DISTILLATION TOWERS INTERNALS

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FUNDAMENTALS OF SEPARATION IN TOWERS

DISTILLATION

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

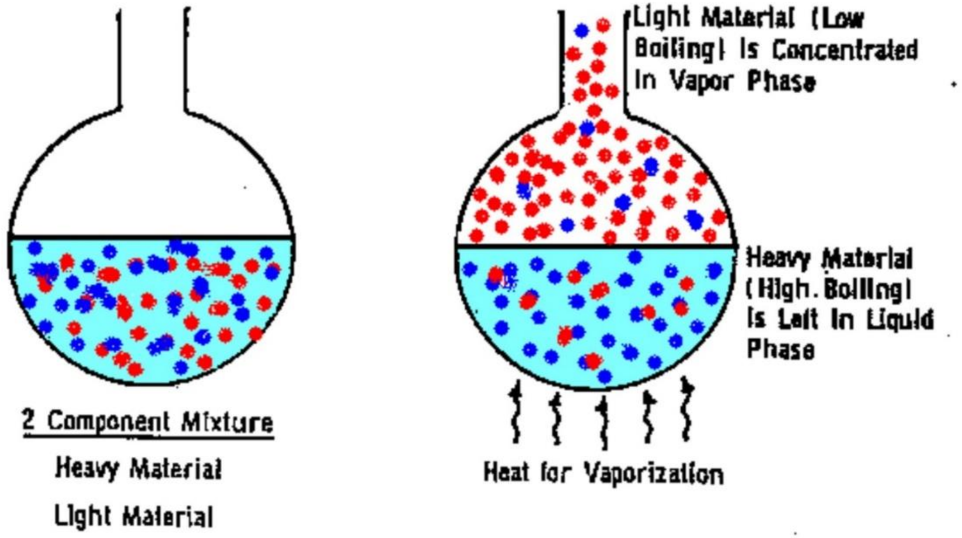
Principles Of Distillation

The basic principle of distillation is simple

- When a solution of two or more components is boiled
- The lighter component (the one most volatile or the one with the greatest tendency to vaporize)vaporizes preferentially

Principles Of Distillation

- Two component mixture is contained in a vessel
- When heat is added until the more volatile material (red dotes) start to vaporize. Now the vapor contains a higher proportion of red dots than dose the original liquid
- It is important to note that an equilibrium in composition will be established at a given temperature and pressure.
- By equilibrium we mean there is a given concentration as “red dots" in the vapor and in the liquid depending upon the original concentration of each component in the liquid and their respective properties in relation to each other



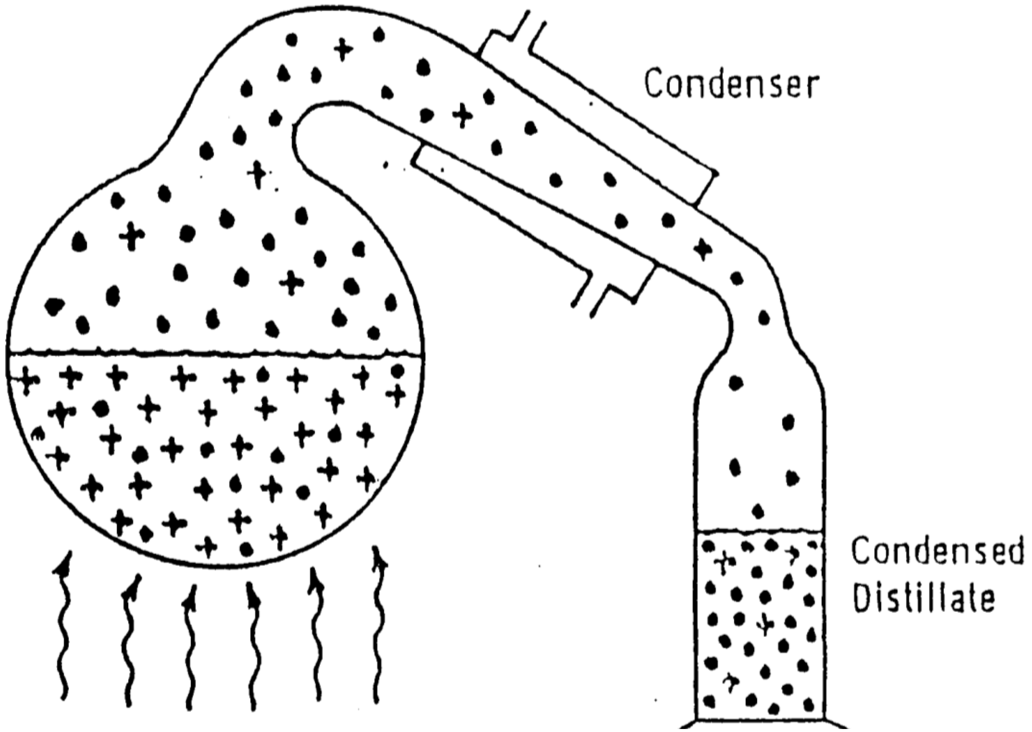
Principles Of Distillation

- This results in the vapor above the liquid being relatively rich in the lighter (more volatile material)
- And the liquid is left with proportionately more of the less volatile (heavier liquid)
- Thus, a separation, to some degree, has taken place

- Now, let's develop this simple distillation concept into a practical operation as it is used in the refinery
- First , let’s separate and remove the product

Principles Of Distillation

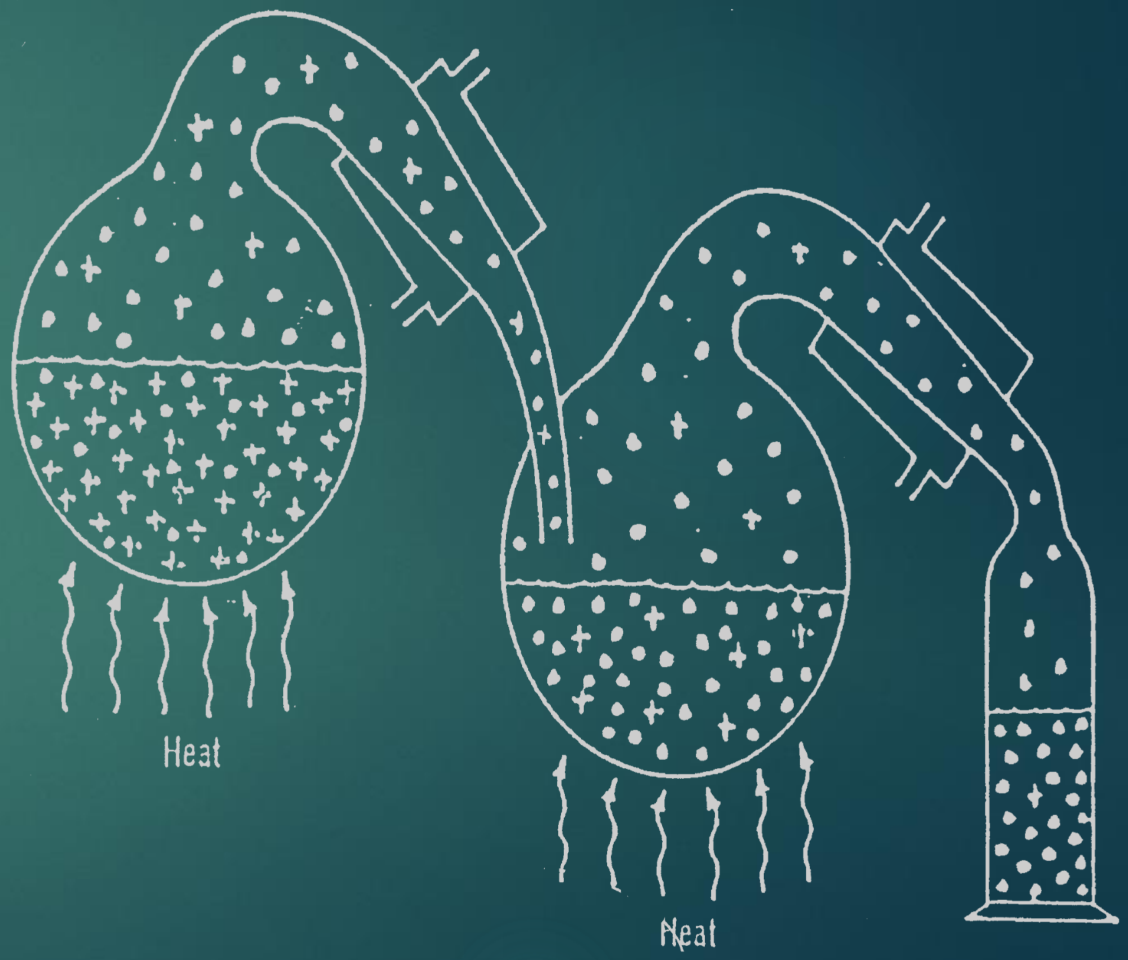
- By cooling the overhead vapor, we condense and remove it from the original mixture
- Thus, to have made a partial separation, partial because you will note that there are a few "blue dotes" in the distillate product
- This has occurred because at the temperature and pressure we are conducting the distillation, the heavier component still vaporizes to some extent
- This is because the components of interest in each distillation usually have close boiling points



Principles Of Distillation

Therefore, **to purify the distillate product, we may have to conduct a second distillation** as shown

Obviously, we can continue to cascade these simple distillations until we achieve the desired purity of product



- The distillations depicted so far are those we call patch, and normally practical in the refinery, although it is done frequently in the laboratory

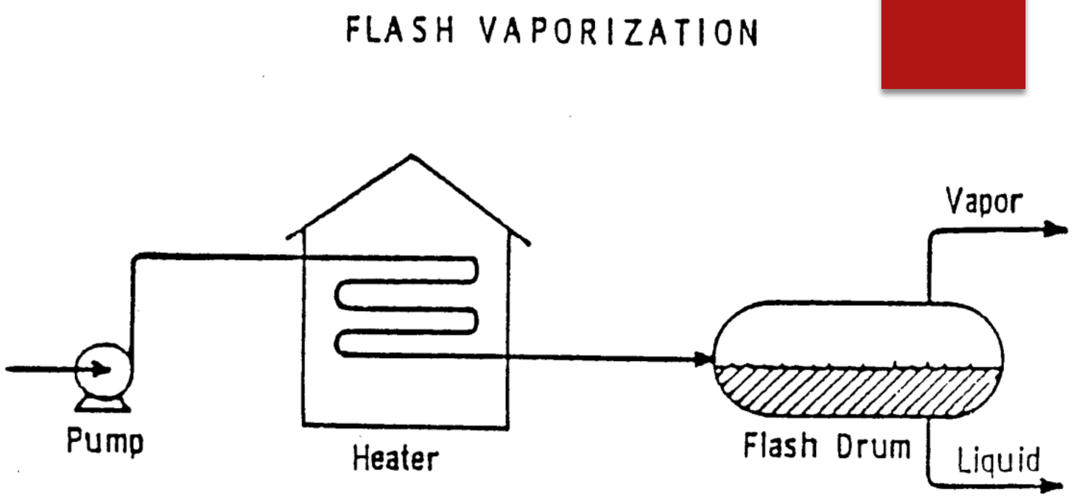
- Let us make our distillation equipment look more like refinery pieces of equipment and let us make continuous instead of patch operation

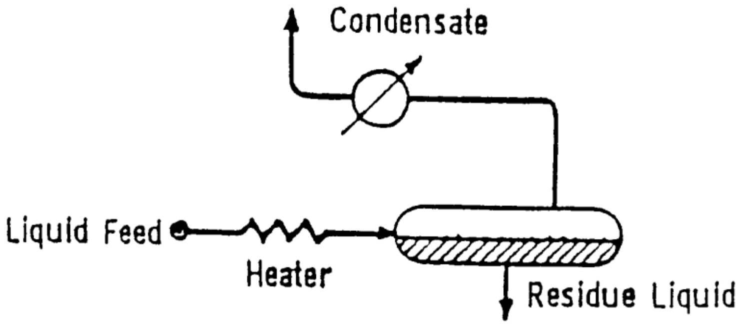
▶ This is called Flash Vaporization As shown.

▶ The liquid is pumped continuously through a heater and into a drum where the pressure is lower

▶ The lighter material flashes instantaneously (vapor and liquid flow from the drum continuously)

▶ The same system is shown diagrammatically in the in the lower section of the Figure.





Principles Of Distillation

- Suppose we have 50% of the charge taken overhead

- That is, we set the temperature and the pressure of the system in such a way that half the charge is boiled off

- 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

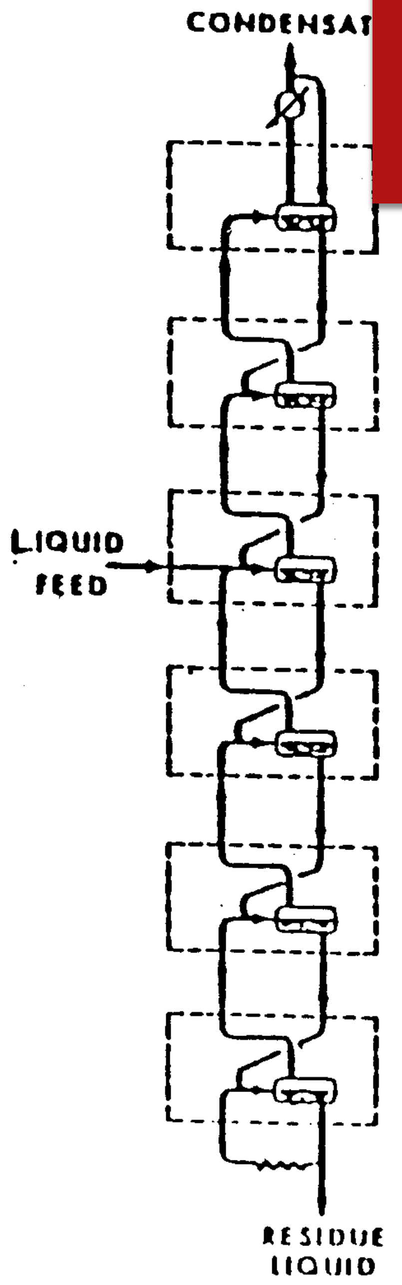
▶Suppose we add two more stages of distillation

▶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

▶An obvious simplification in equipment can be made if we allow the hot vapor from the stage above the next higher (the intermediate product)

▶This eliminates the need for the intermediate condensers and heaters

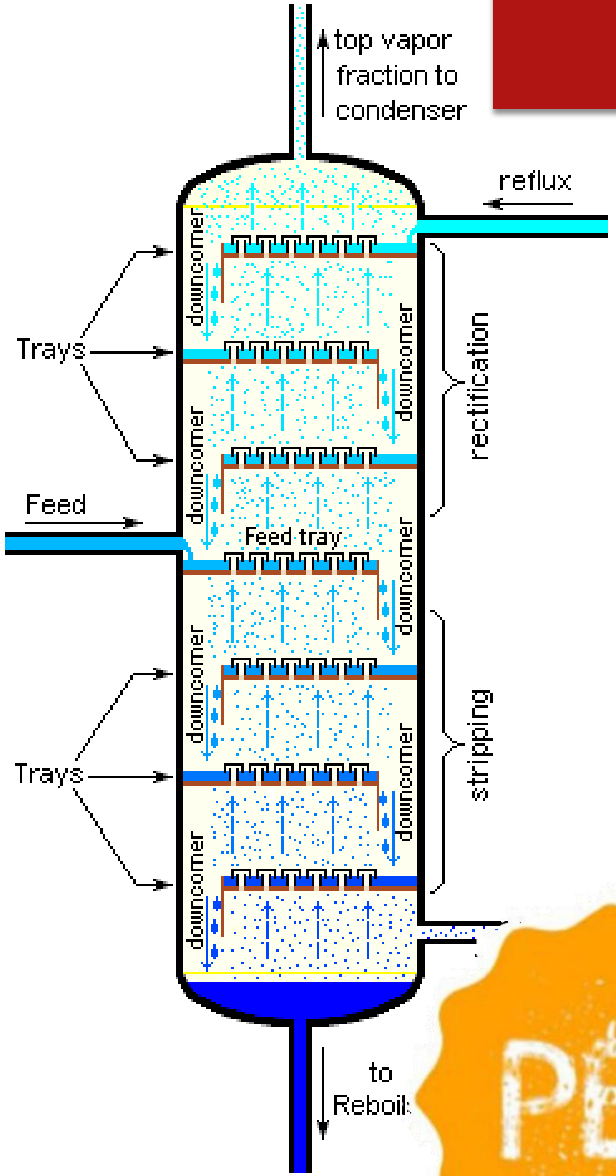
▶Now we have the continuous, multi-stage distillation

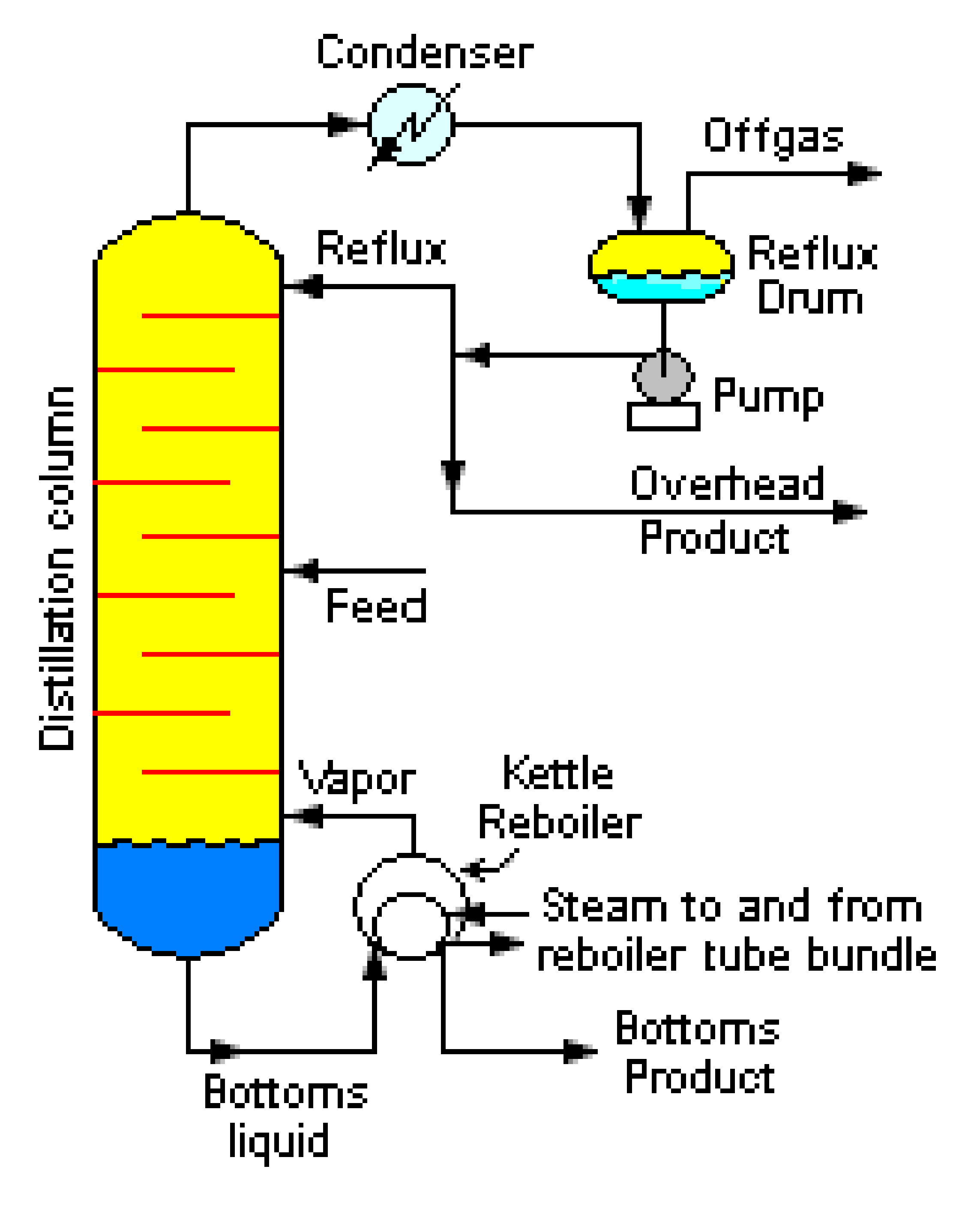


Schematic illustration of a typical distillation operation.

Tower Sections

- We have described staging for the purpose of concentrating the lighter component in the overhead
- The same principles apply to concentrating the heavier component in the bottom product
- The upper stages are called rectifying stages
- These below the feed are called stripping stages




Condenser
Offgas
Reflux
Reflux
Drum
Pump
Overhead
Product
Feed
Distillation column
Vapor
Kettle
Reboiler
Steam to and from
reboiler tube bundle
Bottoms
Product
Bottoms
liquid

Tower Sections

The upper rectifying section increases the purity of the overhead product.

The lower stripping section increases the recovery of the overhead product.

In many cases, the bottom product is the one of primary interest

For the bottom, or heavy, product the rectifying section improves recovery

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.

- 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. The concept of an equilibrium stage is converted to an actual mechanical separation tray by using an efficiency factor which is less than one and depends on the tray design.

Column Internals :

The plates or trays are contacting devices and used to hold up the liquid to provide better contact between vapor and liquid, hence better separation .

