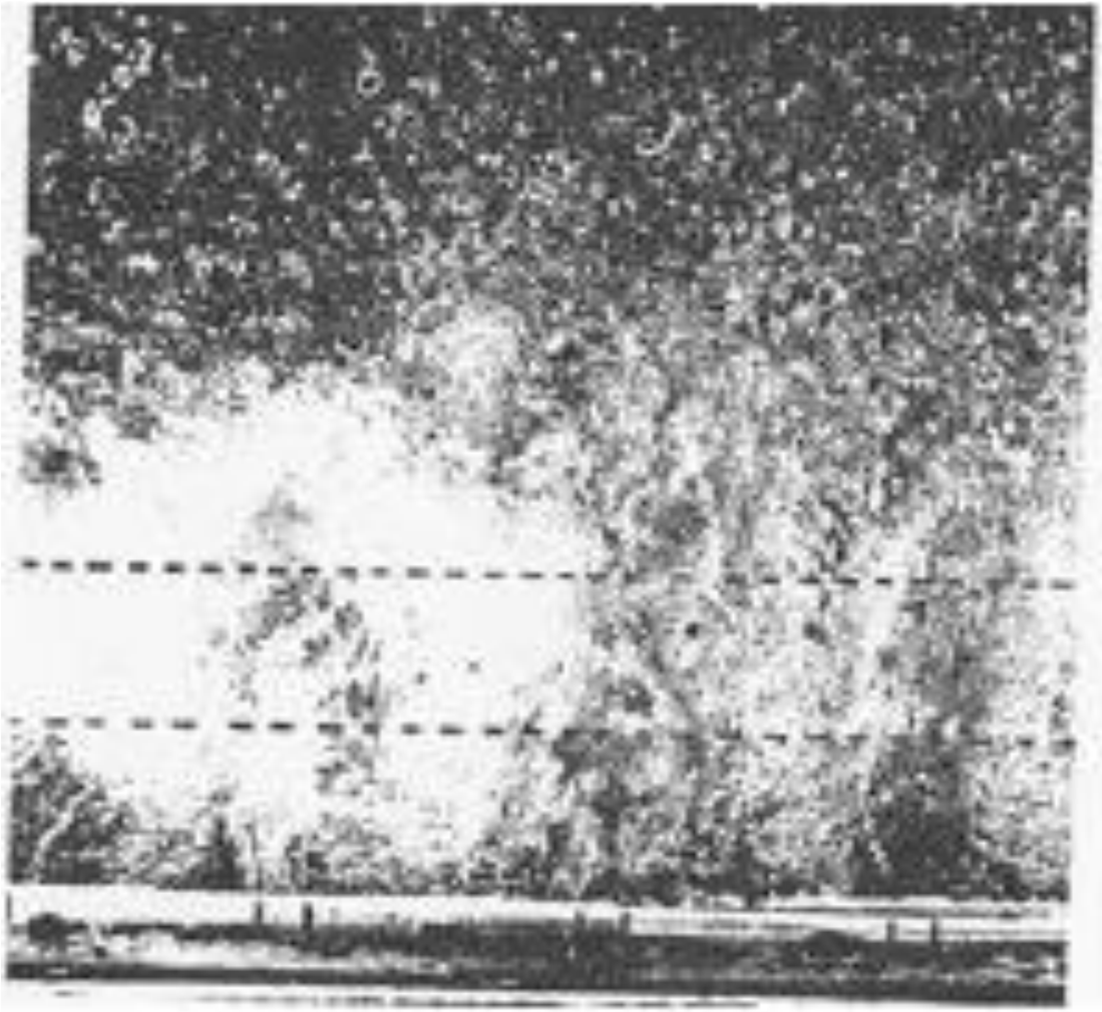
6.3 Damaged Trays

6.4 Water in Hydrocarbon Column

6.5 Foaming

6.6 Condenser Fogging

6.1 Flooding



6.1 Flooding

Design

- Flooding is a common operating problem.
- Companies naturally wish to obtain maximum capacity out of fractionation equipment and thus often run routinely close to flooding conditions.
- New columns are typically designed for around 80% of flood.
- Clearly, the column needs some flexibility for varying operating conditions.

6.1 Flooding

- The designer, therefore, shouldn't expect to design for 100% of flood and be able to accommodate variations In operating conditions.
- Designers recommend a percentage of flood of not more than:

➢ 77% for vacuum towers.

➢ 82% for other services.

➢ 65-75% for columns under 36" diameter.