1. Trays /Plates

TRAYS

- TRAYS WITH DOWNCOMER
  - VALVE TRAYS
  - SIEVE TRAYS
  - BUBBLE CAP TRAYS
- TRAYS WITHOUT DOWNCOMER
  - DUAL FLOW TRAYS
  - BAFFLE TRAYS
  - DISC & DONUT TRAYS
  - RIPPLE TRAYS
- MULTI DOWNCOMER TRAYS
  - PROPRIETARY DESIGNS(MVG, SUPERFRAC)
  - TRITON, PROVALVE
  - NYE TRAYS
- COLLECTOR/ CHIMNEY TRAYS
  - NON- FRACTIONATION TRAYS

2. Packings

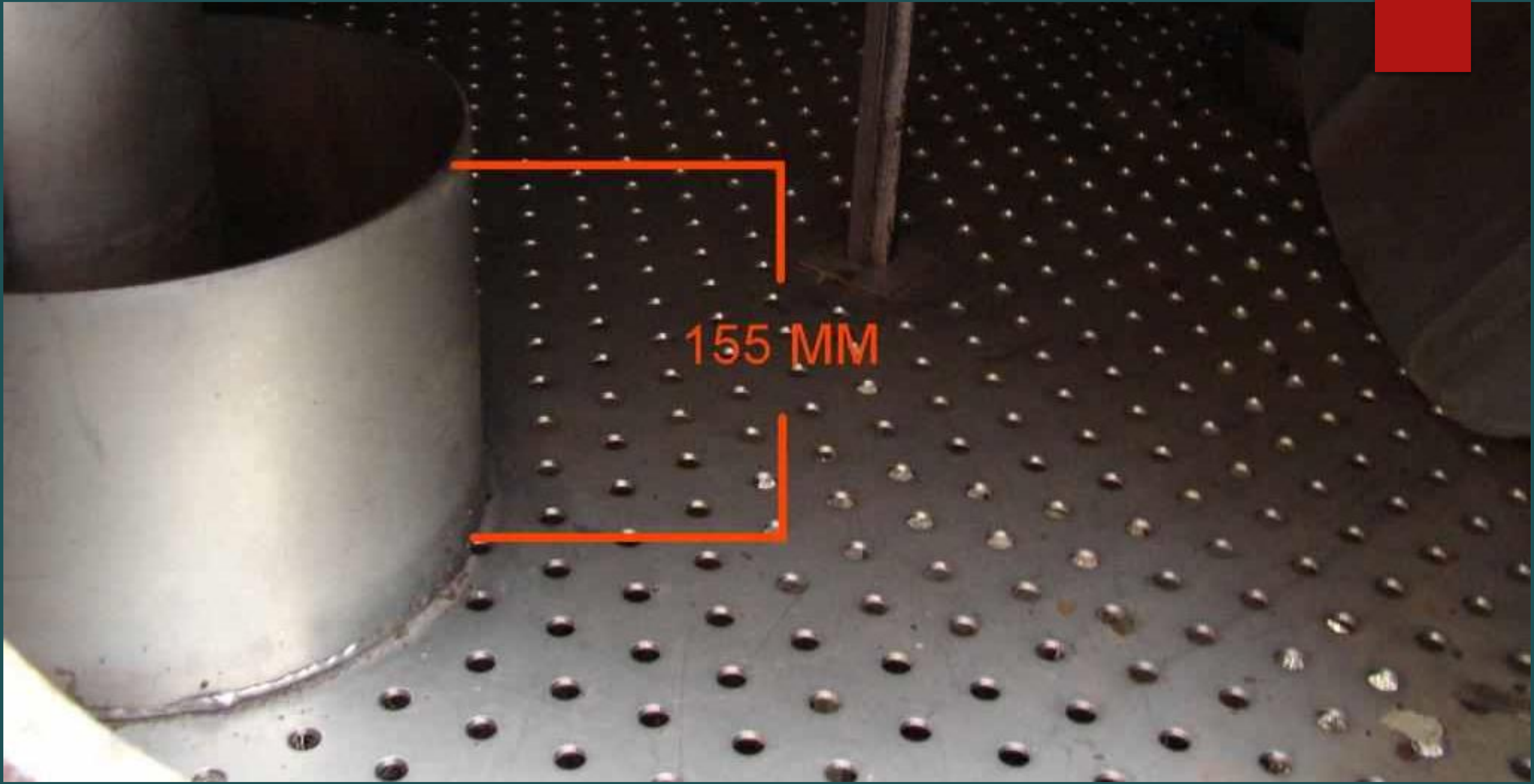
PACKING

- RANDOM
  - I GENERATION
    - RASCHIG
    - LESSING
    - CROSS PARTITION RING
    - BERL SADDLES
  - II GENERATION
    - PALL RING
    - HYPAK
    - IMTP
    - CMR
    - NUTTER RING
- STRUCTURED
  - III GENERATION
    - GEMPAK
    - MELLAPAK
    - INTALOX
    - PARLPAK

- Trays
  - Sieve Tray
  - Valve Tray
  - Bubble cap


Sieve Trays
PEC


44.5 mm
PEC


155 MM

Sieve Tray

This tray is a sheet of light metal with many 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.

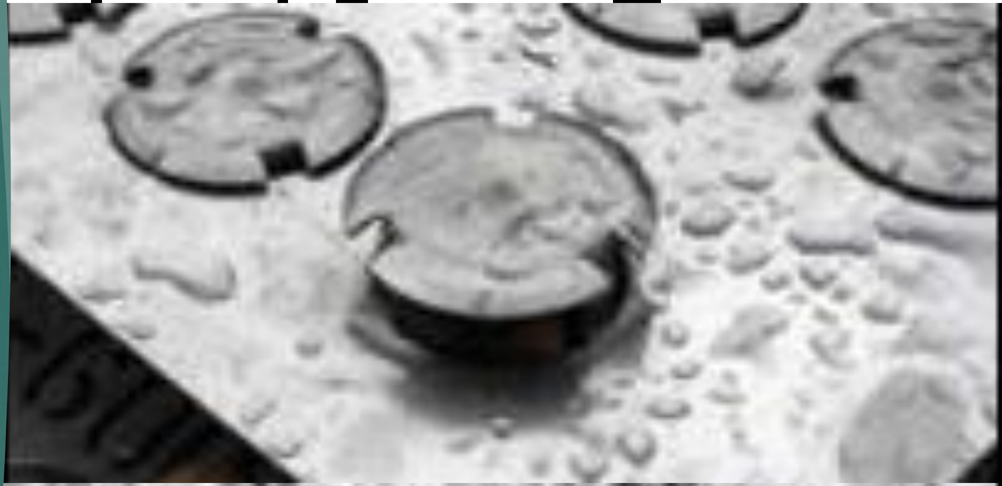
A sieve tray is:

Inexpensive,	Easy to clean, and	Maintains good liquid and vapor contact if it is operated at its design load.

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

Bubble Cap / Valve trays

In valve trays / Bubble Cap trays, *perforations are covered by liftable caps*. Vapor flows lifts the caps, thus self creating a flow area for the passage of vapor. The lifting cap directs the vapor to flow horizontally into the liquid, thus providing better mixing



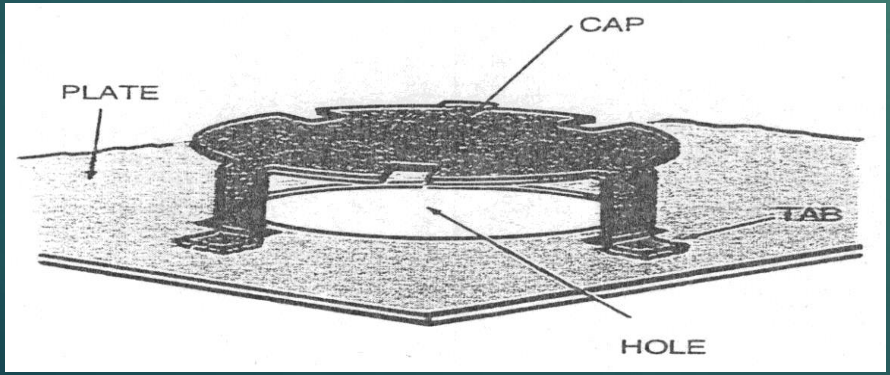
Valve Tray

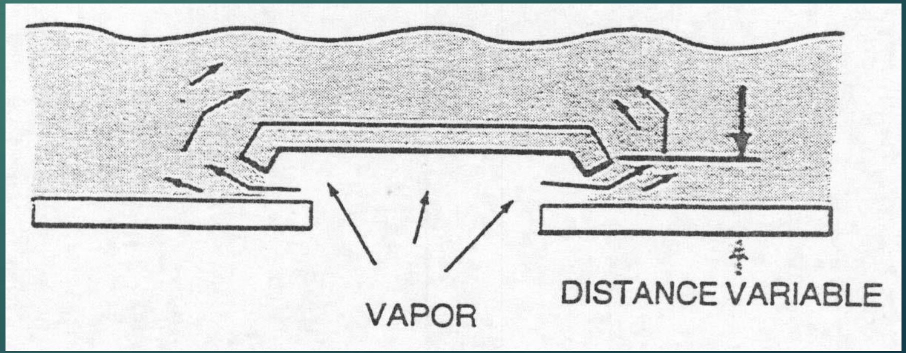
- Floating
- Fixed

Valve Tray

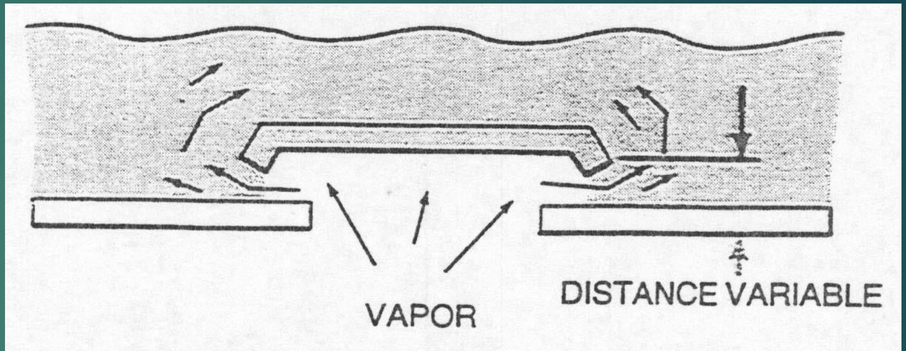
A valve tray has a variable opening for vapors to flow through.

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.

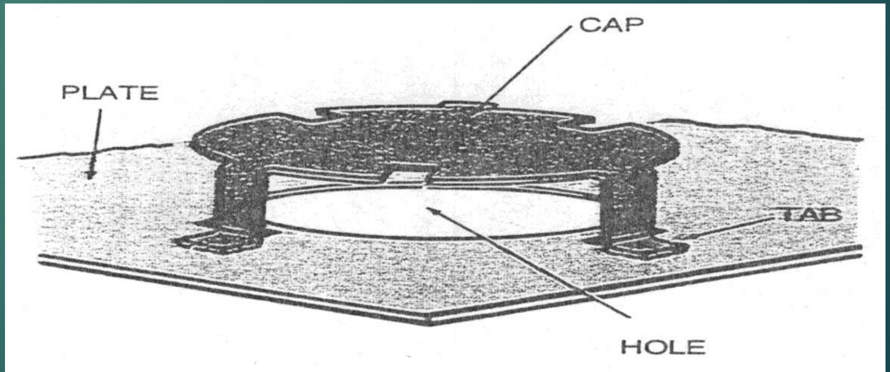




When there is no vapor flow, the caps sits over the hole and close it.



Under low pressure
the cap start to rise.



As the flow of vapors increases, the cap rise until it is stopped by the guide tabs.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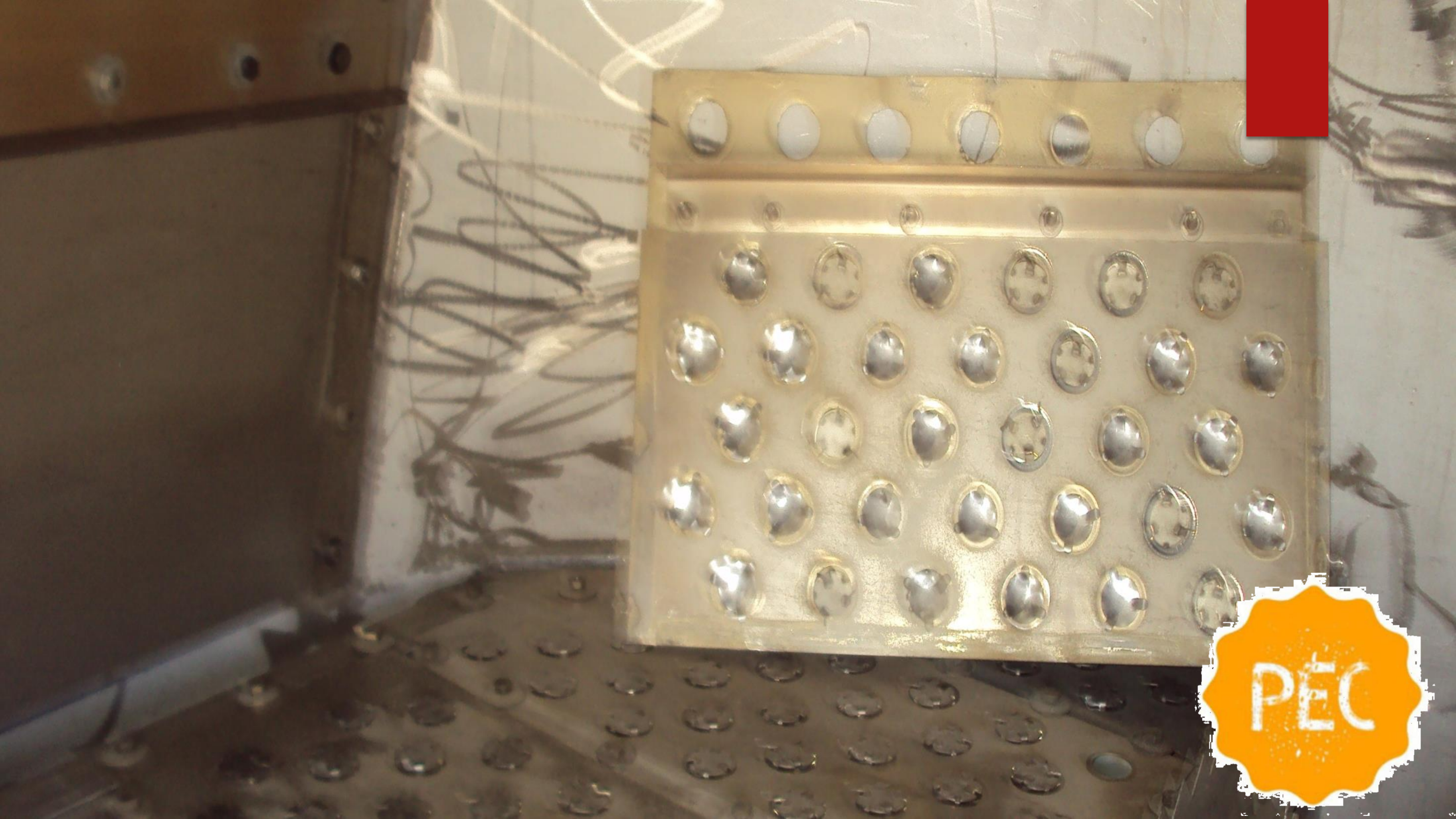
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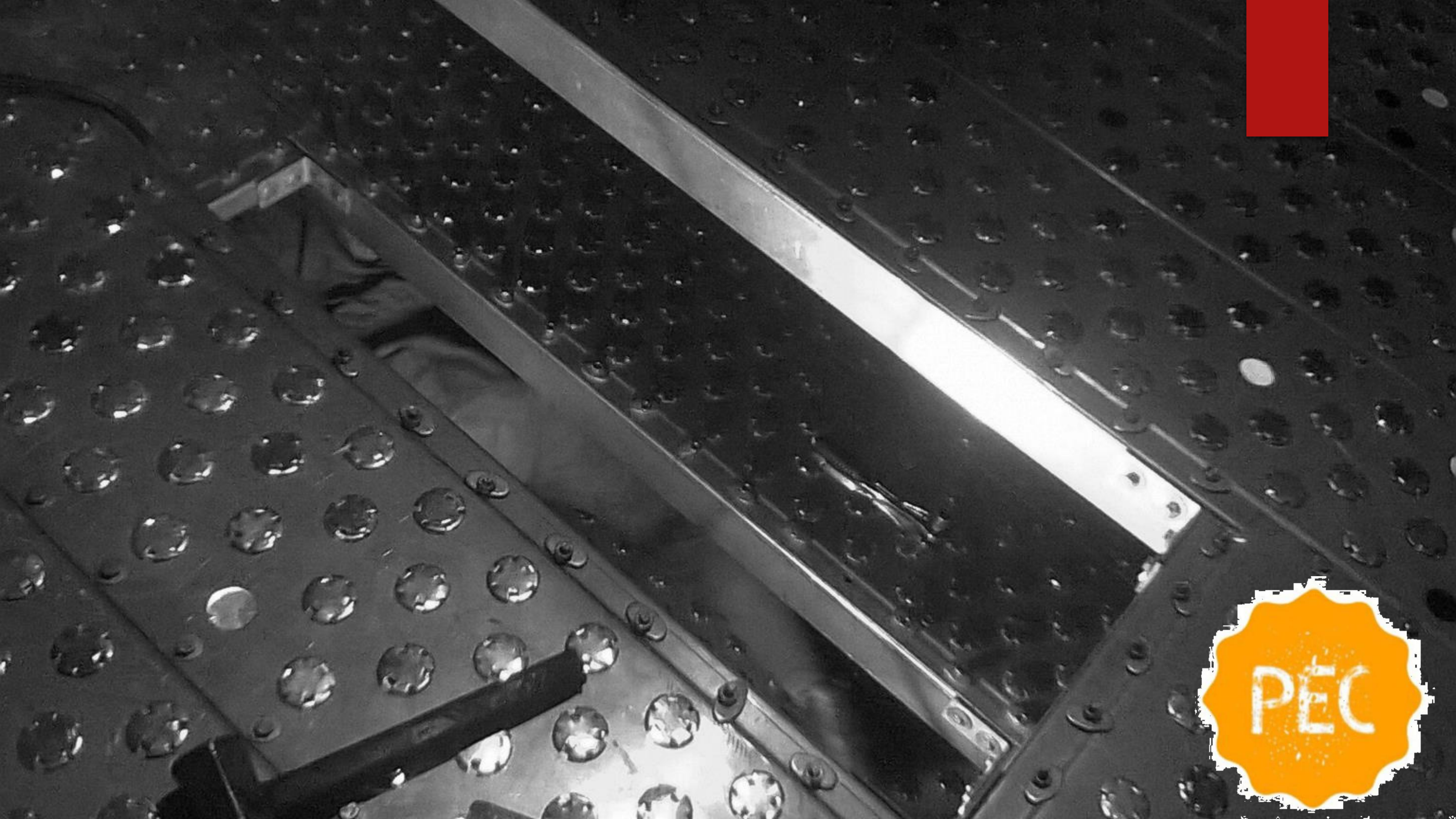
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The valve tray is like the babble cap tray.

Both are more adaptable to variations in tower loads than a sieve tray.

The valve trays and bubble cap trays are designed to perform well with variable tower loads.

Valve Tray


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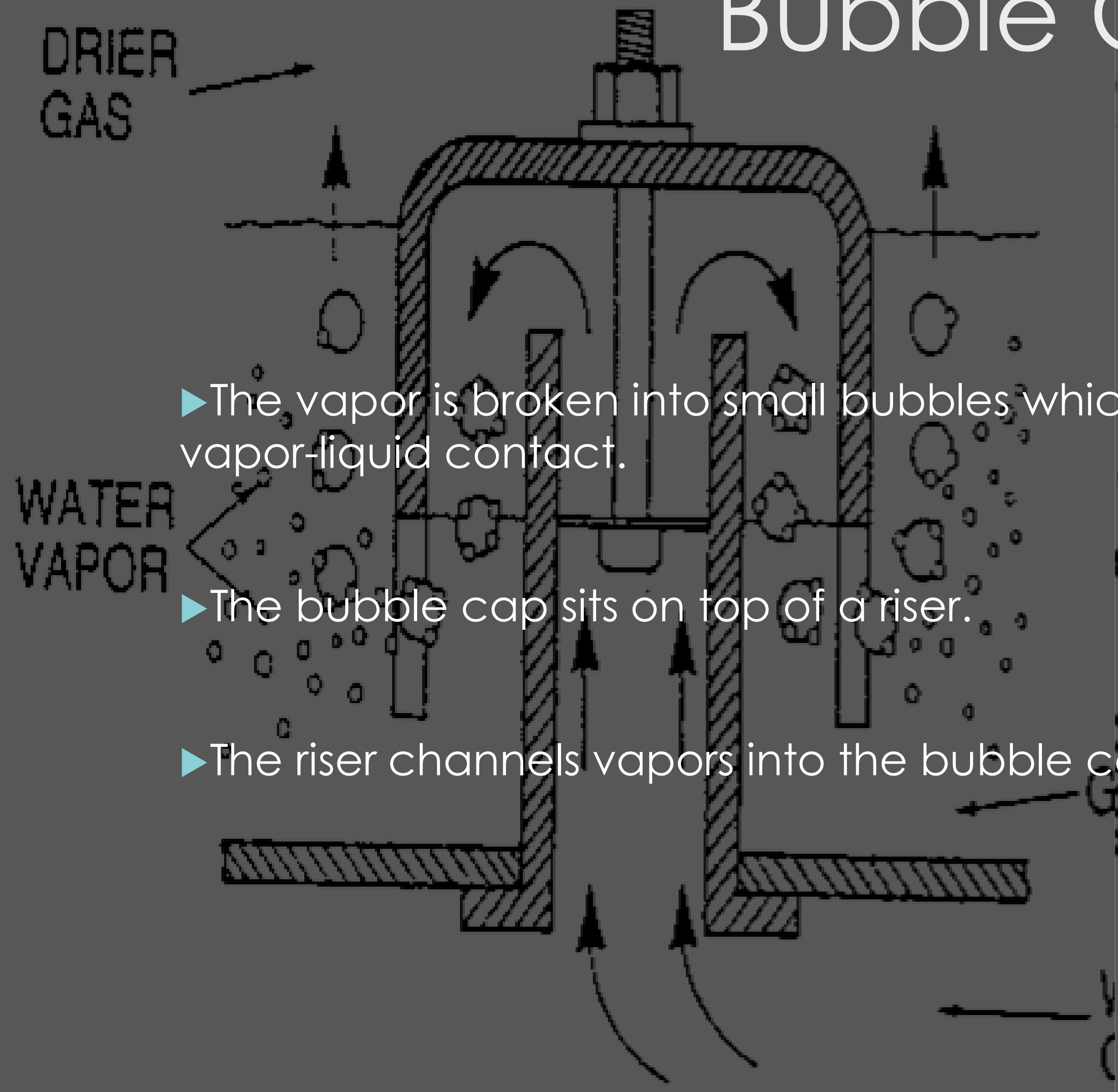
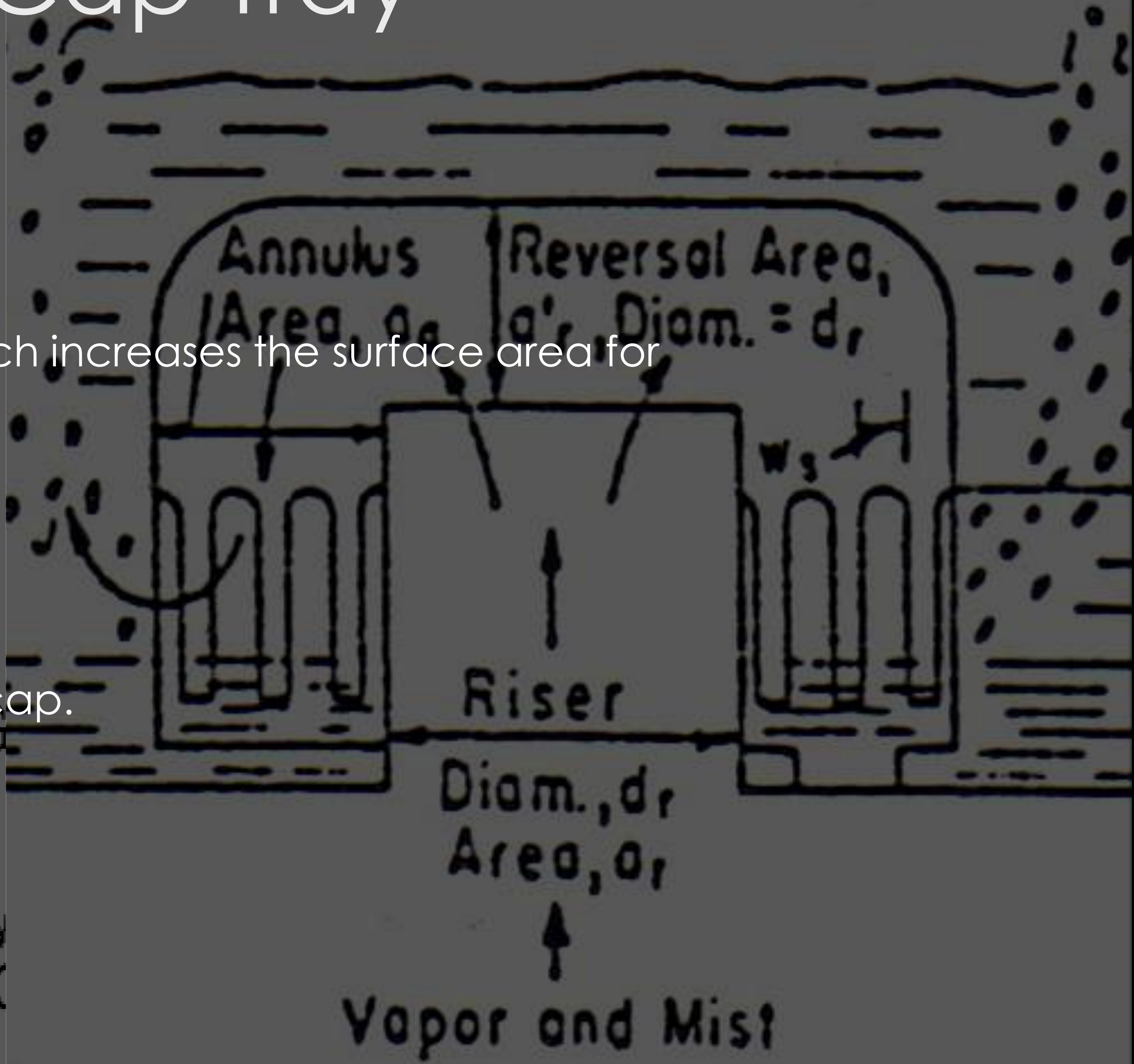
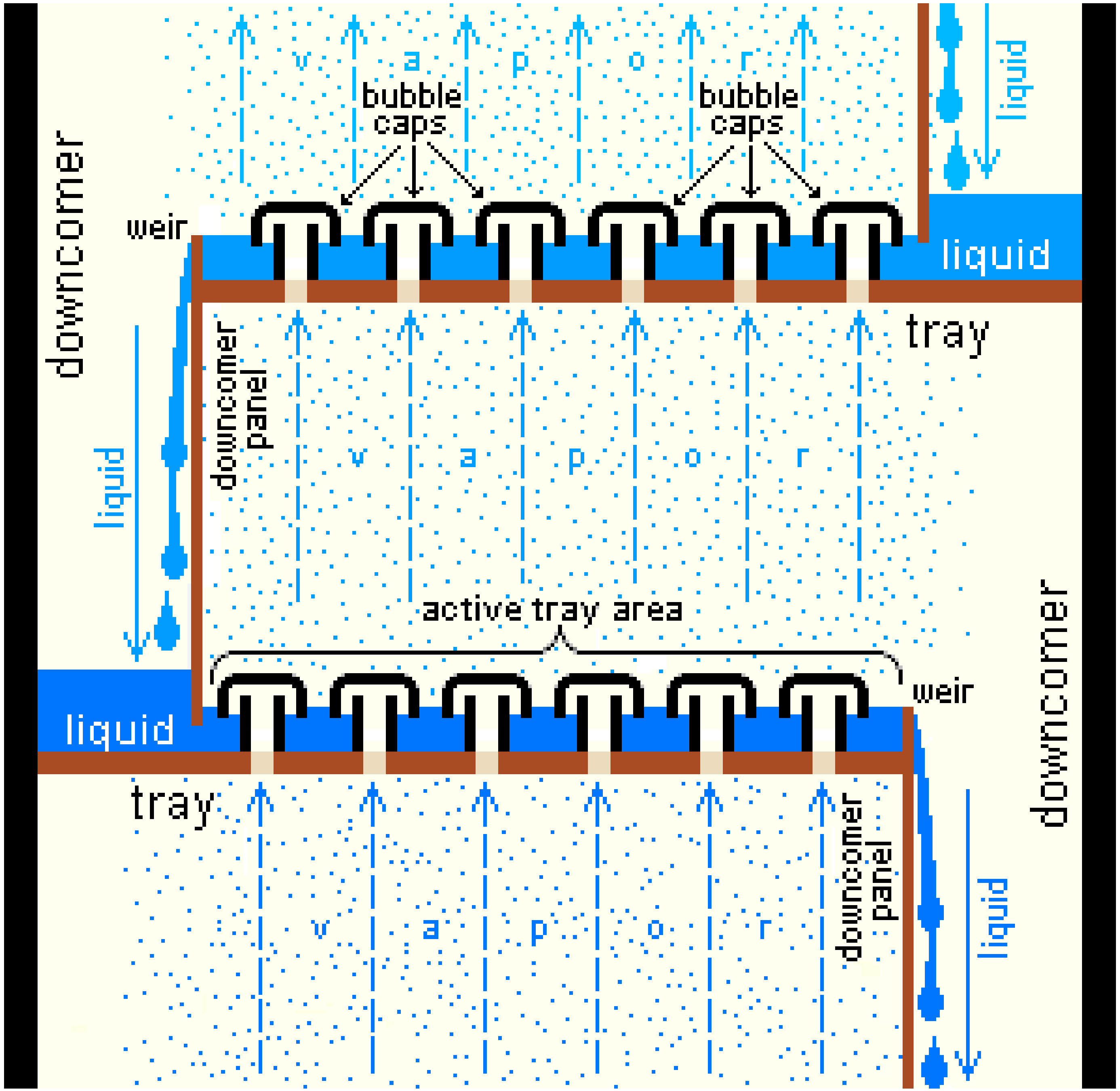
Bubble Cap Tray

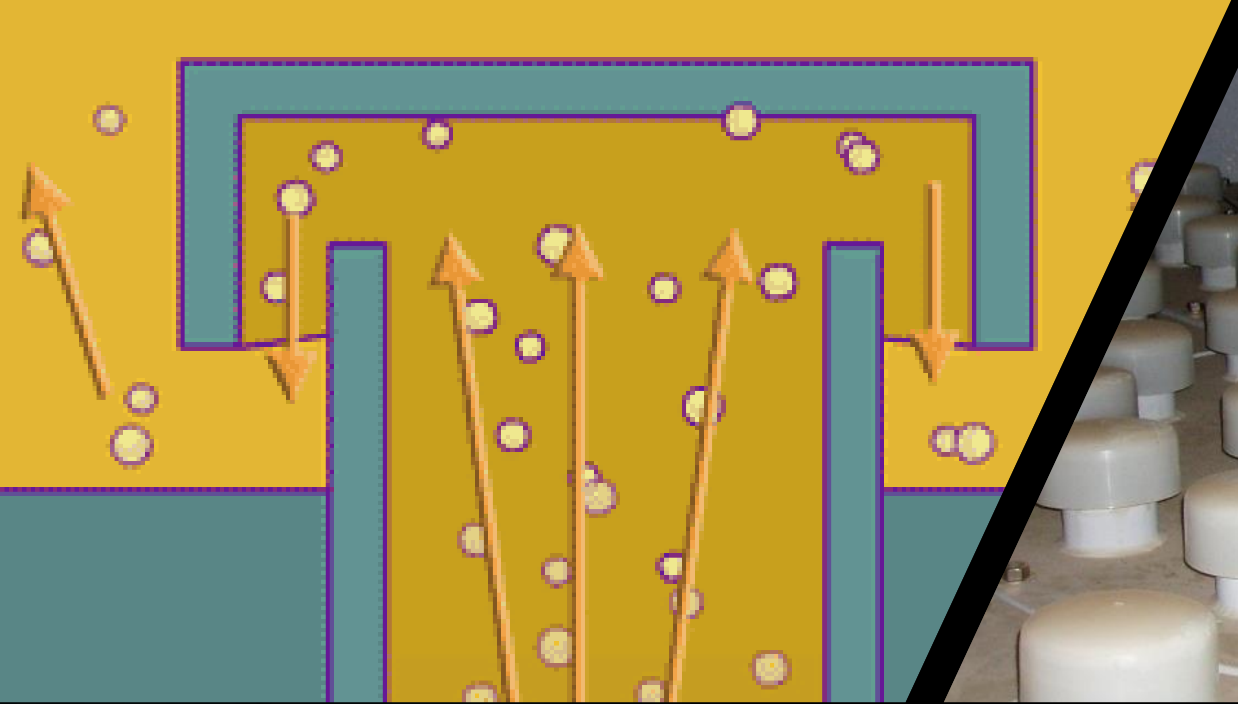




- The vapor is broken into small bubbles which increases the surface area for vapor-liquid contact.
- The bubble cap sits on top of a riser.
- The riser channels vapors into the bubble cap.



vapor
bubble caps
bubble caps
liquid
downcomer
weir
liquid
tray
downcomer panel
liquid
vapor
active tray area
weir
liquid
downcomer
tray
vapor
downcomer panel
liquid





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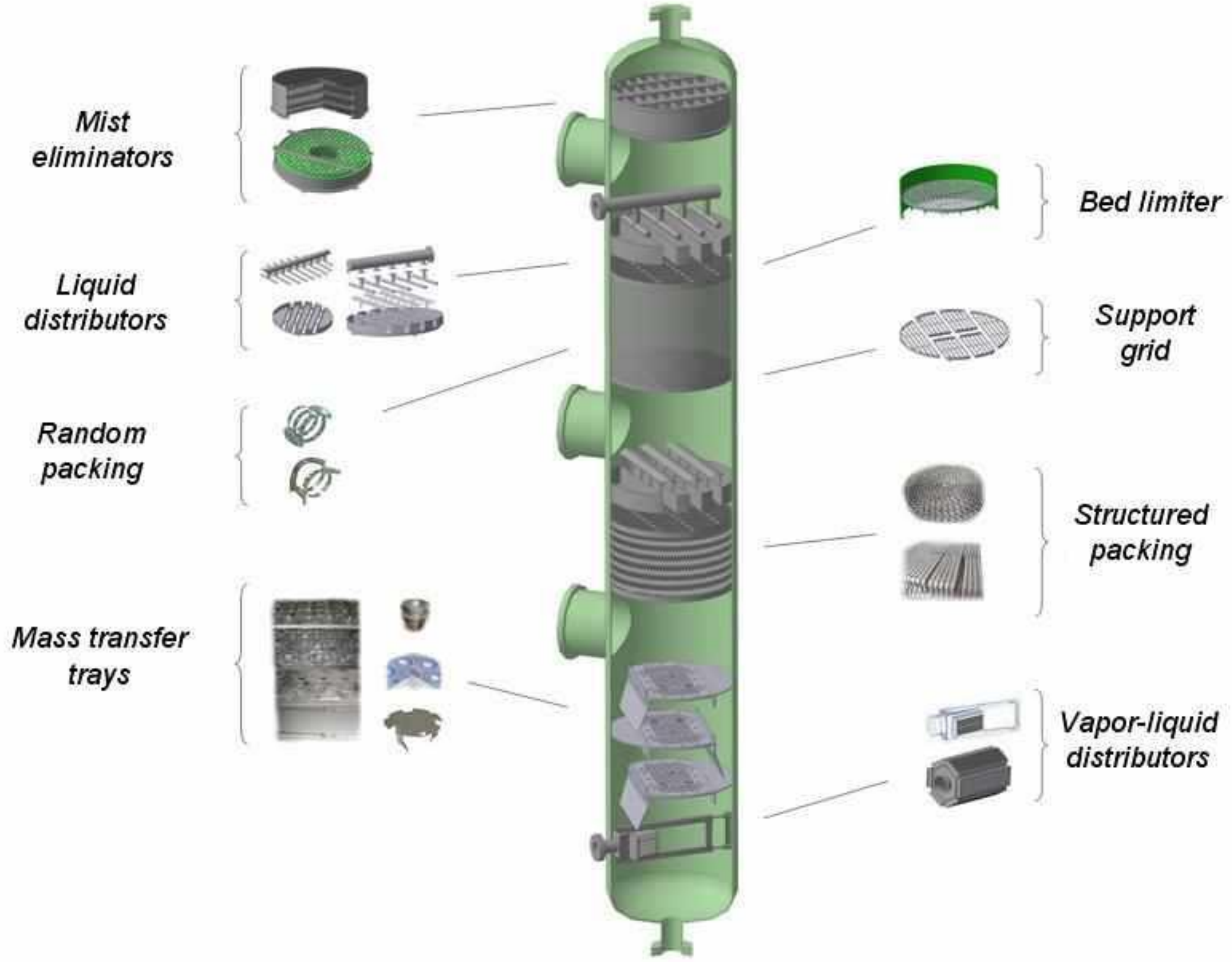
Mist eliminators
Liquid distributors
Random packing
Mass transfer trays
Bed limiter
Support grid
Structured packing
Vapor-liquid distributors


COMPANION
ABNORMA


KNM

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,
  - Maintenance and
  - Pressure drop.

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

Capacity:

- There is a 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


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Technology
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Operating range:

- This is the most significant factor.
- By operating range is meant the range of vapor 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.

▶**Bubble-cap** trays have a positive liquid seal and can therefore operate efficiently at very low vapor rates.

- **Sieve trays** rely on the flow of vapor through the holes to hold the liquid on the tray and cannot operate at very low vapor 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.

Maintenance:

- For dirty services, bubble-caps are not suitable as they are most susceptible to plugging. Sieve trays are the easiest to clean.

Pressure Drop:

- The pressure drop over the trays can be an important design consideration, particularly for vacuum columns.

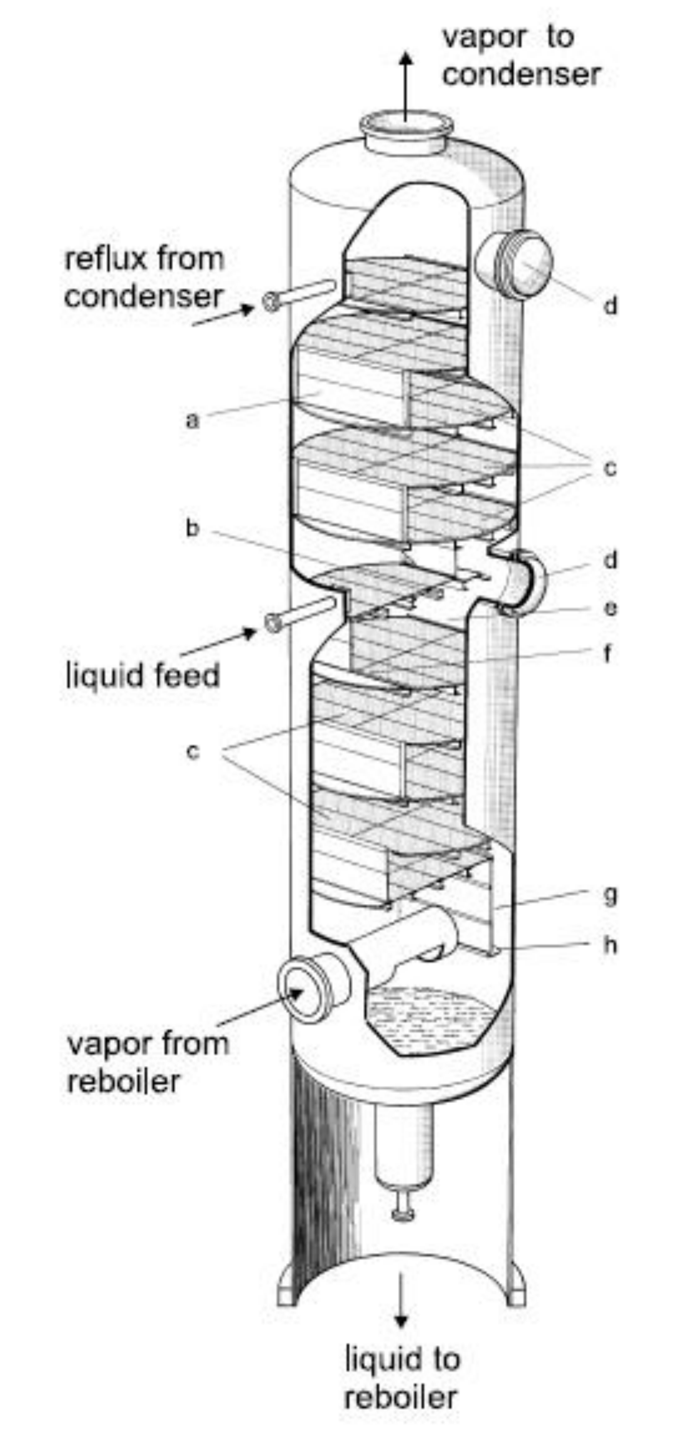
- The trays pressure drop will depend on the detailed design of the tray but.

- In general,

- sieve plates give the lowest pressure drop, followed by valves, with bubble-caps giving the highest.

Summary

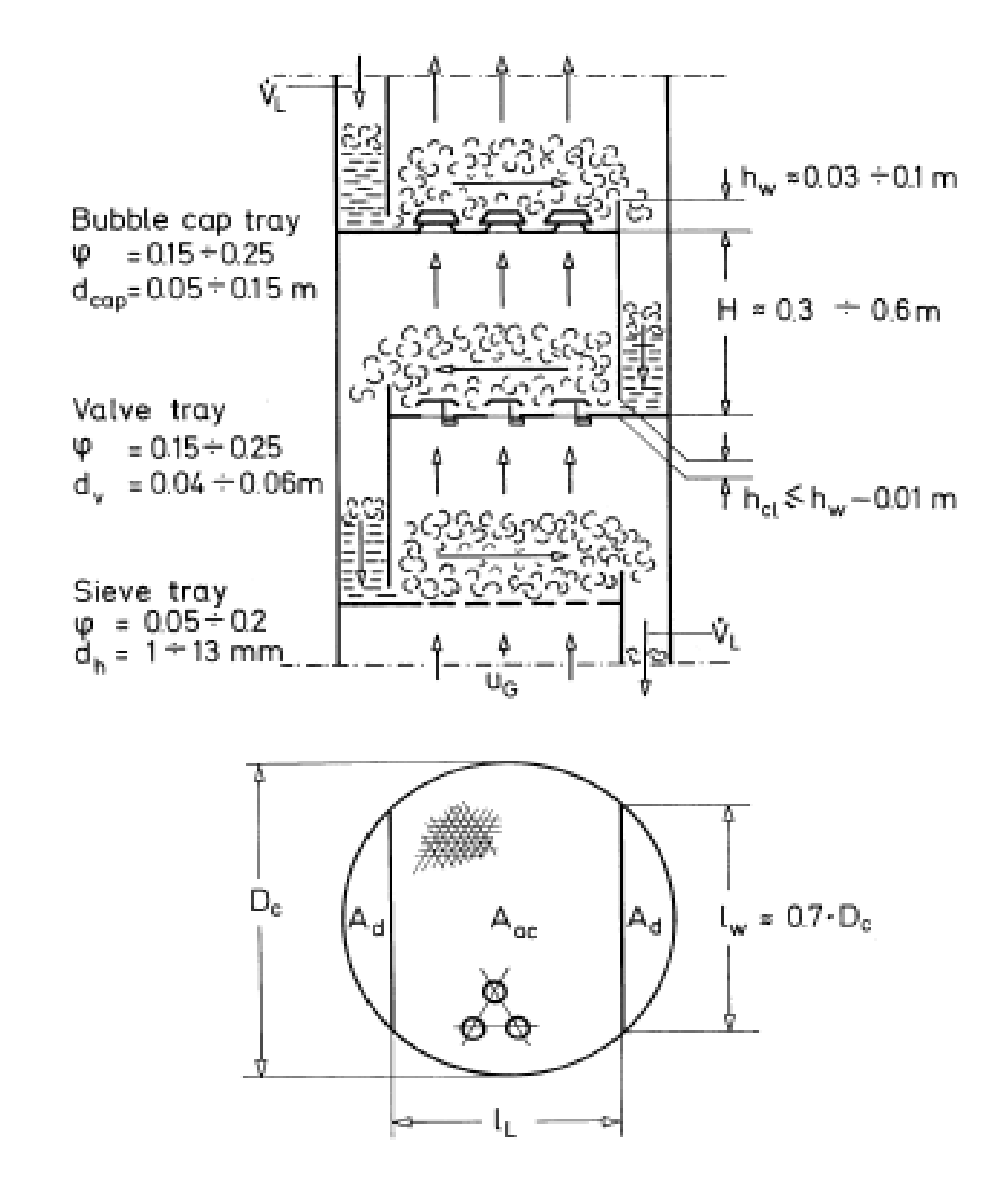
- Sieve trays are the cheapest and are satisfactory for most applications.
- Valve trays should be considered if the specified turn-down cannot be met with sieve trays.
- Bubble-caps should only be used where:
  - Very low vapor (gas) rates have to be handled and
  - A positive liquid seal is essential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