6.1 Flooding

How to Identify Type & Location of Flooding

- Increase in pressure drop and a decrease in temperature difference.
- Pressure fluctuation.
- Possible capacity increase.
- Temperature profile.

6.1 Flooding

Increase in pressure drop and a decrease in temperature difference:

- Product quality is also impaired.
- When a column floods, the levels in the accumulator and bottom often change.
- It can occur that:
  - ➢ The accumulator fills with liquid carried over while,
  - ➢ The reboiler runs dry.

6.1 Flooding

Pressure fluctuation:

- Also, in a flooded column, the pressure will often tend to fluctuate.
- This may help to differentiate between:
  - Flooding, and
  - High column bottom level.
- The high bottom level will give higher than normal pressure drop but often not the magnitude of pressure fluctuations associated with flooding.

6.1 Flooding

Possible capacity increase:

- Here is a tip for possible capacity increase for towers with sloped downcomers.
- Usually, the tray vendor doesn't use the dead area next to the bottom part of the sloped downcomer as active area if the trays are multipass.
- This area could be used for additional vapor capacity in an existing column.

6.1 Flooding

Temperature profile:

- In fractionating columns the temperature of any given plate is dependent on:
  - The pressure, and
  - Composition of the material on the tray.
- When both top and bottom product are very narrow boiling range products only one steep column temperature gradient will be located near the feed inlet.

6.1 Flooding

- When wide boiling range products are manufactured to flattening down of the temperature profile will occur over the trays near the product outlets.
- Comparison of the known profile for normal operation with that when operation is poor may help to locate the source of the trouble.

6.1 Flooding

Operating Difficulties Causing Flooding

- Fouling.
- Operation near Critical Conditions.
- High Loads in Rectifying Section.
- Way of Introducing Feed.
- Downcomer Backup Flood.

6.1 Flooding

Fouling:

- Sometimes upsets in operation are caused in sections of a column due, for example, to local fouling.
- Differential pressure measurements are helpful in locating the sections that are causing the difficulties.
- Careful and repeated tests have to be made to determine the sections at which the increased pressure drop first occurs.

6.1 Flooding

Operation near Critical Conditions:

- When a column is operated under conditions of temperature and pressure which are very near to the critical values of the hydrocarbons to be processed, fractionation can be poor owing to the fact that a column section contains only one phase and is consequently flooded.

6.1 Flooding

High Loads in Rectifying Section:

- Sometimes this tray is flooding and further increases in reflux are ineffective because it merely goes overhead as liquid.
- A heat balance around the overhead condenser shows, if much liquid is entrained, which is an indication of overloading of at least the top part of the column.

6.1 Flooding

Way of Introducing Feed:

- As the vapour or liquid entering may upset the flows in that part of the column.
- Further more attention must be given to the velocity of the vapour and liquid feed in the inlet.
- Too high a vapour velocity may cause atomization of the liquid feed resulting in considerable entrainment.

6.1 Flooding

Downcomer Backup Flood:

- If the downcomer backup for valve trays exceeds:
  - 40% of tray spacing for high vapor density systems (3.0 lbs/ft^3),
  - 50% for medium vapor densities, and
  - 60% for vapor densities under 1.0 Ibs/ft^3.
- Flooding may occur.

6.1 Flooding

- Another good rule of thumb is that the downcomers area should not be less than 10% of the column area, except at unusually low liquid rates.
- Note that:
  - High vapor rates as well as
  - High liquid rates
- Can cause down comer backup flooding.

6.2 Dry Trays

- No fractionation occurs in the dry section, so the temperature difference decreases.
- However, unlike flooding the pressure drop Decreases
- The problem is caused by either:
  - ➢ Insufficient liquid entering the section, or
  - ➢ Too much liquid boiling away.

6.2 Dry Trays

- Insufficient liquid entering a section caused by:
  - Too little reflux, or
  - Too much sidestream withdrawal.
- Excessive liquid boiloff caused by:
  - Too hot a feed, or
  - Too much reboilling.

6.3 Damaged Trays

- Trays can become damaged by several ways:
  - A pressure surge can cause damage.
  - A slug of water entering a heavy hydrocarbon fractionator will produce copious amounts of vapor.
  - Bottom liquid level is reached the reboiler outlet line, the wave action can damage some bottom trays.
  - Steam/Water Operations.
  - Depressuring.

6.3 Damaged Trays

- Effects of damaged trays
  - Poorer fractionation,
  - A decrease in temperature difference because of the poorer fractionation.
  - An increase in pressure difference.