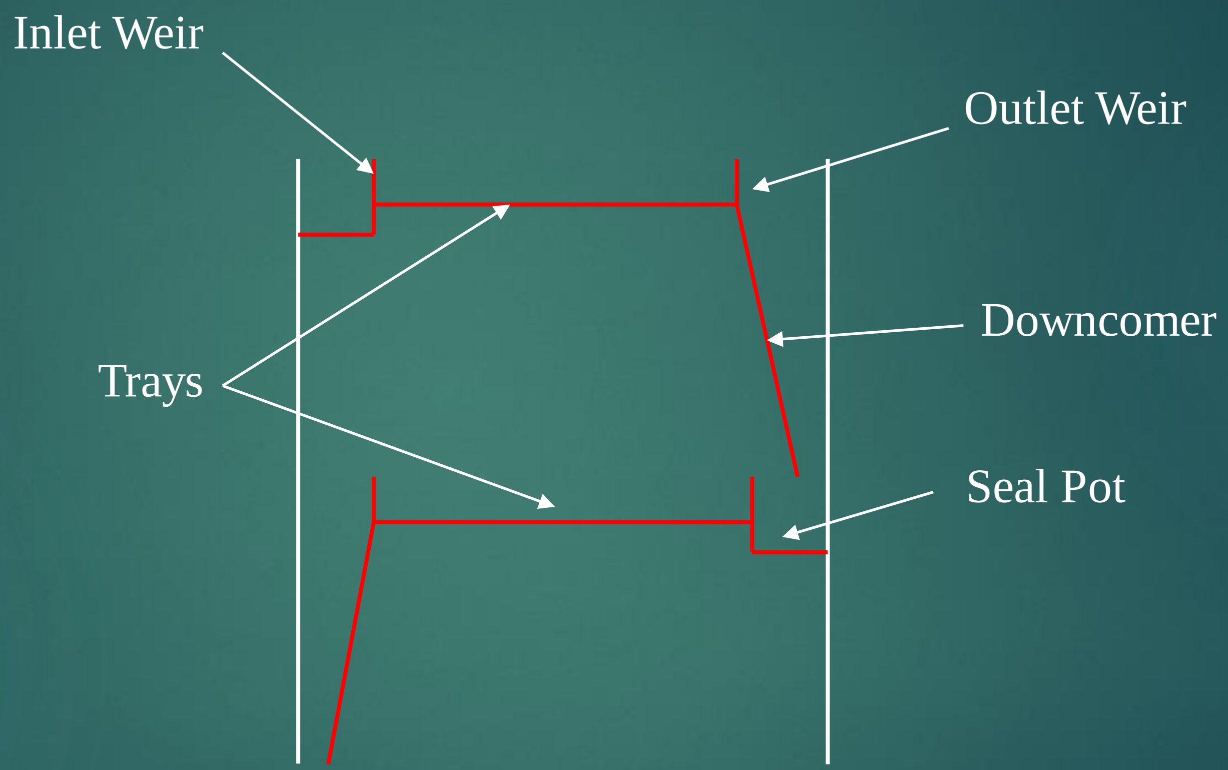
a: downcomer
b: tray support
c: sieve trays
d: man way
e: outlet weir
f: inlet weir
g: side wall of downcomer
h: liquid seal

Characteristic dimensions of industrial tray designs

A_{ac}	**active area**
A_d	downcomer area
D_C	column diameter
$d_{cap,\ v,\ h}$	bubble cap, valve, hole diameter
H, Δz	tray spacing
h_{cl}	height of down-comer clearance
h_W	weir height
l_W	weir length
l_L	length of liquid flow path
φ	relative free area



Typical Tray Section

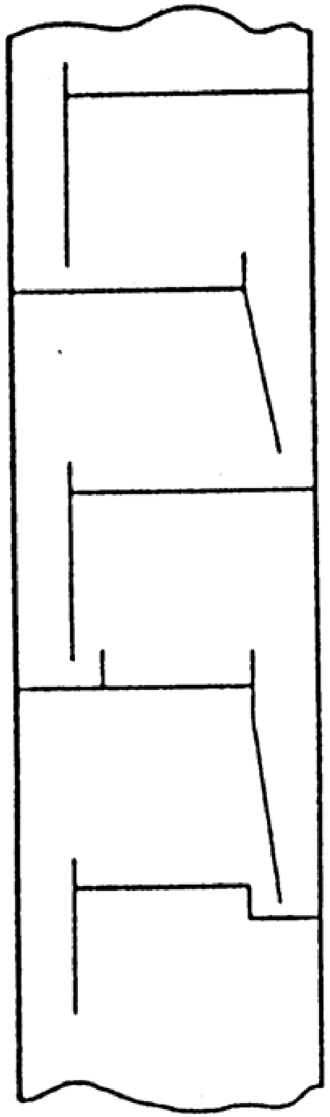


Inlet Weirs

- 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.

- If a more positive seal is required at the downcomer at the outlet, an inlet weir can be fitted or a recessed seal pan used.

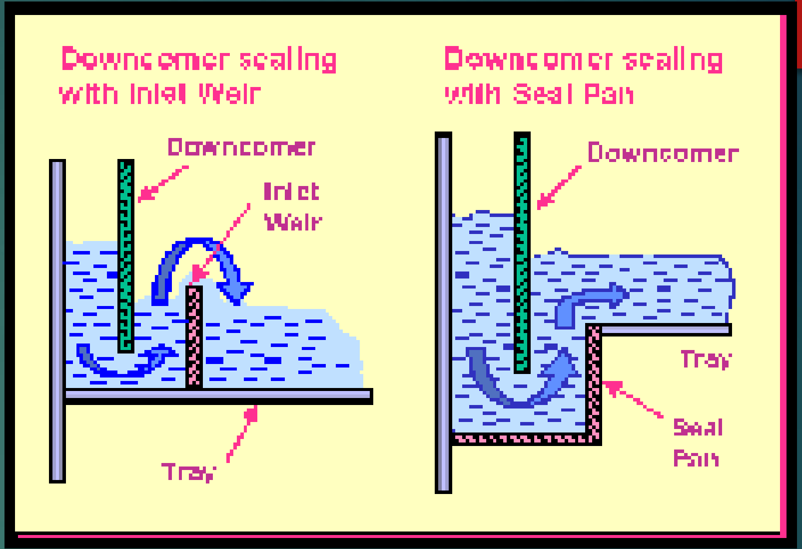


(c) Inlet weir

- Downcomer sealing can be achieved primarily by 2 means:

  (1) inlet weirs

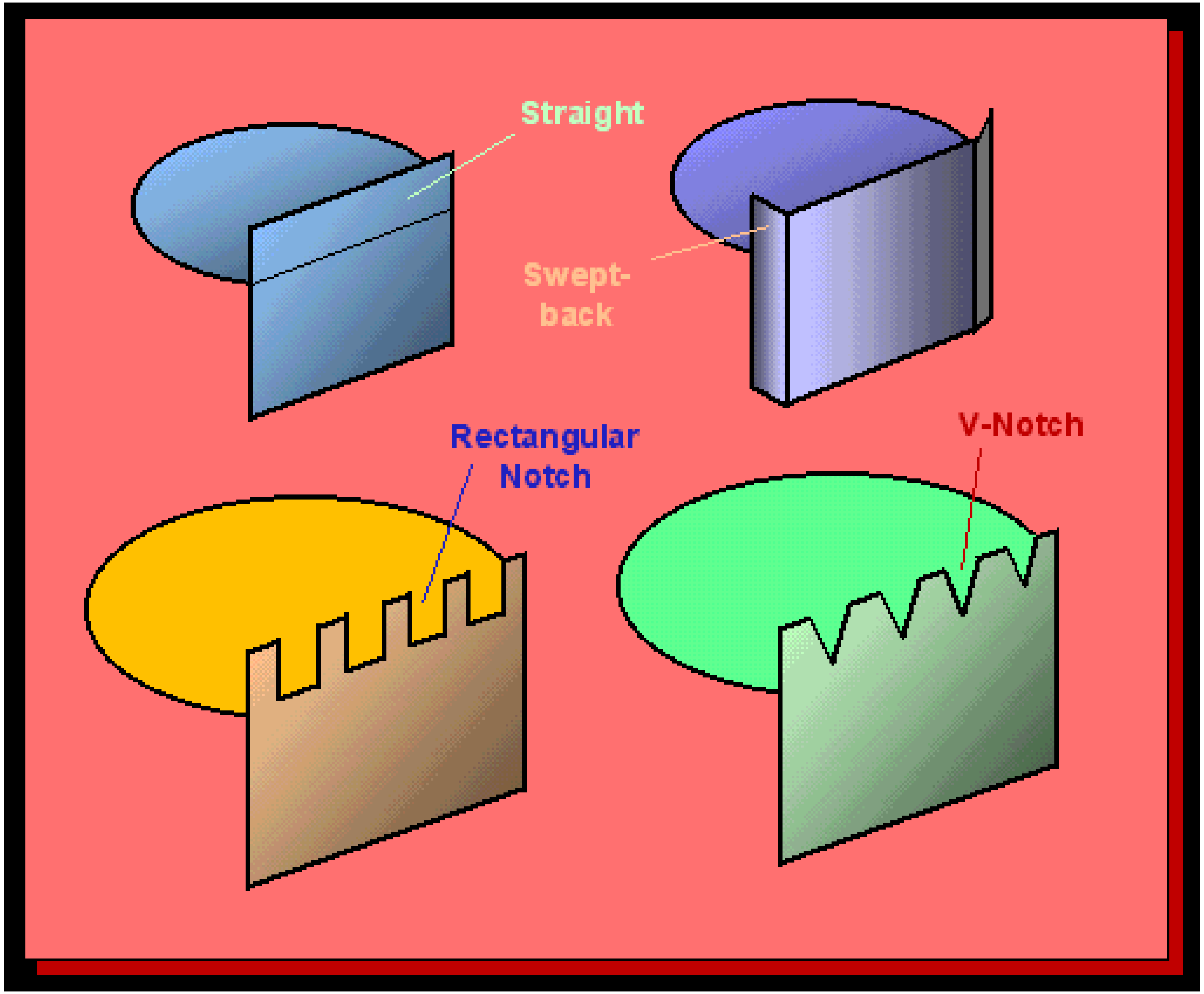
  (2) recessed seal pan.

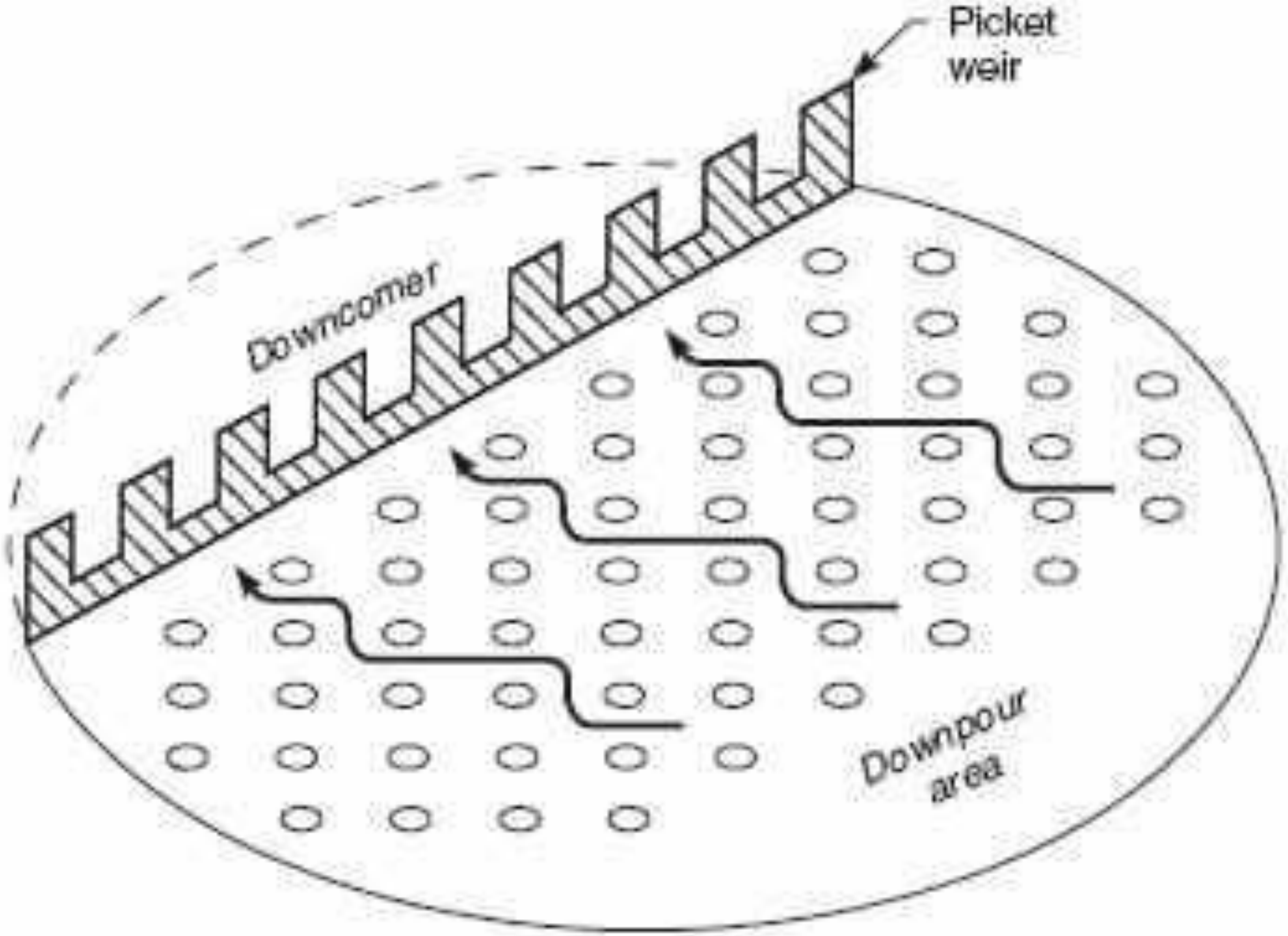


These devices provide a positive seal on the tray. The disadvantage is that they create a pocket of stagnant liquid where dirt, sediments, etc can build up. A large amount of such build up can restrict the downcomer outlet area and lead to premature flooding. **Thus, the use of these devices is not recommended in fouling or corrosive services.**

Outlet Weirs

- The function of a weir is to maintain a desired liquid level on the tray , **thus insuring bubbling of vapors through liquid.** Typical weir height is between 2 - 4 inches. Low weirs are frequently used in low pressure or vacuum columns. Notched (rectangular or V-shaped) weirs are commonly used for low liquid loads


Straight
Swept-
back
Rectangular
Notch
V-Notch


Picket
weir
Downcomer
Downpour
area


PEC

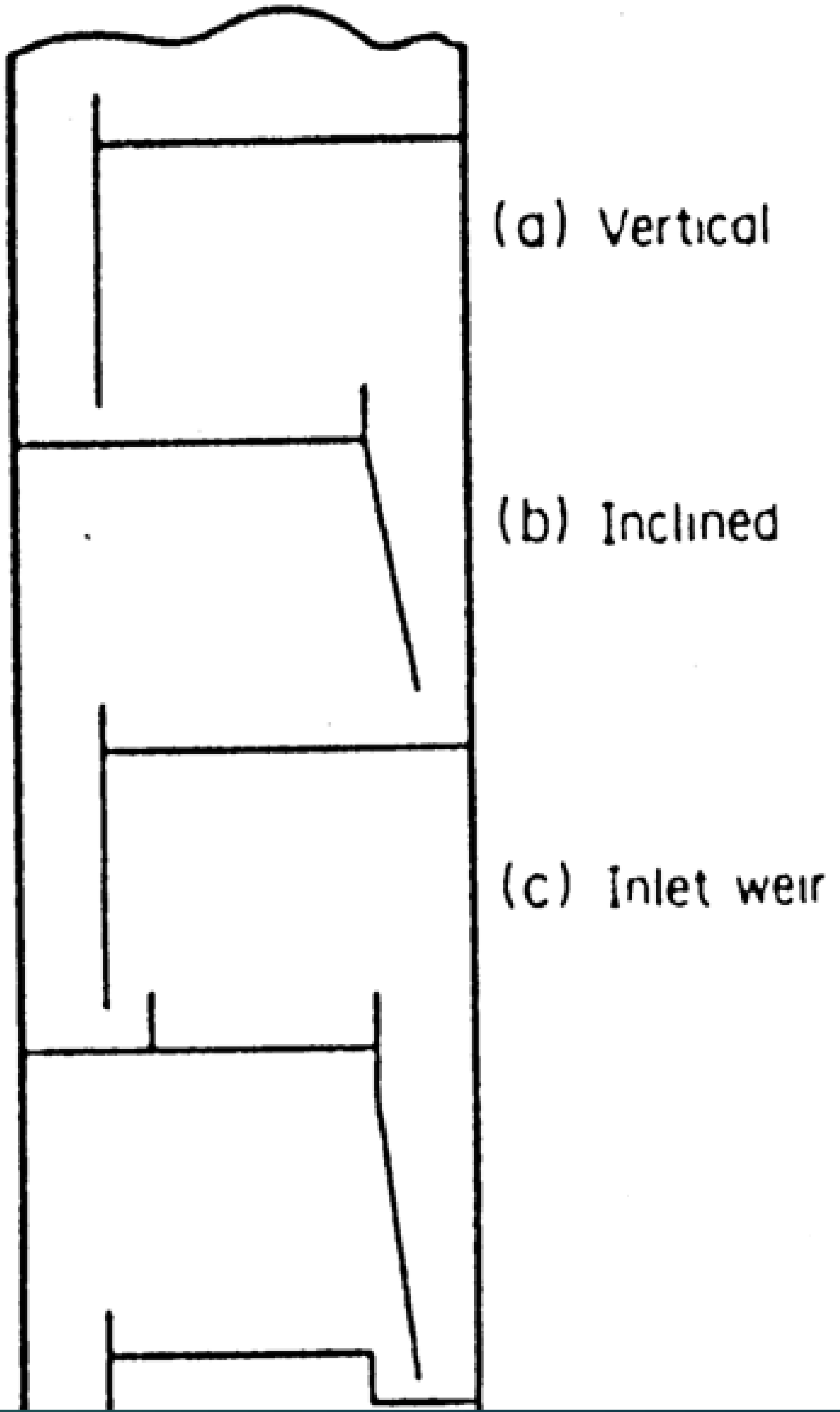

PEC

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.

- Downcomers can be designed in several different ways to provide smooth flow from tray to tray.



Downcomers

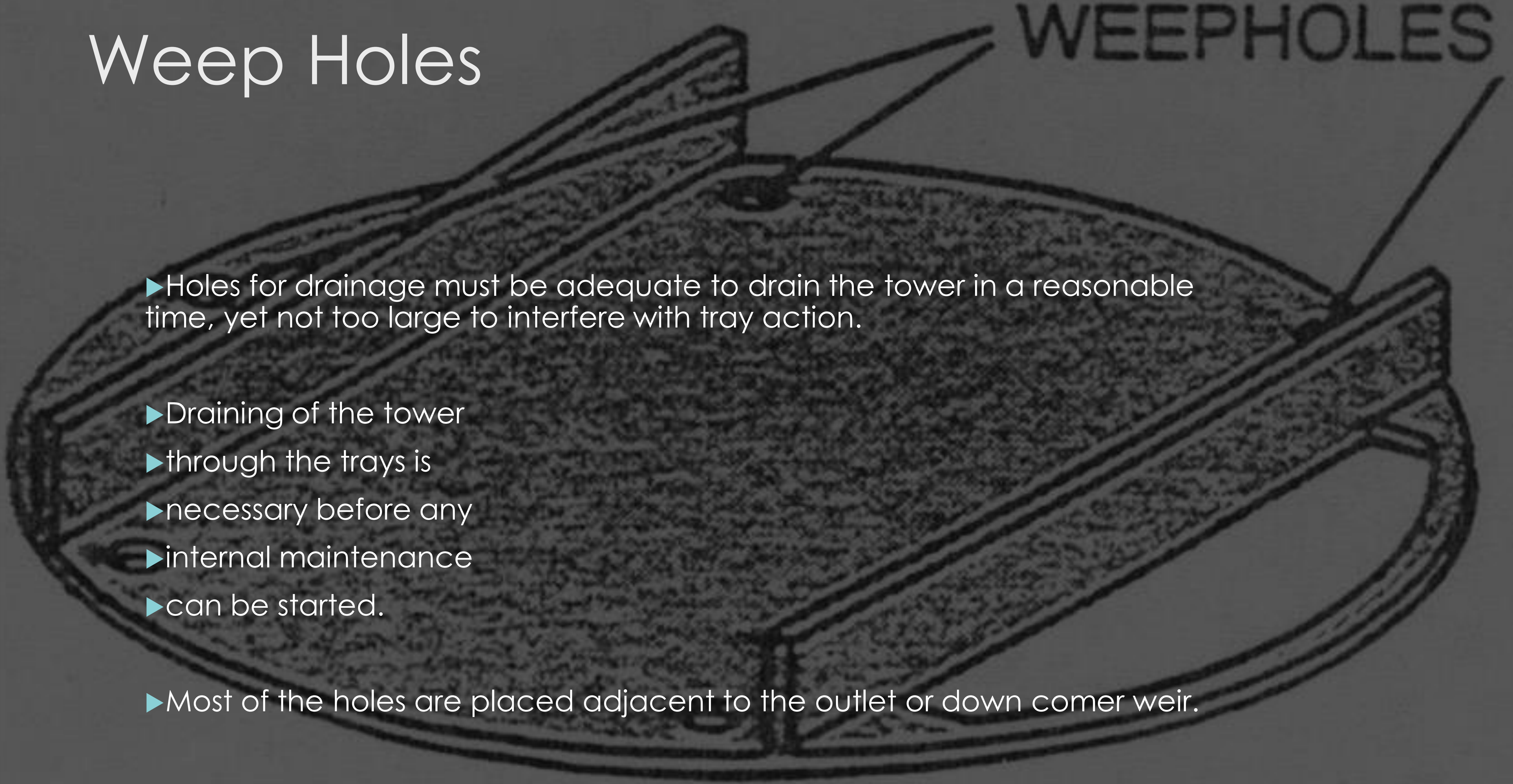
- The straight, segmental, vertical downcomer is widely used as it provides good utilization of column area for downflow and has cost and simplicity advantage. **Sloped** downcomer can be used **if vapor-liquid disengagement is difficult** (e.g. due to **foaming**). Sloped downcomer also provide a **slightly larger active area** for vapor-liquid contact, but it is also **more expensive.**

Downcomers

A downcomer must be sufficiently large to allow liquid to flow smoothly without choking. Sufficient time must also be provided in the downcomer to allow proper vapor disengagement from the down-flowing liquid, so that the liquid is relatively free of vapor by the time it enters the tray below.

Inadequate downcomer area will lead to downcomer choking, whereby liquid backs up the downcomer into the tray above and eventually flood the column.

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.

- Draining of the tower
- through the trays is
- necessary before any
- internal maintenance
- can be started.

- Most of the holes are placed adjacent to the outlet or down comer weir.

Bottom Strainer

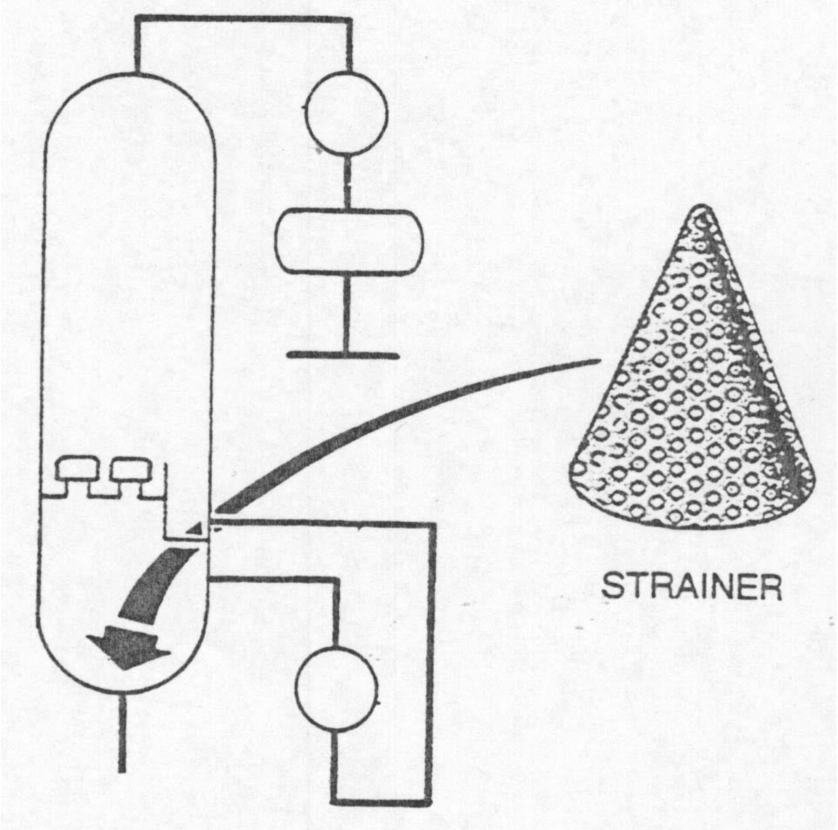
- During the operation of a tower:
  - The bubble caps,
  - Bolts, and
  - Other foreign objects
- may be dislodged and carried along with bottom stream.

Bottom Strainer

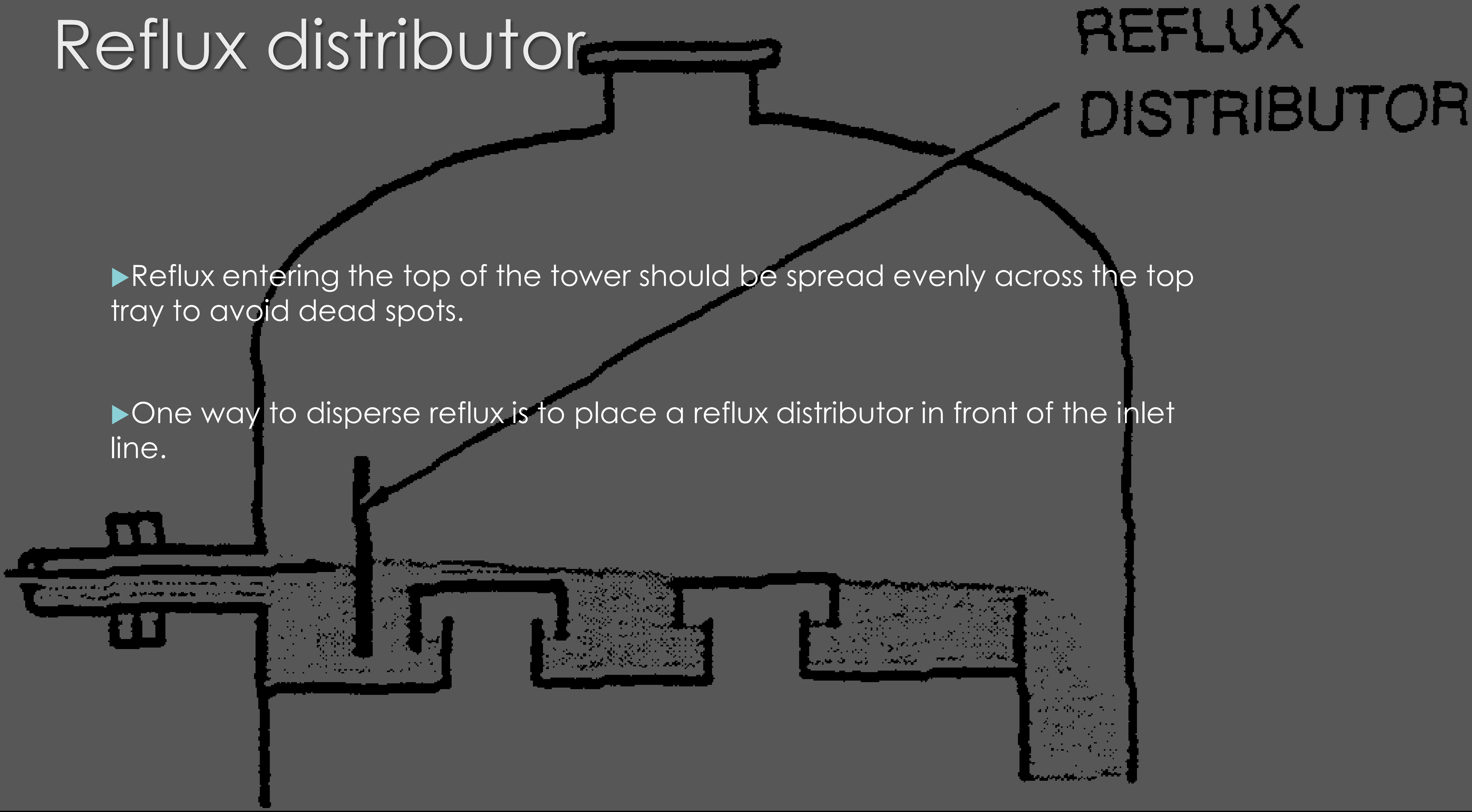
- To prevent these objects leaving the tower and damaging pumps, a strainer is installed in the bottom outlet line.

- Strainers must have openings small enough to catch small objects, but large enough not to hinder the flow of liquid, or product, or oil out of the tower.

- 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.



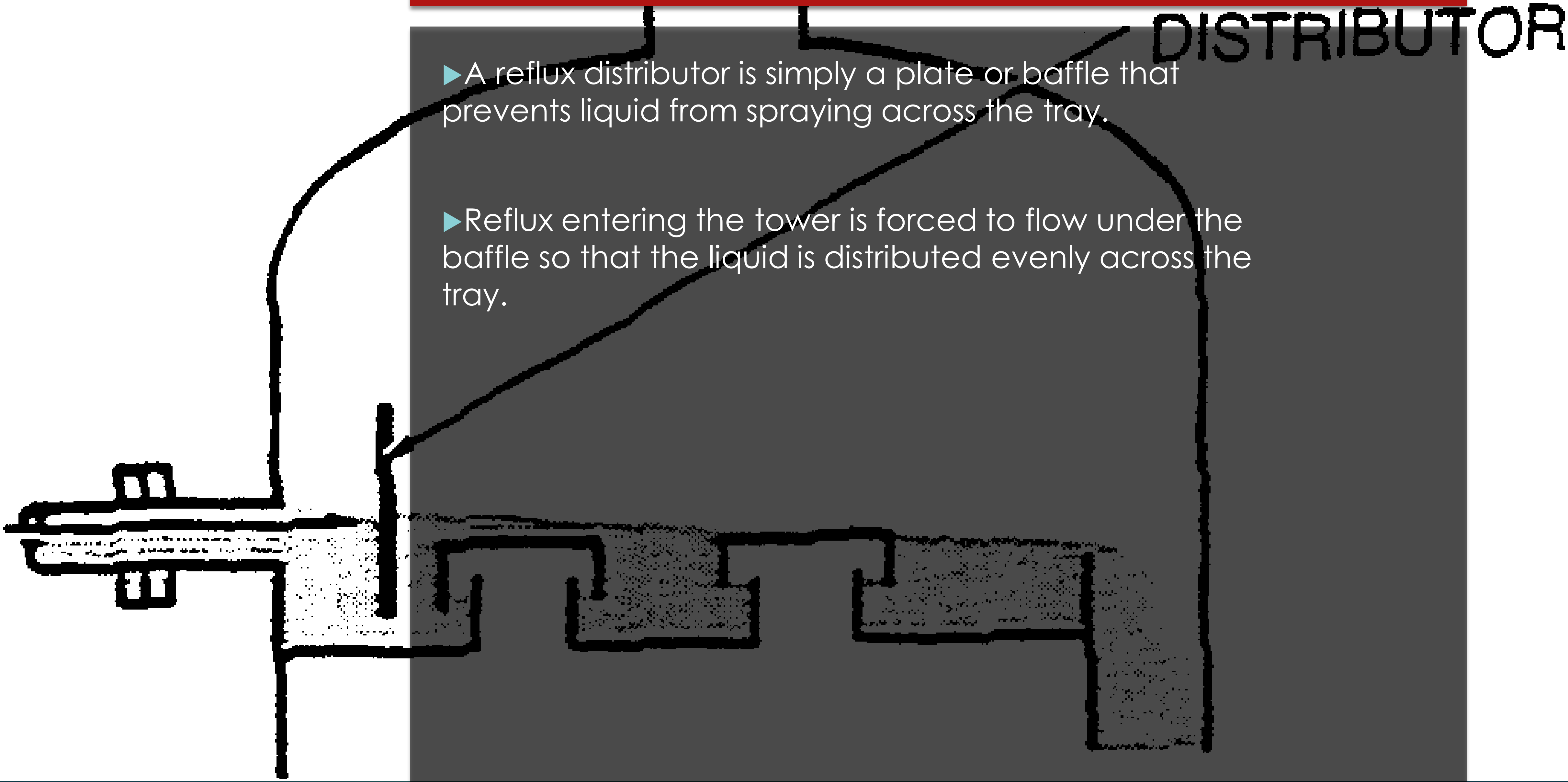
Reflux distributor



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

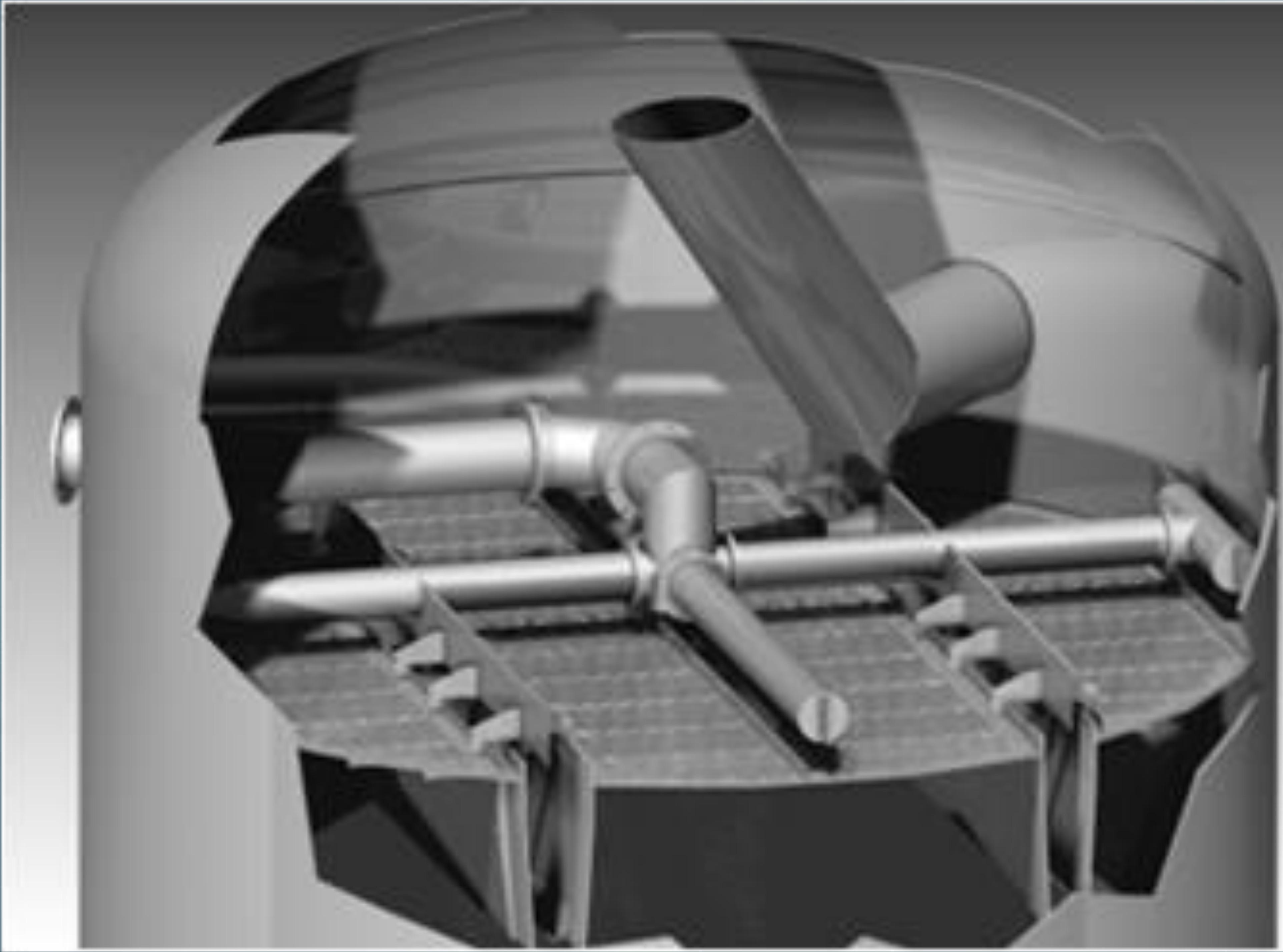
- One way to disperse reflux is to place a reflux distributor in front of the inlet line.

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.

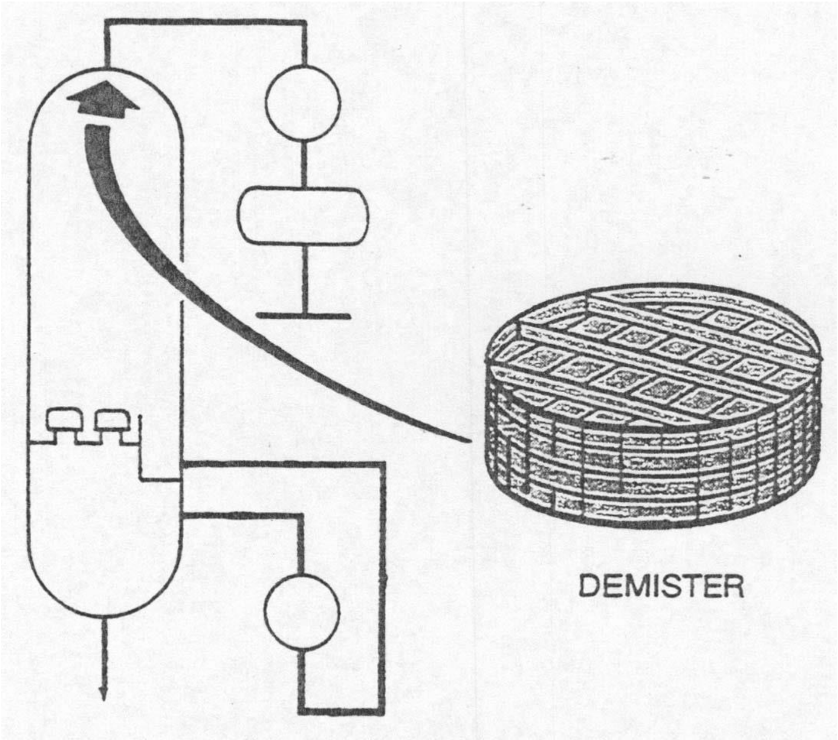


Top Tower Demister

- 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 entrainment.
- 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.

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.
- Demisters must be kept clean of dirt and foreign matter, or the flow of vapor will be restricted or stopped.



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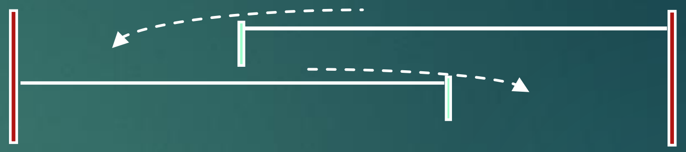
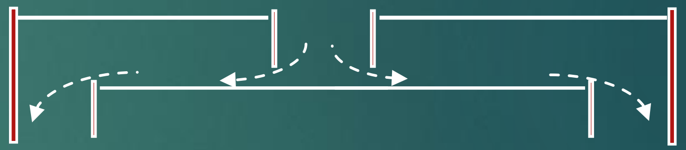
Classification of Trays

Based on the Number of liquid paths

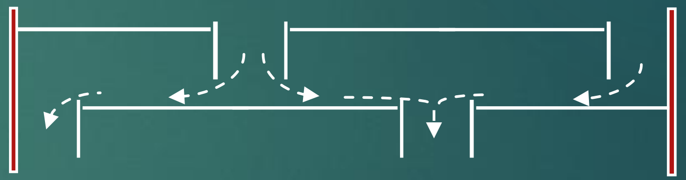
1. Single Pass



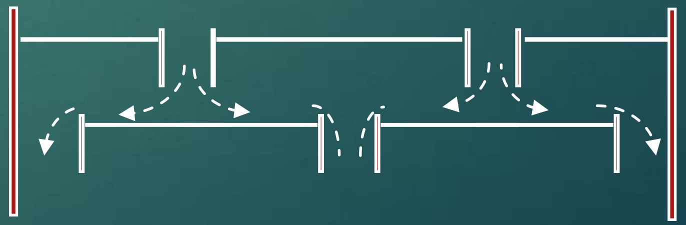
2. Two Pass



3. Three Pass



4. Four Pass



Packing

Packing :

1. Random Packing
2. Structured Packing

INTALOX SADDLE

PALL RING

RASCHIG RING

First Generation (Raschig Ring, Berl Saddle)

1895 to the 1950s

- simple shapes with closed surfaces, robust and stable design, cost-effective production

Second Generation (Pall Ring, Intalox Saddle)

late 1950s to the early 1970s

- surfaces with cutted windows and bent tongues, improved area distribution lowering pressure drop and enhancing capacity

Third Generation (Net/Grid Structures, IMPT Ring)