6.3 Damaged Trays

Steam/Water Operations

- Steam/water operations during shutdown have high potential for tray damage if not handled correctly.
- If a high level of water is built up in the tower and then quickly drained, as by pulling off a bottom manway, extensive tray damage can result, similar to pumping out hydrocarbons too fast during operation.

6.3 Damaged Trays

- Steam and water added together to a tower can be a risky operation.
- If the water is added first at the top, for instance, and is raining down from the trays when steam is introduced, the steam can condense and impose a downward acting differential pressure, this can result in considerable damage.

6.3 Damaged Trays

- If steam and water must be added together:
  - Start the steam first.
  - Then *slowly* add water, not to the point of condensing all the steam.
  - When finished, the water is removed first.

6.4 Water in Hydrocarbon Column

- Here small amounts of water are meant rather than large slugs which could damage the trays.
- Often the water will boil overhead and be drawn off in the overhead accumulator bootleg.
- However, if the column top temperature is too low, the water is prevented from coming overhead.
- The water can often make the tower appear to be in flood.

6.4 Water in Hydrocarbon Column

- Many columns have water removal trays designed into the column.
- Top or bottom temperatures may have to be changed to expel the water if the column isn't provided with water removal trays.
- In some instances, the water can be expelled by venting the column through the safety relief system.

6.5 Foaming

6.5 Foaming

- The mechanism of foaming is little understood. During the design phase, foaming is provided for in both the tray downcomer and active areas.
  - The higher the pressure, the more foaming tendency, since the heavy oil will contain more dissolved gases at higher pressures.
  - Liquids with low surface tension foam easily.
  - Suspended solids will stabilize foam.

6.5 Foaming

Solving Foaming Problem

- Adding antifoam,
- Providing adequate tray spacing,
- Providing adequate column downcomer area, and sometimes
- Filling the downcomer with Raschig rings to provide coalescing area.

6.6 Condenser Fogging

- Fog, like smoke, is a colloid.
- Fogging occurs in a condenser when:
  - The mass transfer doesn't keep up with the heat transfer.
  - A higher temperature differential (ΔT) with noncondensibles present, or
  - A wide range of molecular weights can produce a fog.

6.6 Condenser Fogging

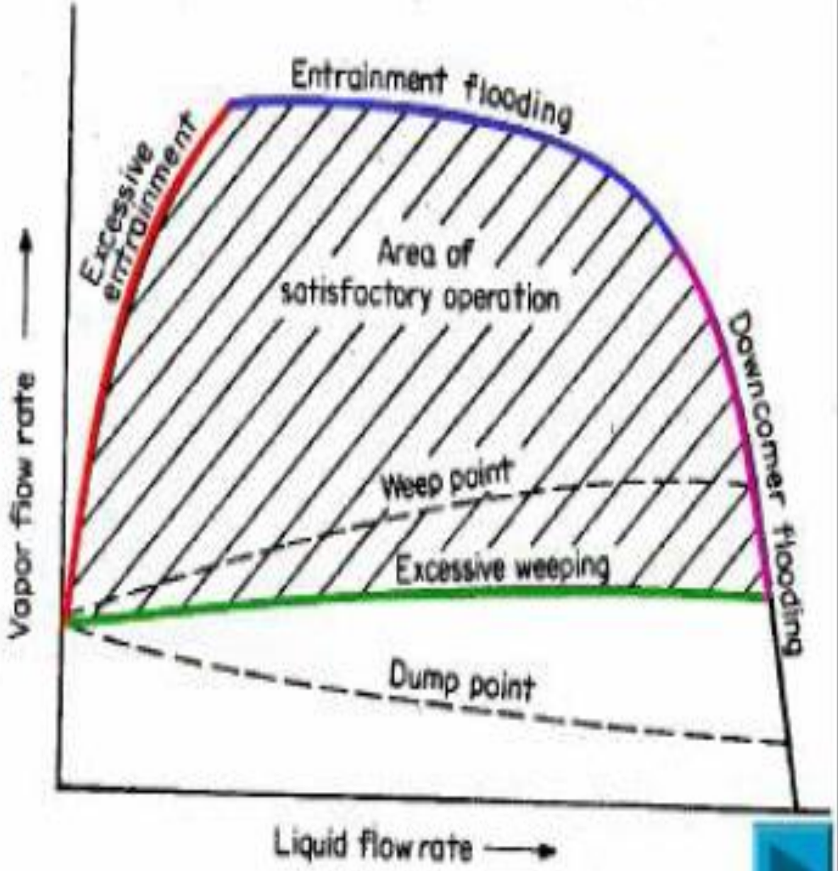
- Once a fog is formed, it is very difficult to knock down.
- It will go right through:
  - Packed columns,
  - Mist eliminators, or
  - Other such devices.