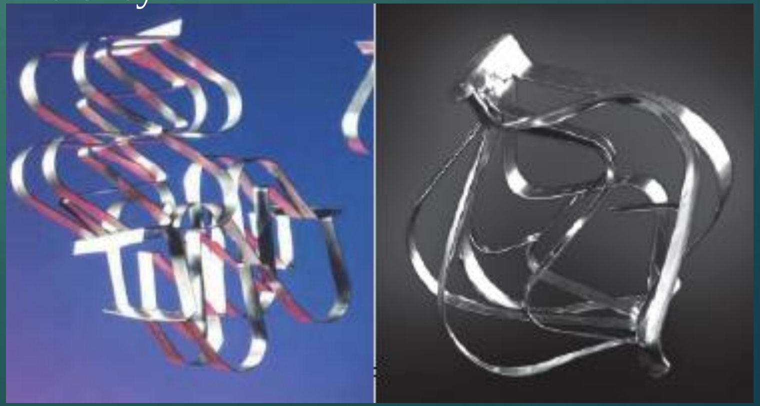
late 1970s to the 1990s

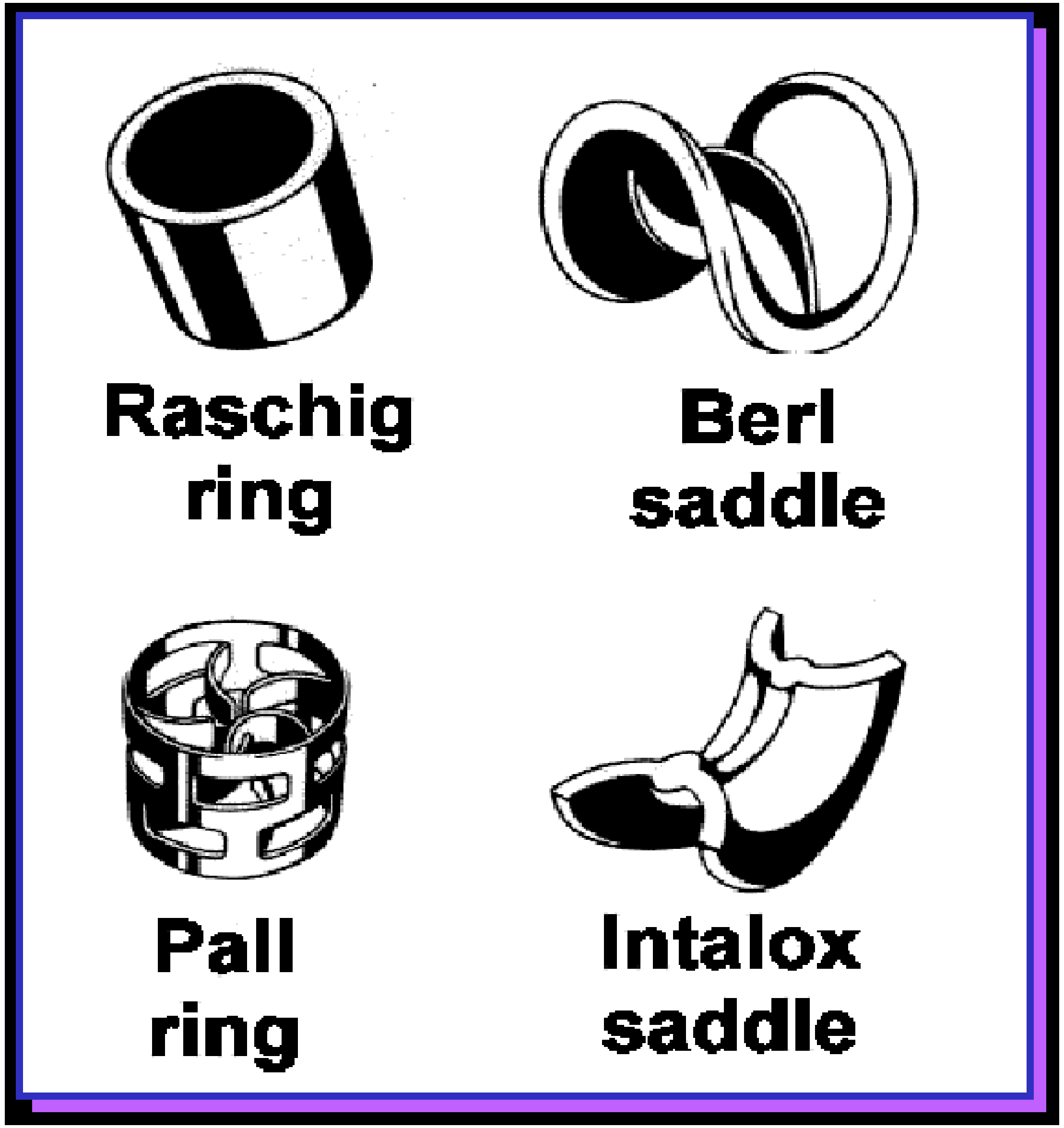
- framework structure, large free cross section, low pressure drop, high efficiency

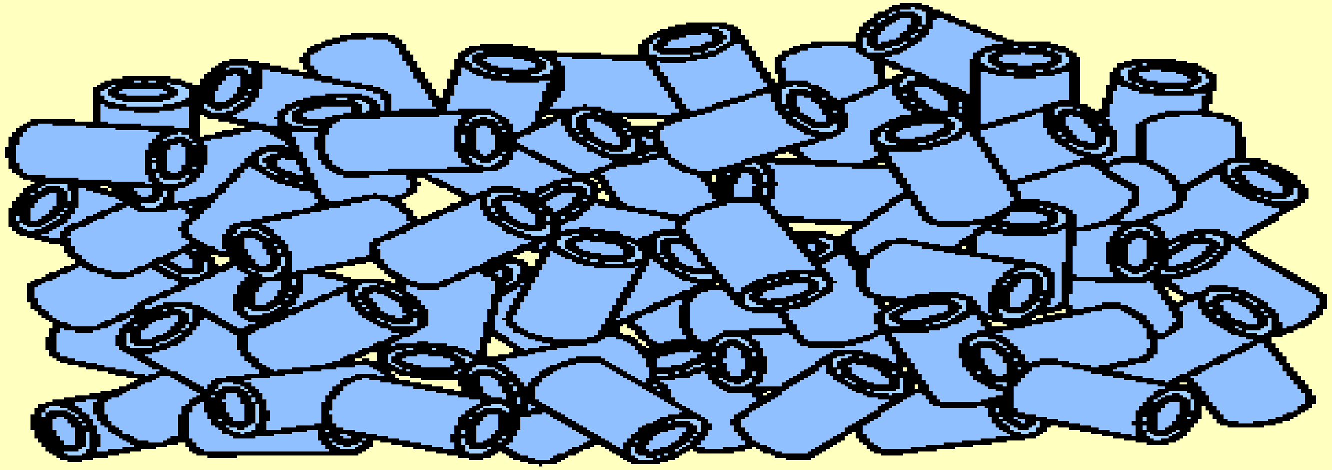
Fourth Generation (Raschig Super-Ring)

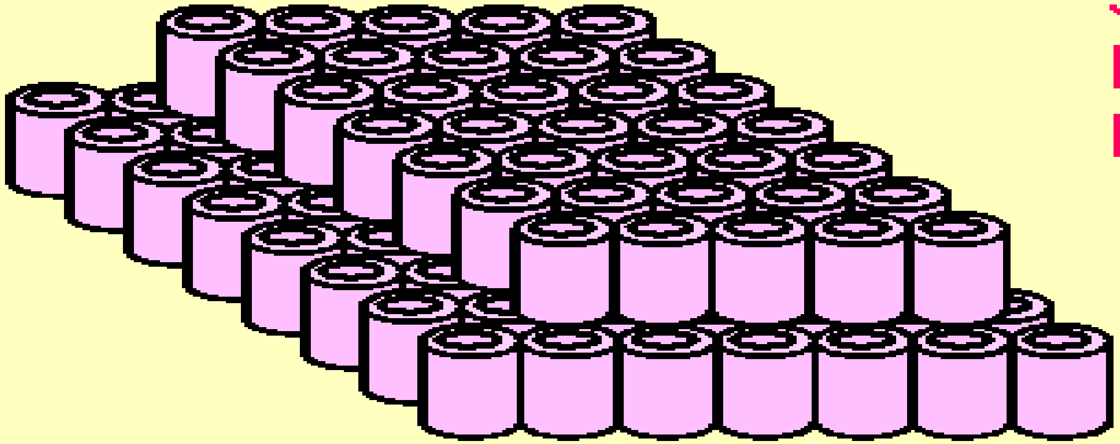
late 1990s until present

- lower pressure drop and better mass transfer efficiency




Raschig ring
Berl saddle
Pall ring
Intalox saddle

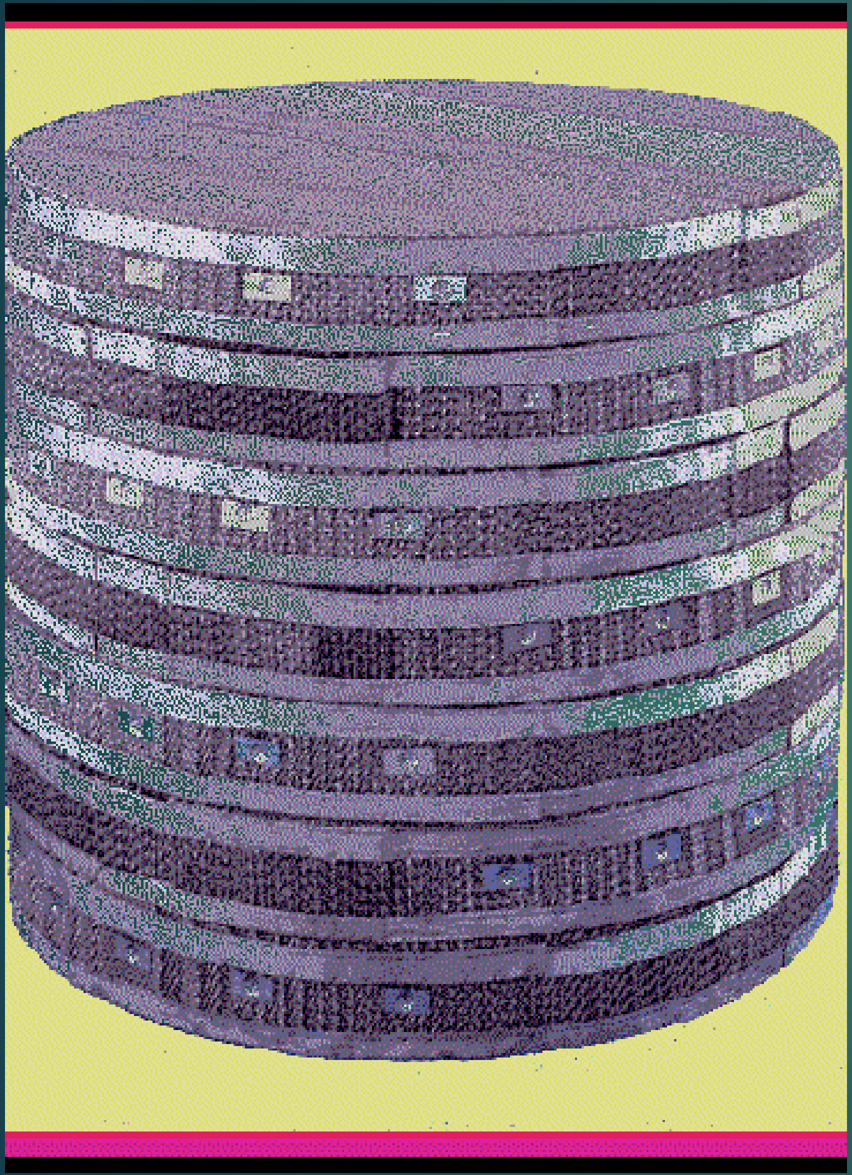

Randomly-packed Raschig Rings

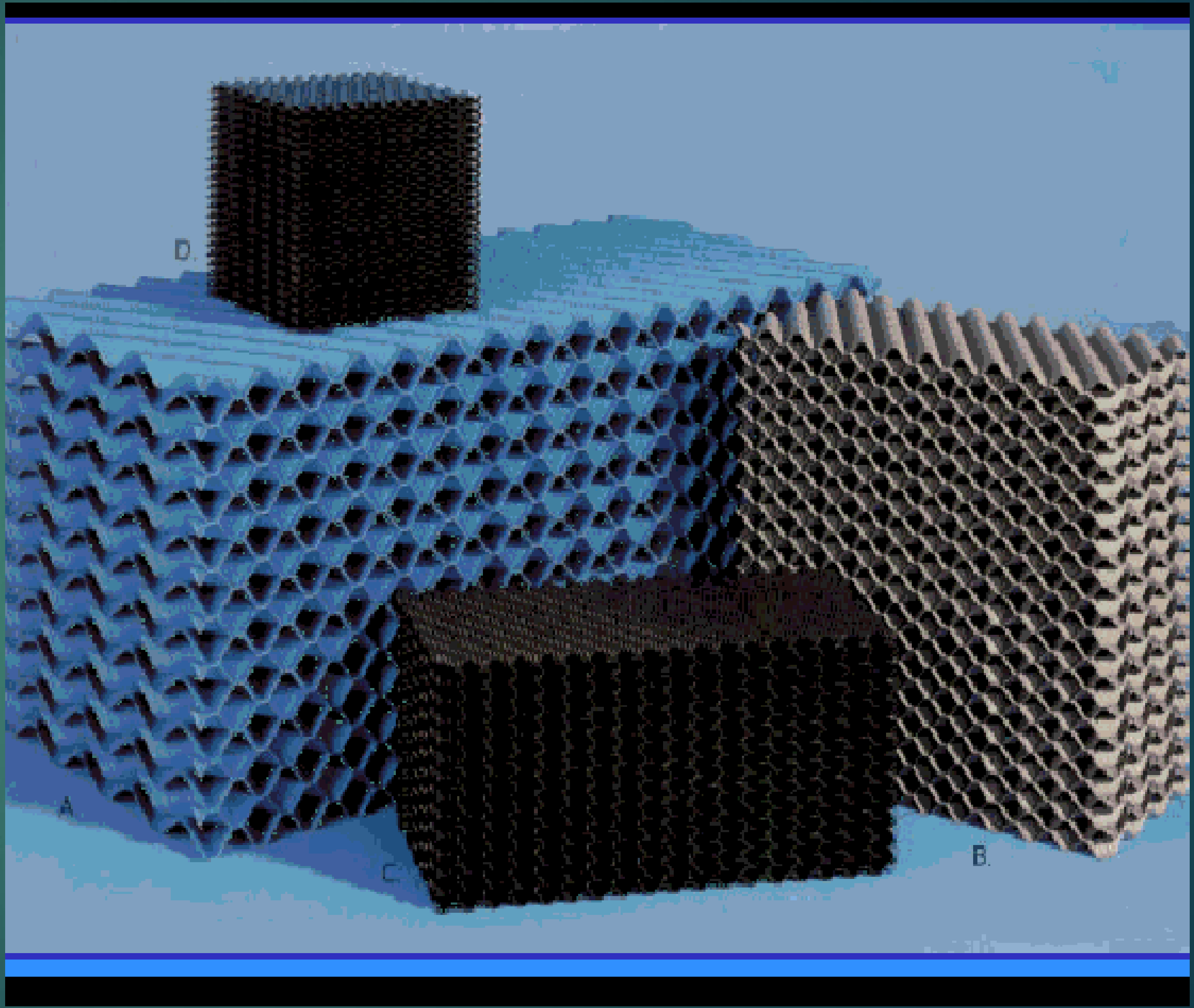

Stacked Raschig Rings


PEC

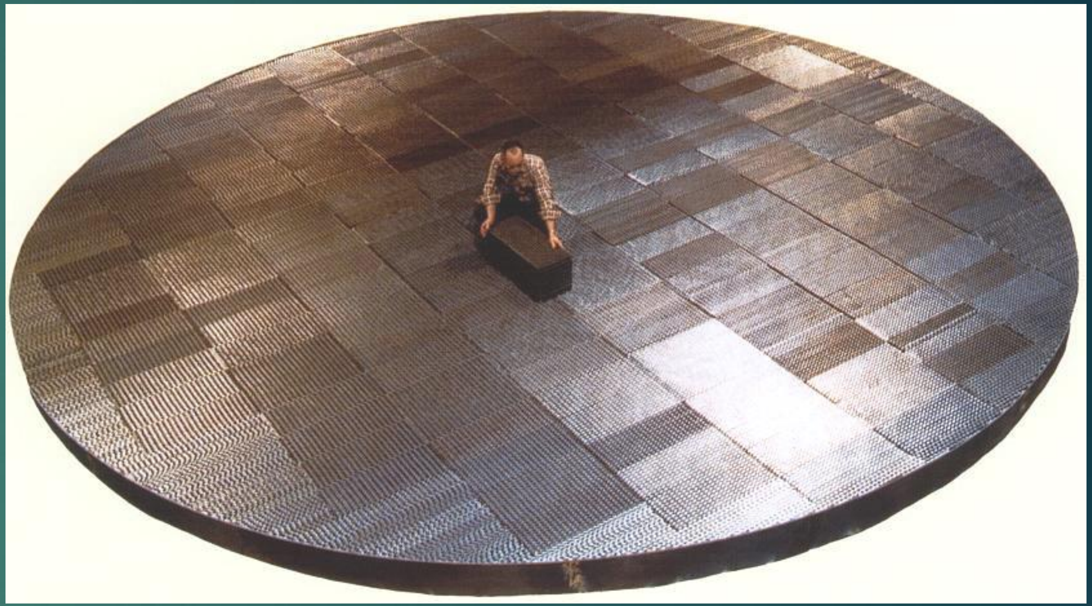
Structured Packing

- Structured packing are considerably more expensive per unit volume than random packing. They come with different sizes and are neatly stacked in the column. Structure packing usually offer:
  - less pressure drop and
  - have higher efficiency and capacity than random packing.




D.
A
C
B.

Structured packing of corrugated metal sheets



Fitting structured packing elements Flexipac™ to a large-diameter tower

Structured packings Mellapak™ made of metal and plastic

Conditions favoring packed columns:

- Small-diameter Columns (Less Than 0.6m)
- More Choices In Materials Of Construction For Packings Especially In Corrosive Service (E.G. Plastic, Ceramic, Metal Alloys)
- Lower Pressure Drop (Important In Vacuum Distillation)
- Less Liquid Entrainment · Low Liquid Hold-up, Especially Suitable For Thermally Sensitive Material
- Foaming Liquids Can Be Handled More Readily (Less Agitation Of Liquid By The Vapor)

Conditions favoring plate columns:

- Variable Liquid And/Or Vapor Loads
- Low Liquid Rates · Large Number Of Stages And/Or Diameter
- High Liquid Residence Time
- Dirty Service (Plate Columns Are Easier To Clean)
- Presence Of Thermal Or Mechanical Stress Due To Large Temperature Changes Which Might Lead To Cracked Packings
- Exotherms Requiring Cooling Coils Inside Column

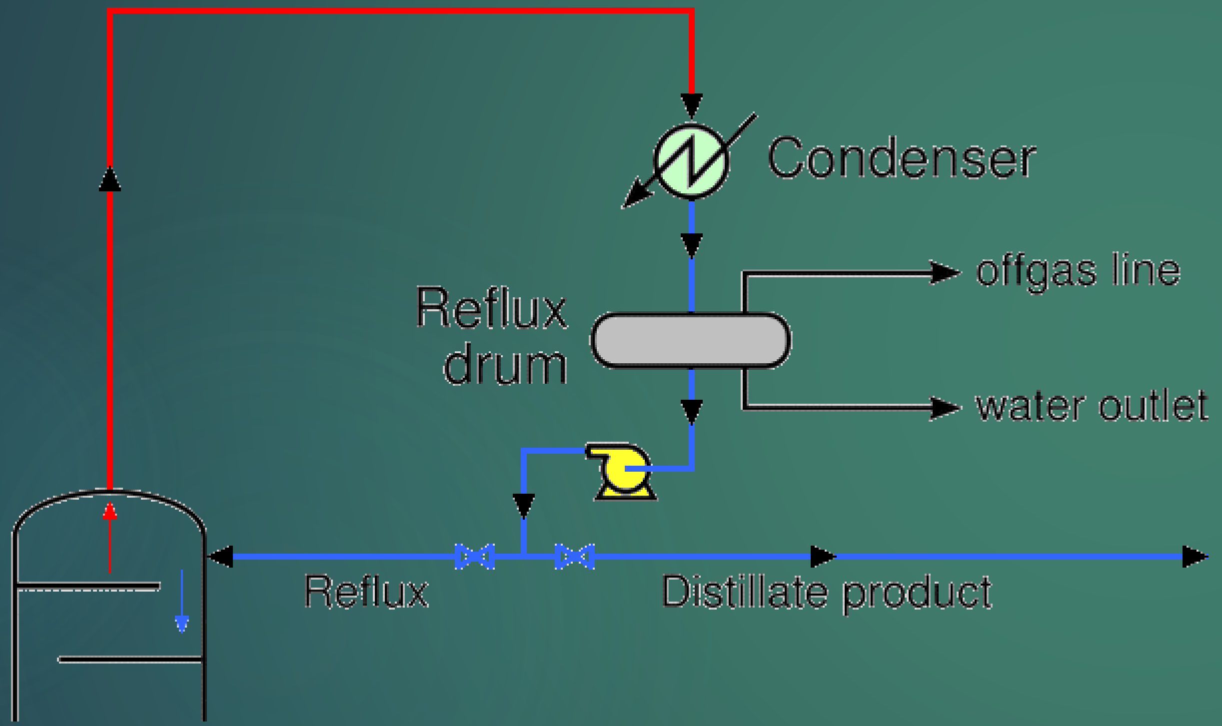
Reflux & Reboilers

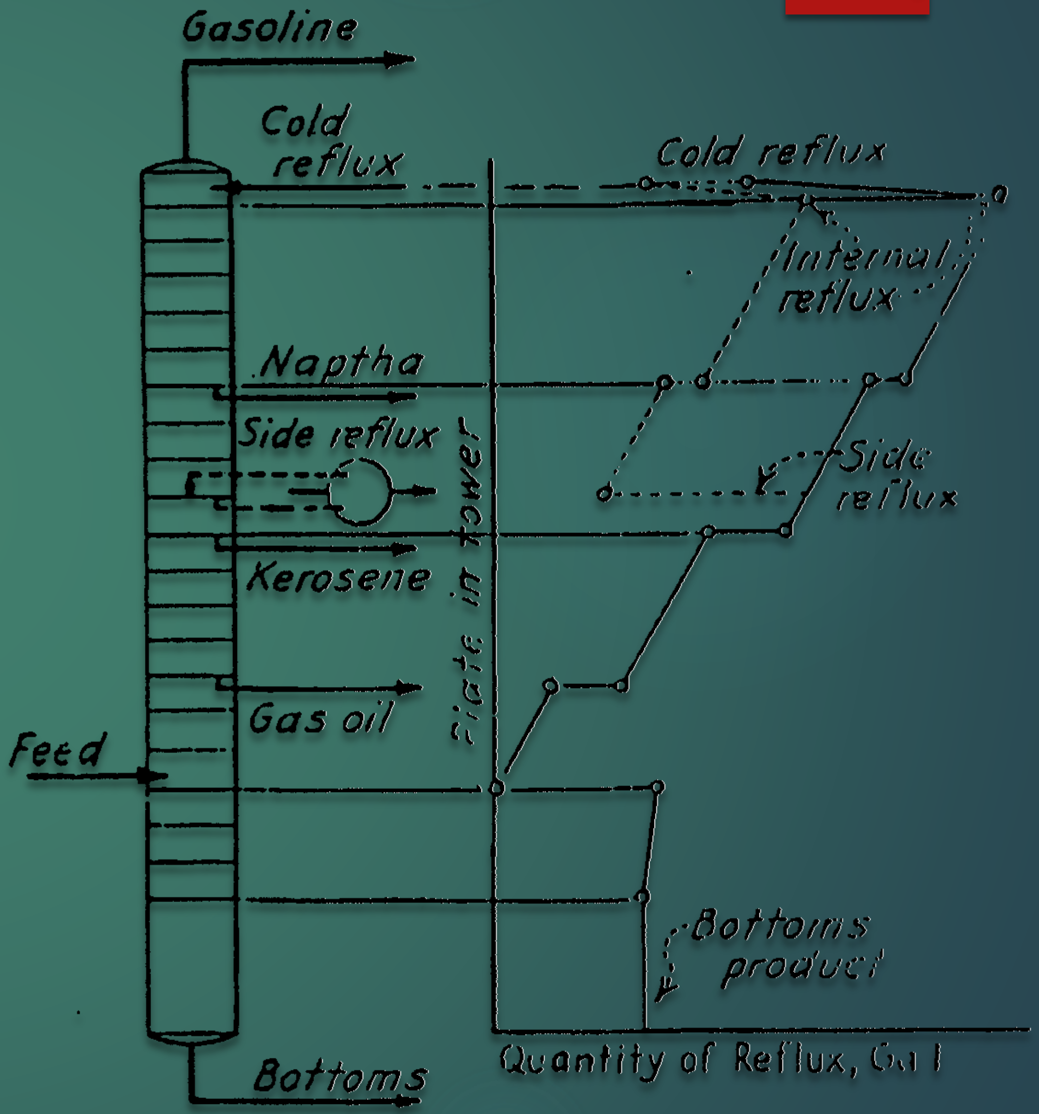
Reflux & Reboilers

Reflux

- The word reflux is defined as "flowing back“
- Applying it to distillation tower, reflux is the liquid flowing back down the tower from each successive stage

Reflux


Condenser
Reflux
drum
offgas line
water outlet
Reflux
Distillate product


Gasoline
Cold
reflux
Cold reflux
Internal
reflux
Naptha
Side reflux
Side
reflux
Kerosene
Gas oil
Feed
Bottoms
product
Bottoms
Quantity of Reflux,

Types of Reflux

Cold Reflux

Cold reflux is defined as 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 required to raise its temperature from reflux drum temperature to the temperature at the top of the tower

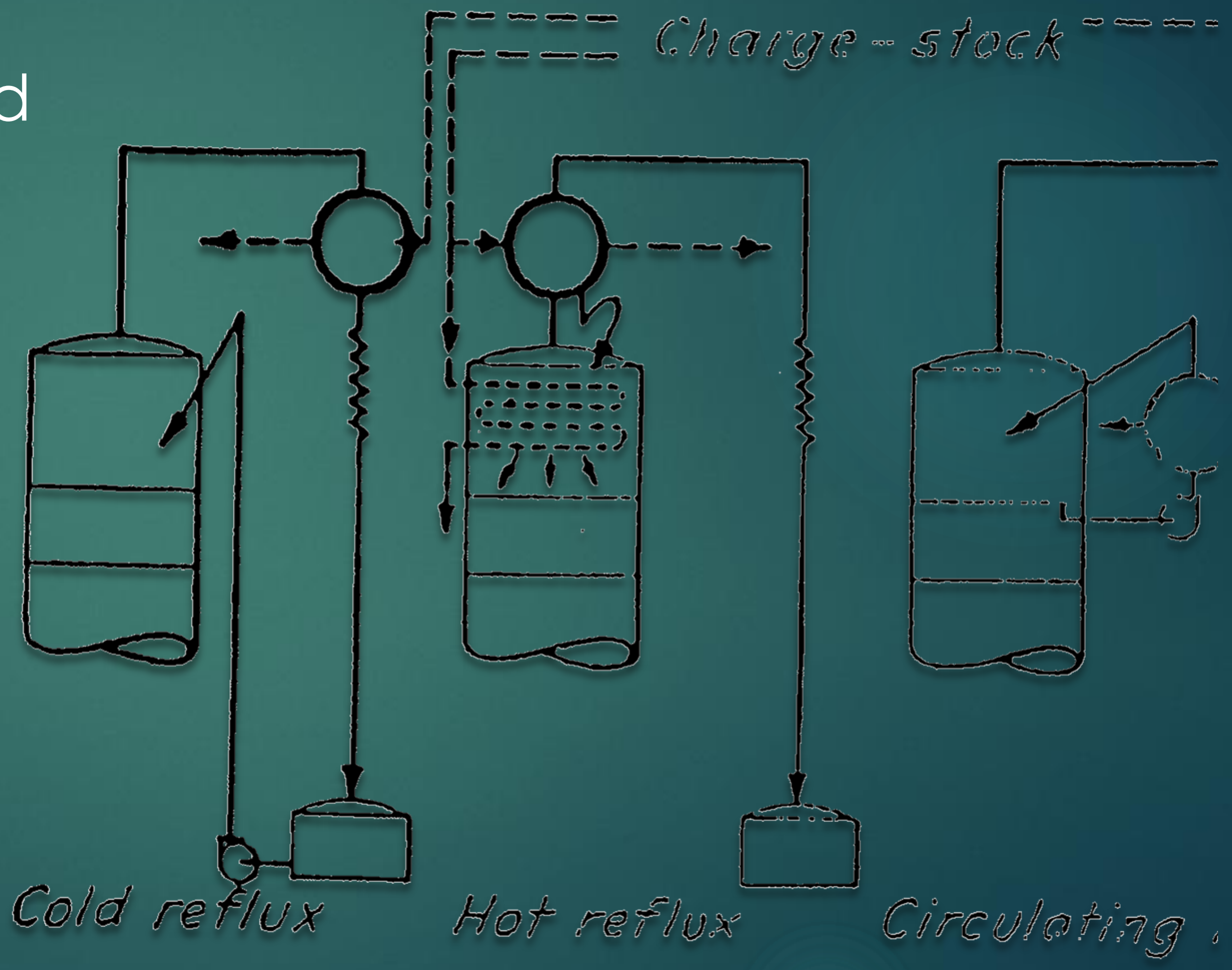
A constant quantity of reflux is recirculated from the reflux drum into the top of the tower

It is vaporized and condensed and then returns in like quantity to the 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

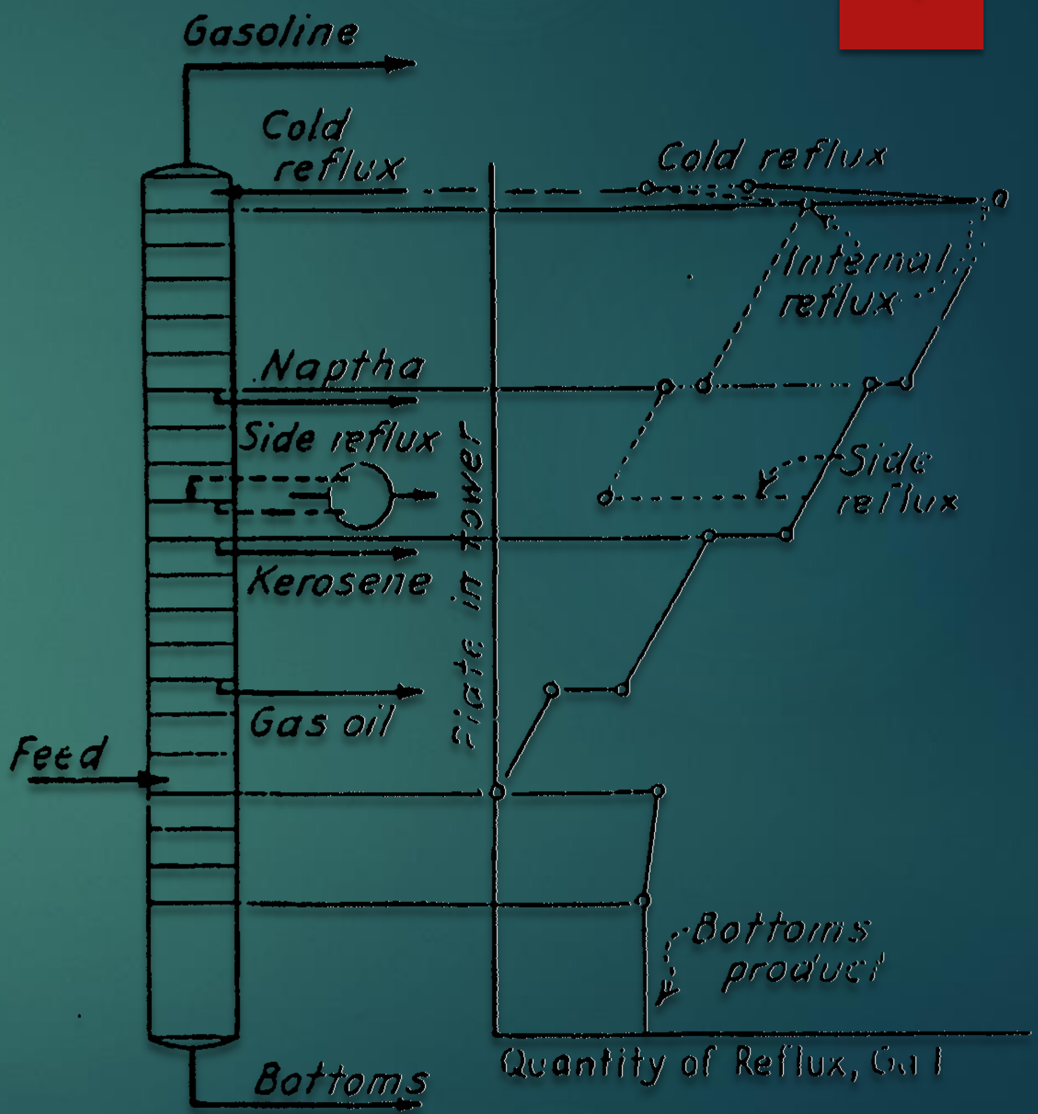
- It can remove the latent heat because no difference in temperature is involved.



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

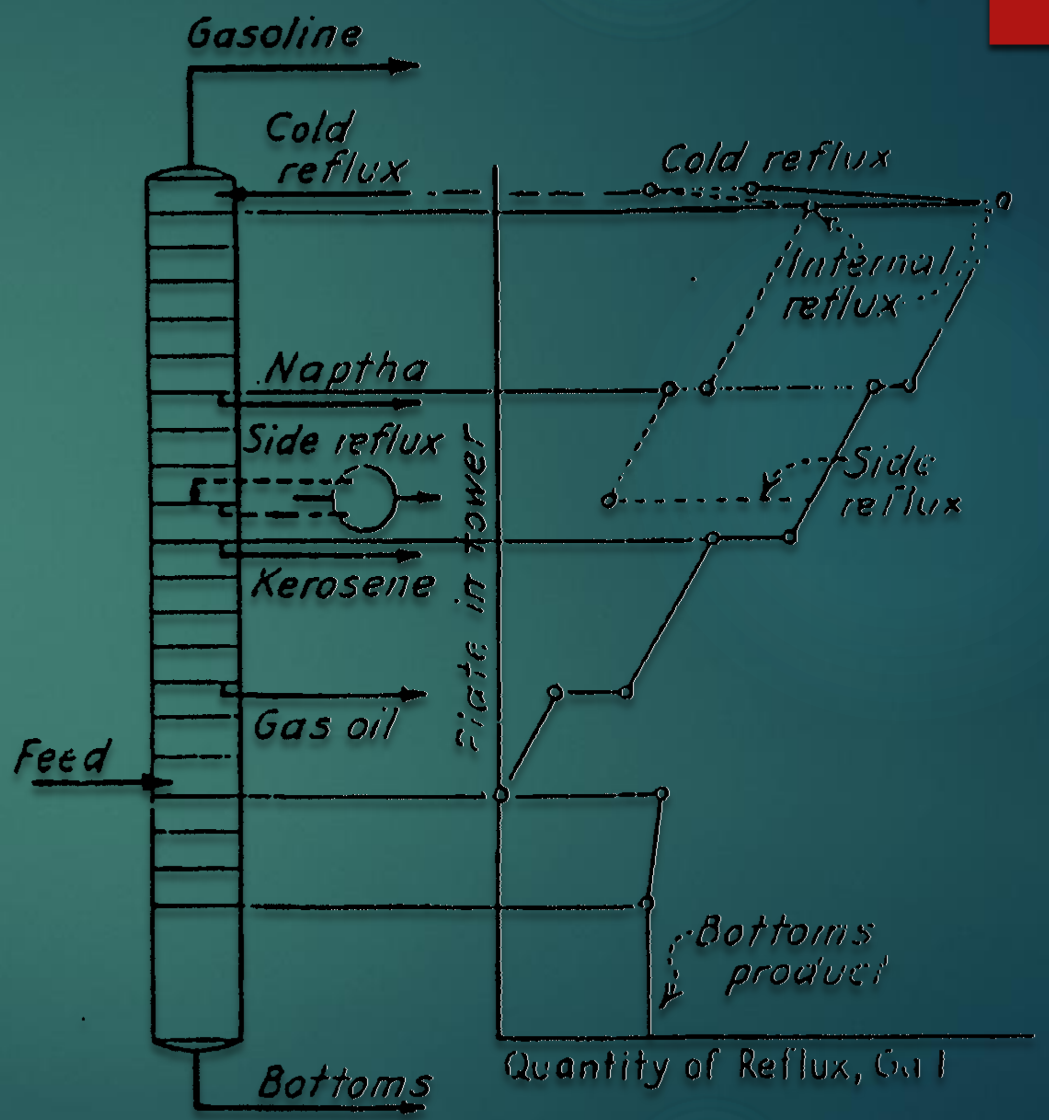
It also capable of removing the latent heat only because no difference in temperature is involved.



Circulating Reflux

- It is also 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



Reflux Ratio

It is defined as the amount of actual reflux divided by the amount of top product

It is denoted by R which equals L/D

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

Two points to consider

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

Total Reflux

- Total reflux is the conclusion when all the condensate 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
2. Testing of the tower

Minimum Reflux

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

This sets the minimum possible reflux ratio for the specified separation

Optimum Reflux Ration

Practical reflux ratio will lie between

The **minimum** for the specified separation and **Total** reflux

The optimum value will be the one at which the specified separation is achieved at the lowest annual cost

For many systems, the optimum value of reflux ratio will lie between

1.2 to 1.5 times the minimum reflux ratio

Reboilers

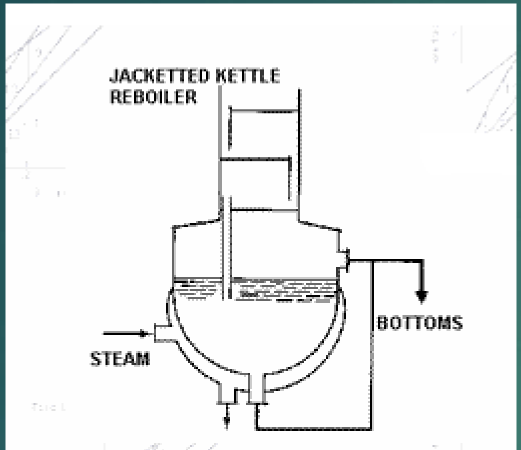
In all distillations processes. Heat been added by

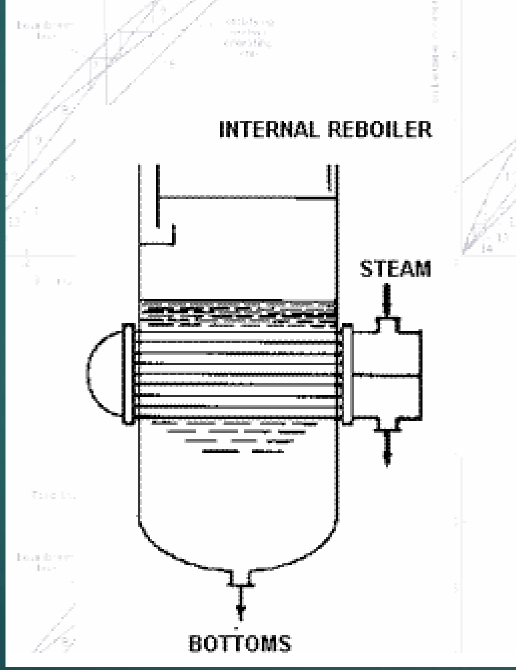
- Means the feed
- Means of a reboiler

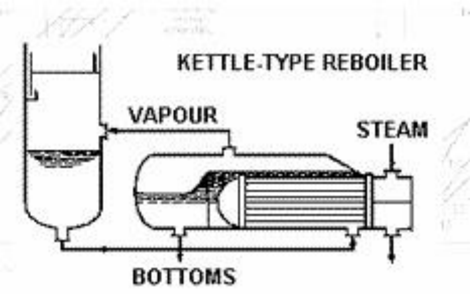
Reboilers

- The Reboiler is a heat exchanger through which the bottom liquids circulate
- 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

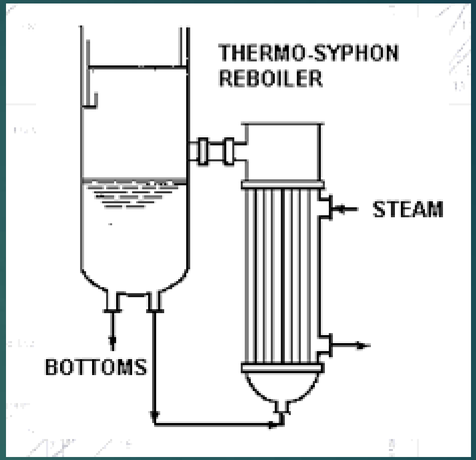
COLUMN REBOILERS







Tube bundle



Tubesheet

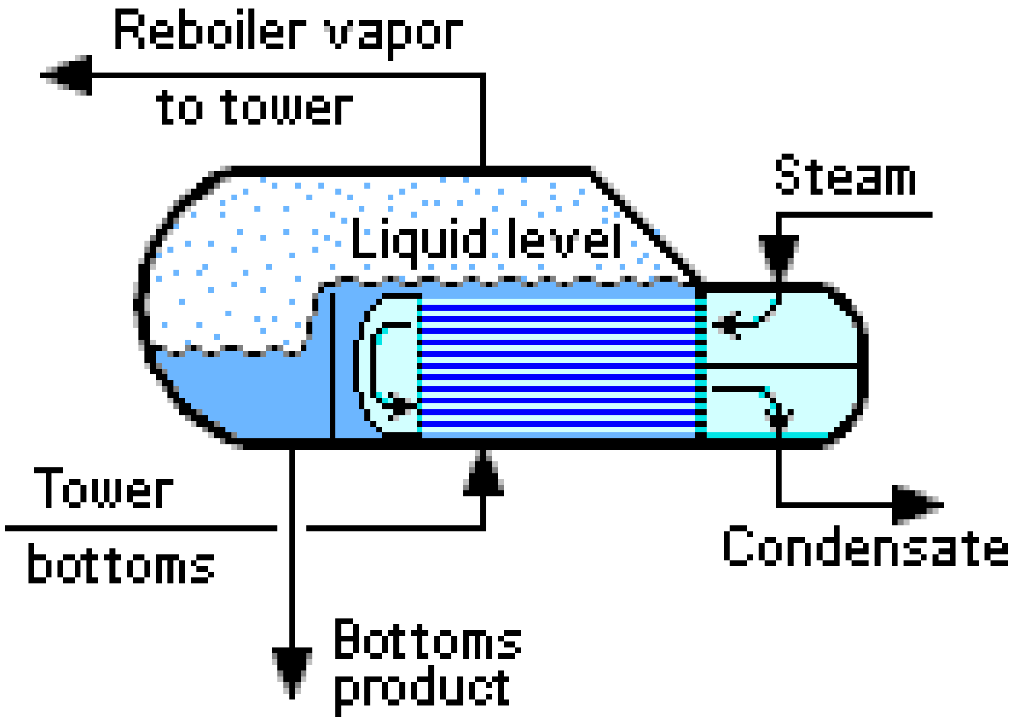
Types of reboilers

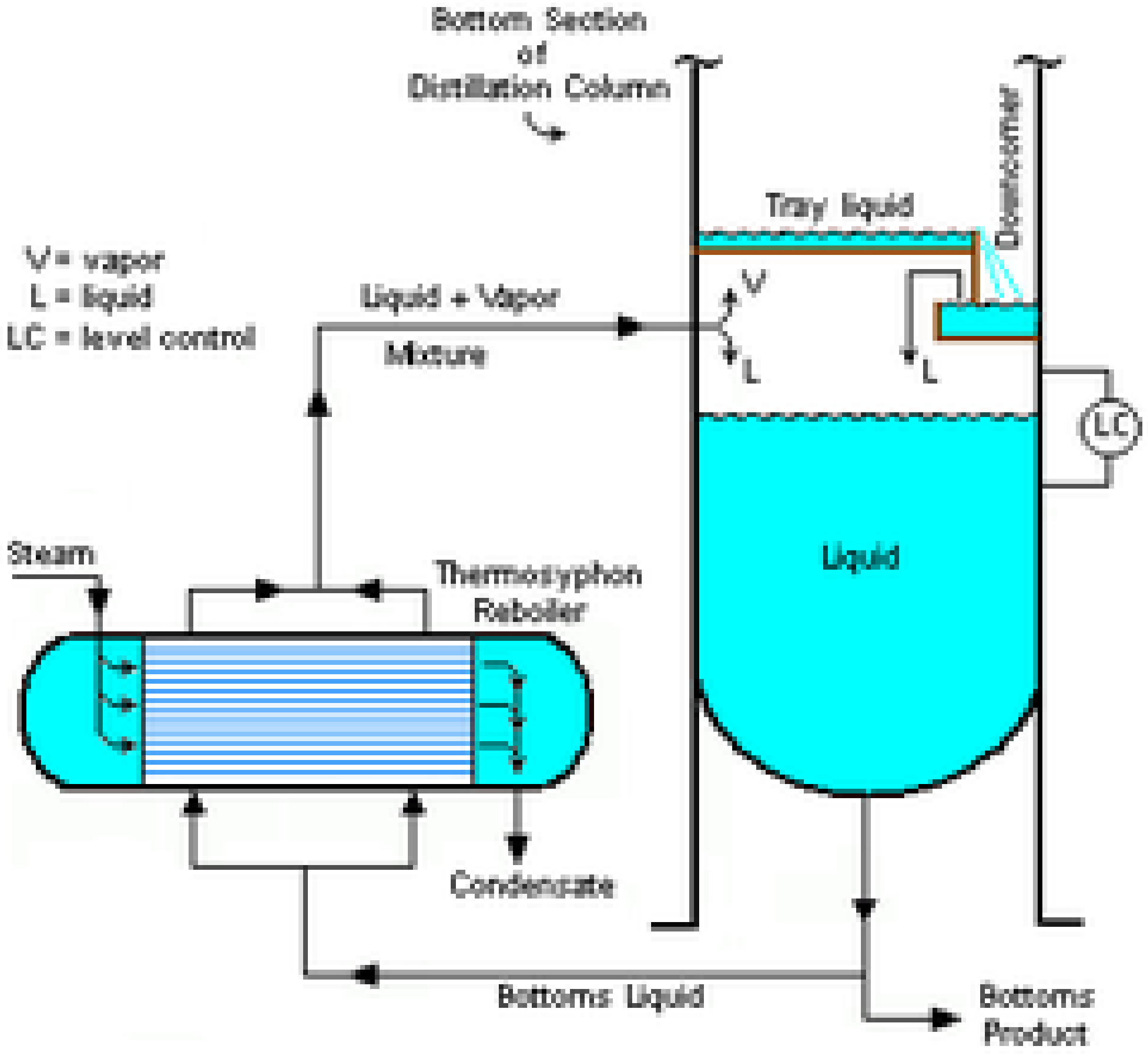
- The most critical element of reboiler design is the **selection of the proper type of reboiler** for a specific service.
- Most reboilers are of the shell and tube heat exchanger type and normally steam is used as the heat source in such reboilers.
- However, other heat transfer fluids like hot oil or Dowtherm (TM) may be used.
- Fuel-fired furnaces may also be used as reboilers in some cases.