Special devices are required to overcome a fog, such as an electric precipitator with charged plates.

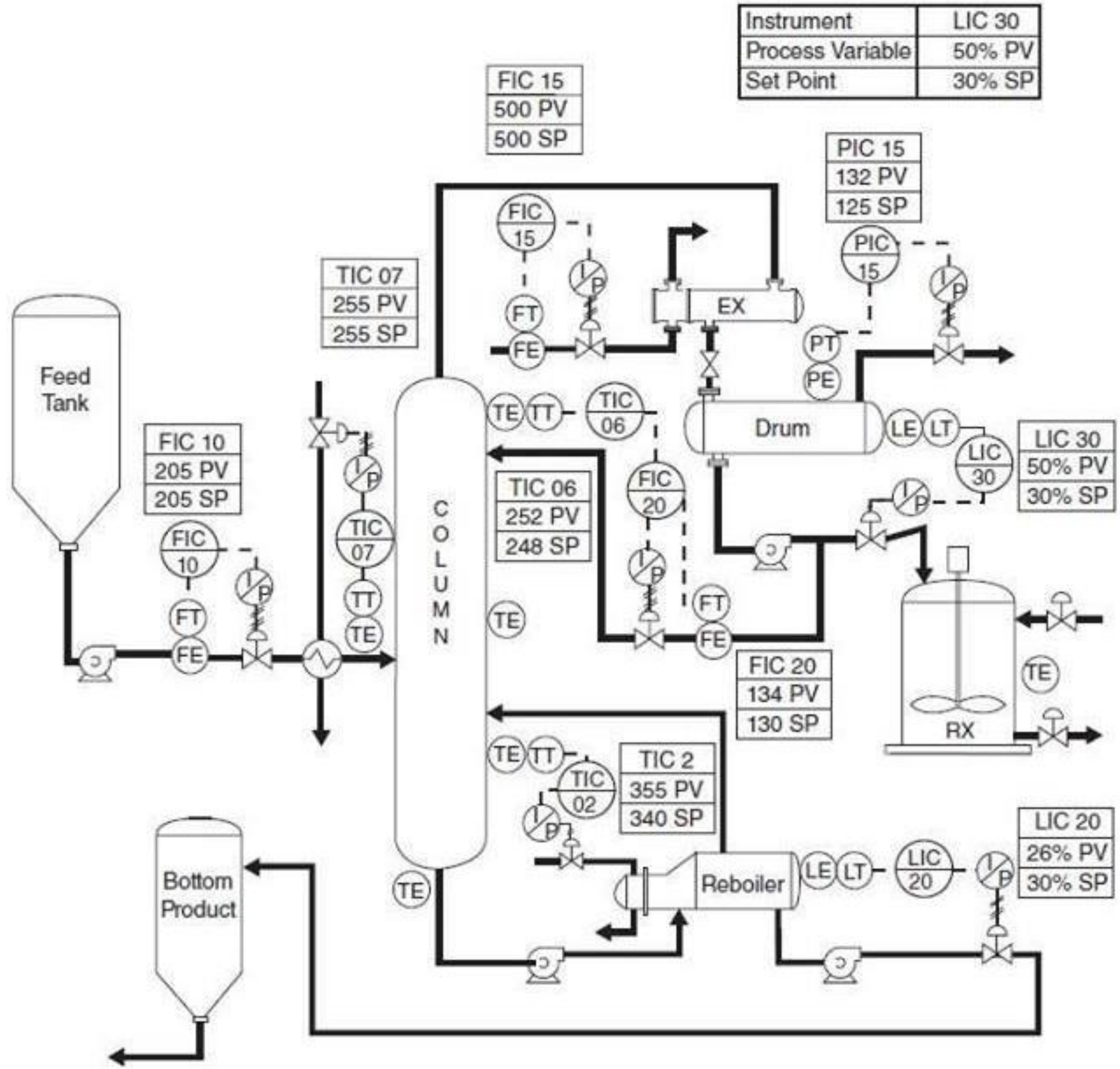
❶ Tray Performance Constraints

Adverse vapor/liquid flow conditions can cause:

- Foaming
- Entrainment
- Flooding
- Weeping/dumping
- Downcomer flooding



7. CASE STUDY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Set Point | 30% SP
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PIC 15
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TIC 07
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Feed Tank
FIC 10
205 PV
205 SP
TIC 06
252 PV
248 SP
FIC 20
134 PV
130 SP
LIC 30
50% PV
30% SP
TIC 2
355 PV
340 SP
LIC 20
26% PV
30% SP
EX
Drum
COLUMN
RX
Reboiler
Bottom Product
FIC 15
FIC 10
FIC 20
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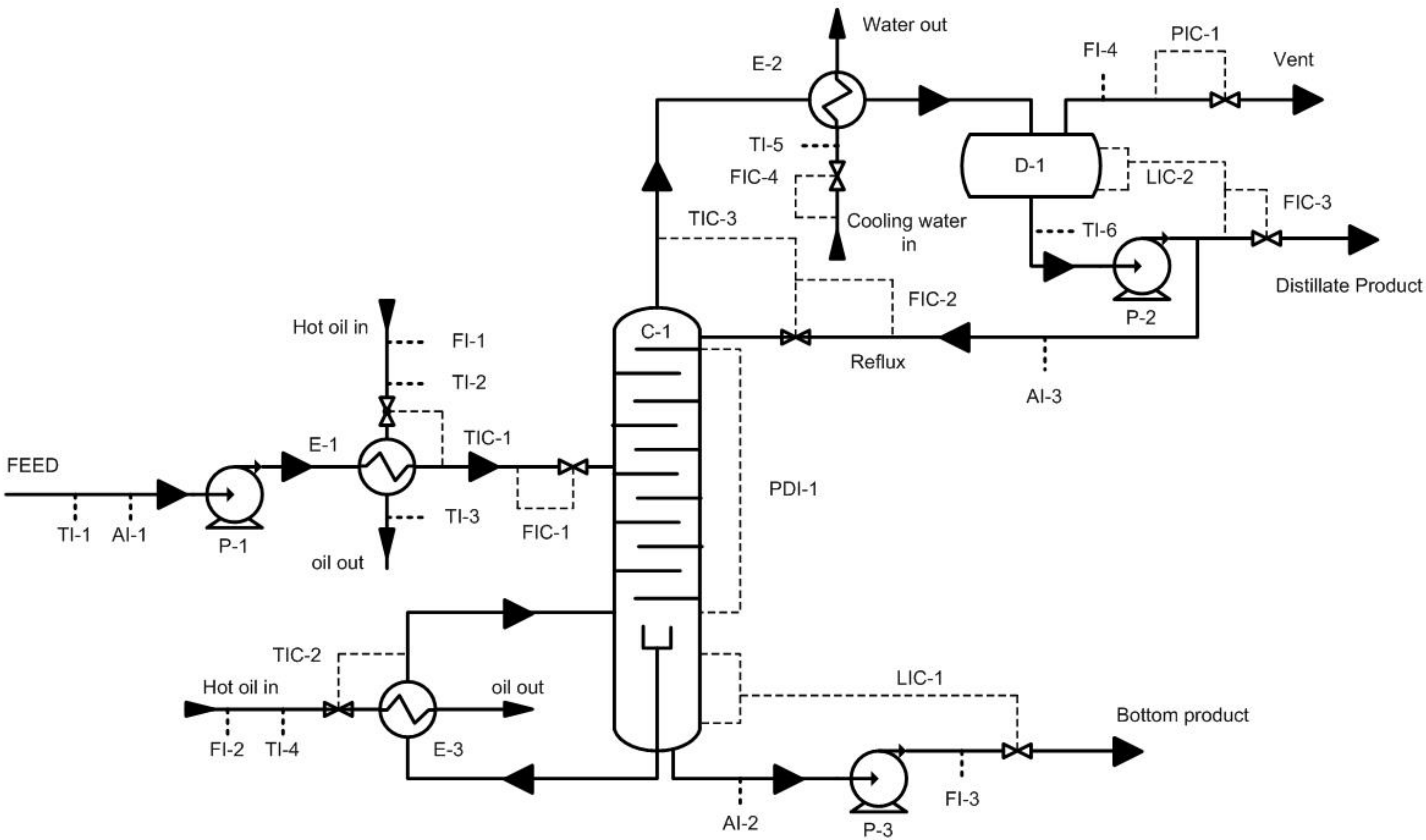
I/P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FI-4
PIC-1
Vent
TI-5
FIC-4
D-1
LIC-2
FIC-3
TIC-3
Cooling water in
TI-6
Distillate Product
FIC-2
P-2
Hot oil in
C-1
FI-1
Reflux
AI-3
TI-2
TIC-1
E-1
FEED
PDI-1
TI-3
TI-1
AI-1
P-1
FIC-1
oil out
TIC-2
Hot oil in
oil out
LIC-1
Bottom product
FI-2
TI-4
E-3
FI-3
AI-2
P-3

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