Factors influence reboiler type selection

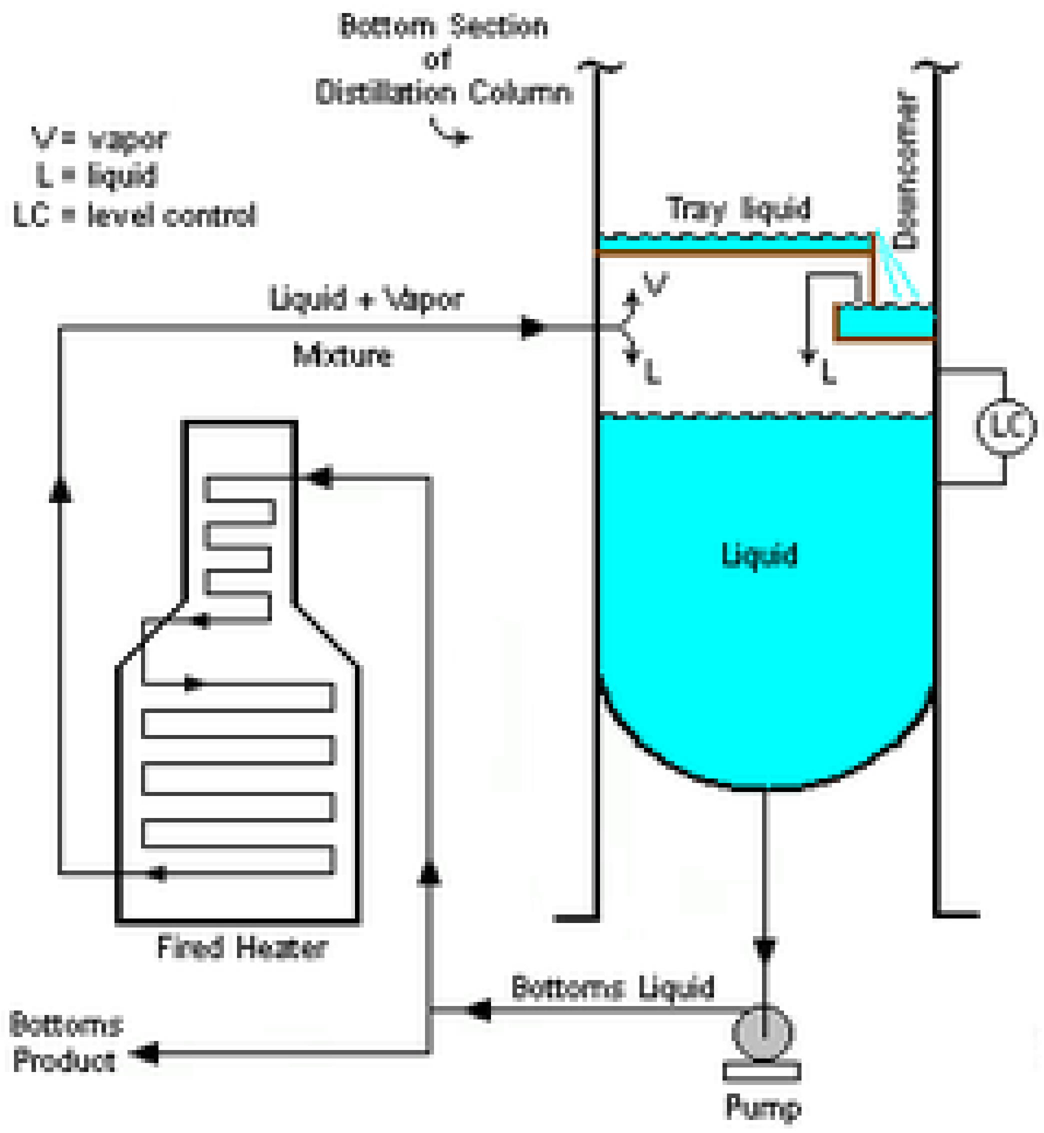
- Plot space available
- Total duty required
- Fraction of tower liquid traffic vaporized
- Fouling tendency
- Temperature approach available
- Temperature approach required

Kettle reboilers





Thermosyphon reboilers

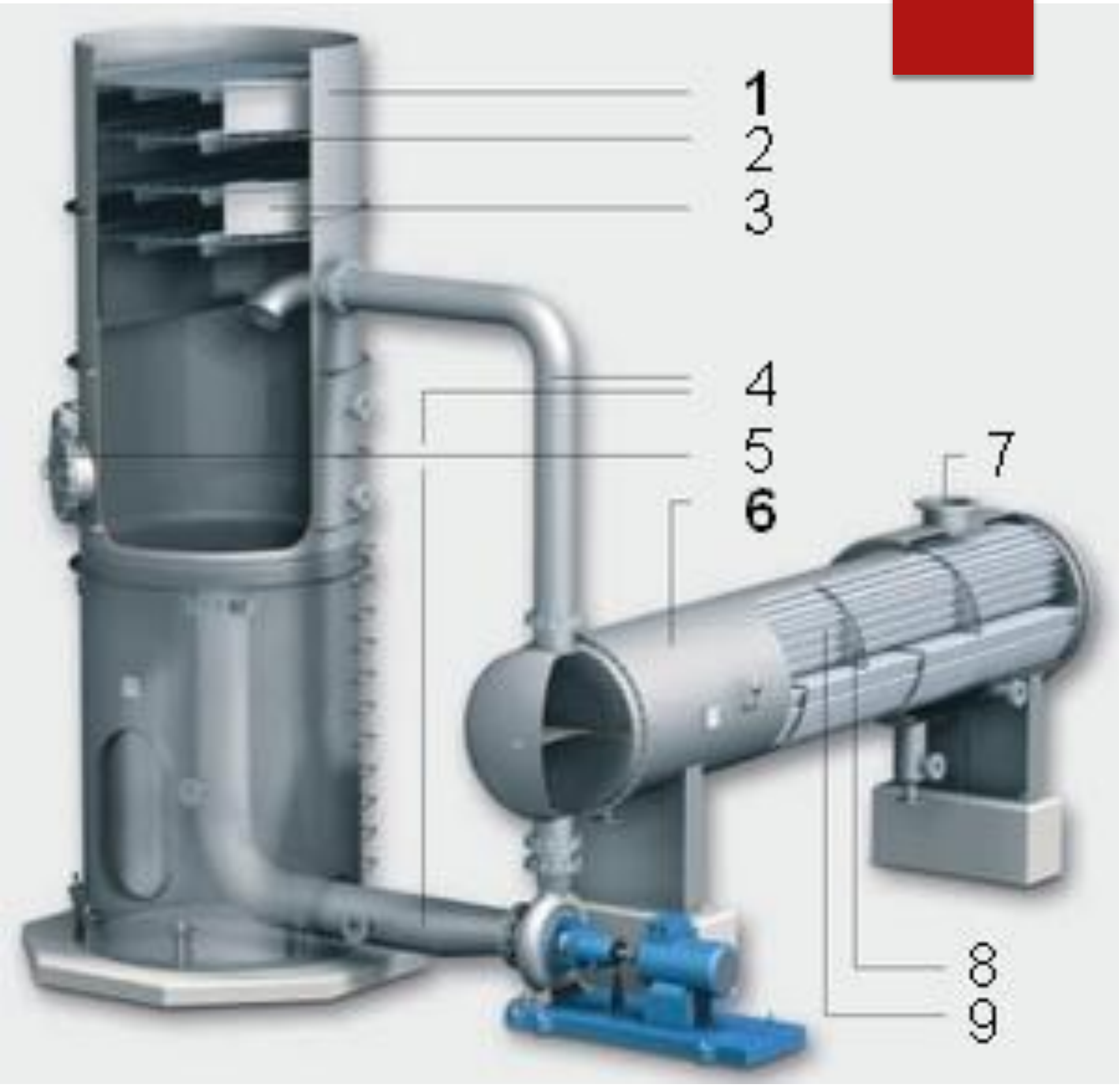


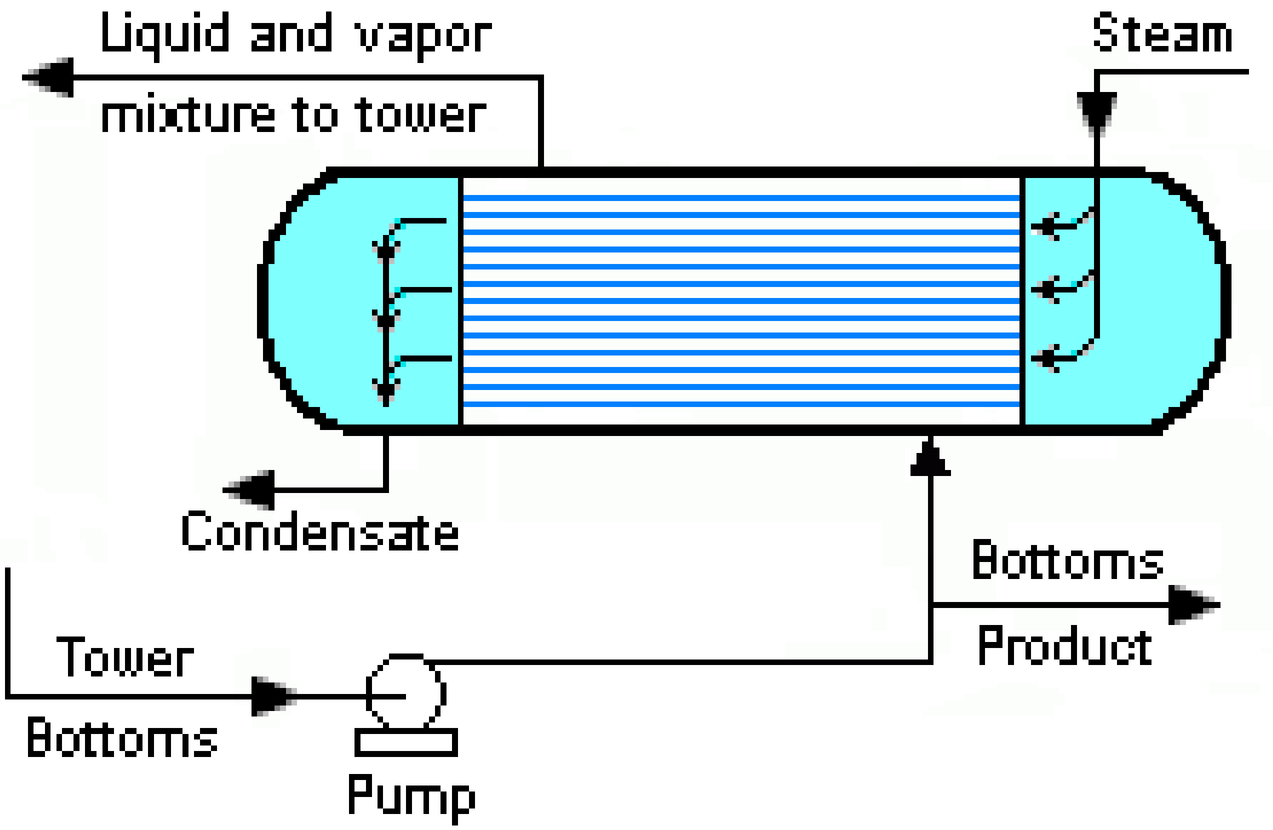
Fired reboiler

Forced circulation reboilers

- Forced circulation reboilers are used for reboiler duties where viscous and/or heavily contaminated media are to be expected in the bottom product.
- High liquid velocities in the tubes and the resulting shearing forces ensure that this type of heat exchanger is operated within its optimum performance range, while keeping fouling to a minimum. Pump selection influences performance and efficiency.
- Forced circulation reboilers can be designed for either horizontal or vertical installation.

- 1 = Column
2 = Trays
3 = Downcomer
4 = Reboiling circulation line
5 = Manhole
6 = Forced circulation reboiler
7 = Steam inlet
8 = Baffles
9 = Heating tubes




Liquid and vapor
mixture to tower
Steam
Condensate
Bottoms
Product
Tower
Bottoms
Pump

QUESTION (1)

- Reflux Rate Changing

- Suppose the reflux rate is increased from 1,000 to 1,200 barrels per hour, and the other tower operating conditions are held constant which of the following will occur

- Lighter overhead, bottom, and side draw products.
- Heavier overhead and side draw products.
- Heavier bottom product.
- More overhead product.

- This extra reflux flowing down the tower causes the temperature on each tray to decrease

- Some of the heavier hydrocarbons in the upward flowing vapors will now condense and fall back down the tower
- The extra reflux flowing down the tower reduces the temperature of the liquid at the bottom of the column. When the bottom temperature decreases, the amount of light material vaporized out of the liquid at the bottom of the tower is decreased
- Because fewer vapors are now going overhead, the amount of top product formed is decreased, or less. Lighter overhead, bottom, and side draw products are produced by increasing the reflux rate

QUESTION (2)

- 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, and a higher tower temperature mean heavier products. So overhead, bottom, and side draw products become heavier. The amount of overhead product produced increases and the amount of bottom product formed decreases

Operating Range

Flooding

- Occurs when the pressure drop across a tray is so high that the liquid cannot flow down the tower as fast as required.
- The pressure drop across the tray increases to very high values, and the tray efficiency drops markedly.
- When the froth and foam in the down comer back up to the tray above and begin accumulating on this tray.

Flooding

- Flooding is brought about by excessive vapor flow, causing liquid to be entrained in the vapor up the column. The increased pressure from excessive vapor also backs up the liquid in the downcomer, causing an increase in liquid holdup on the plate above. Depending on the degree of flooding, the maximum capacity of the column may be severely reduced. Flooding is detected by sharp increases in column differential pressure and significant decrease in separation efficiency.

Flooding

- Entrainment Flooding
  - For a constant liquid rate, increasing the gas rate results eventually in excessive entrainment and flooding. At the flood point it is difficult to obtain net downward flow of liquid, and any liquid fed to the column is carried out with the overhead gas. Furthermore, the column inventory of liquid increases, pressure drop across the column becomes quite large, and control becomes difficult.
- Downflow Flooding
  - Flooding may also be brought on by increasing the liquid rate while holding the gas rate constant. Excessive liquid flow can overtax the capacity of downcomers or other passages, with the ultimate result of increased liquid inventory, increased pressure drop, and the other characteristics of a flooded column.

Weeping/ Dumping

- This phenomenon is caused by low vapor flow. The pressure exerted by the vapor is insufficient to hold up the liquid on the tray. Therefore, liquid starts to leak through perforations. Excessive weeping will lead to dumping.

- That is the liquid on all trays will crash (dump) through to the base of the column (via a domino effect) and the column will have to be re-started. Weeping is indicated by a sharp pressure drop in the column and reduced separation efficiency.

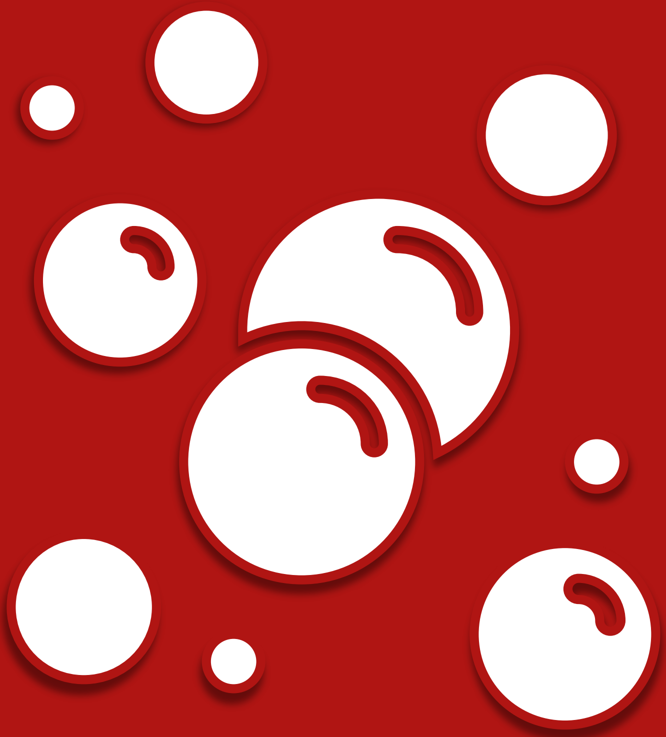
Weeping/ Dumping

- Occurs at:
  - High liquid rates, and
  - Low vapor loads.

- Some of slots or holes will dump liquid instead of passing vapor, resulting in poor tray efficiency.

- For towers with conventional down comers, dumping usually occurs at the upstream raw of caps or holes, where the liquid has the largest head and kinetic energy.

Foaming



- Foaming refers to the expansion of liquid due to passage of vapor or gas.
- Although it provides high interfacial liquid-vapor contact, excessive foaming often leads to liquid buildup on trays. In some cases, foaming may be so bad that the foam mixes with liquid on the tray above.
- Whether foaming will occur depends primarily on physical properties of the liquid mixtures but is sometimes due to tray designs and condition.
- Whatever the cause, separation efficiency is always reduced.

Coning

- Occurs at low liquid rate or seals.
- The vapor pushes the liquid back from the slots or holes and passes upward with poor liquid contact.
- This causes poor tray efficiency.

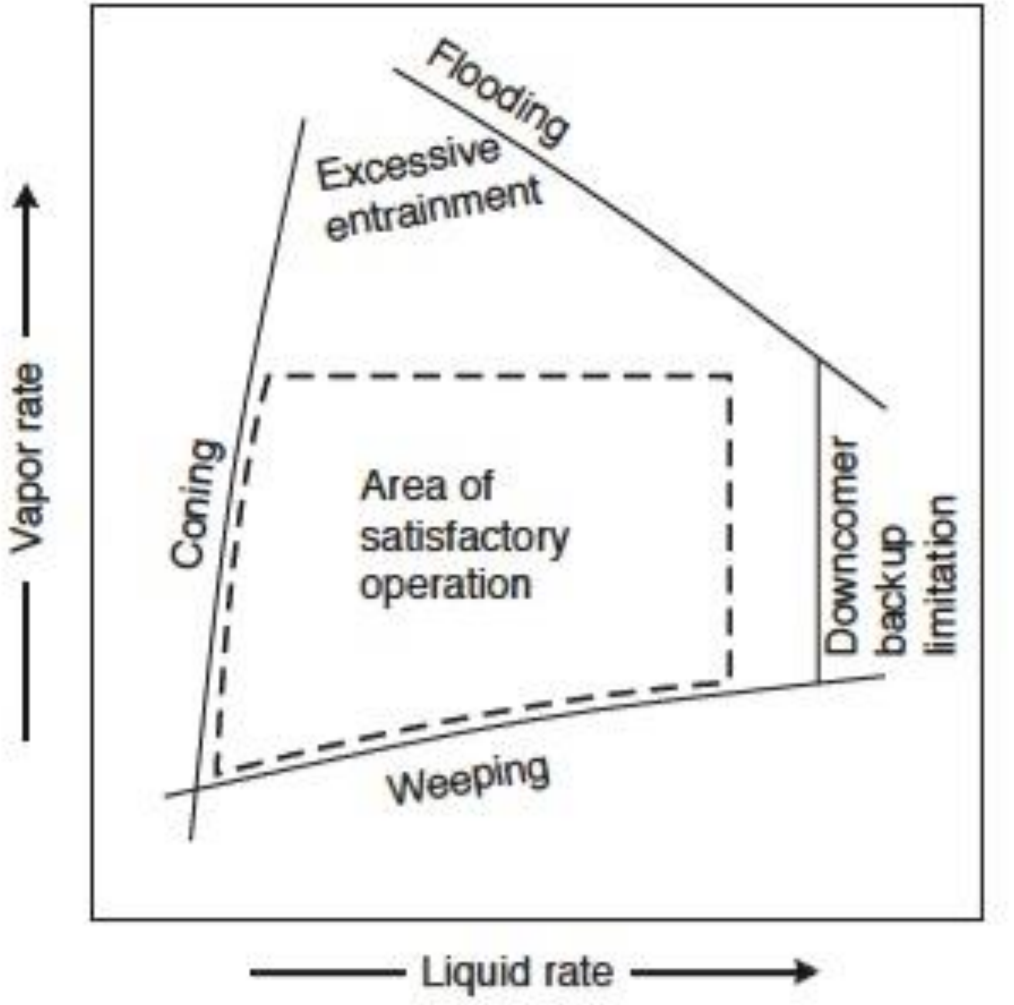
Puking

- Usually occurs at:
  - High liquid rate and
  - Low gas rate.
- At high liquid rate the liquid level on each tray will rise.
- As the level rises, the flow of gas up the tower is restricted.
- The gas pressure in the bottom of the tower will begin to rise.
- It will reach the point that a surge of a gas will suddenly move up the tower with enough velocity to carry the liquid with it.

Puking

- Reducing the liquid flow rate will usually eliminate puking.
- Puking should not be confused with carryover.
- Puking occurs almost instantaneously.
- Furthermore, if the liquid rate is not reduced, the tower will puke again when the liquid stacks up.
- Carryover is usually caused by a high vapor flow rate (It happens continuously, whereas puking is an intermittent thing).

Satisfactory operation will only be achieved over a limited range of vapor and liquid flow rates.



Operating Range

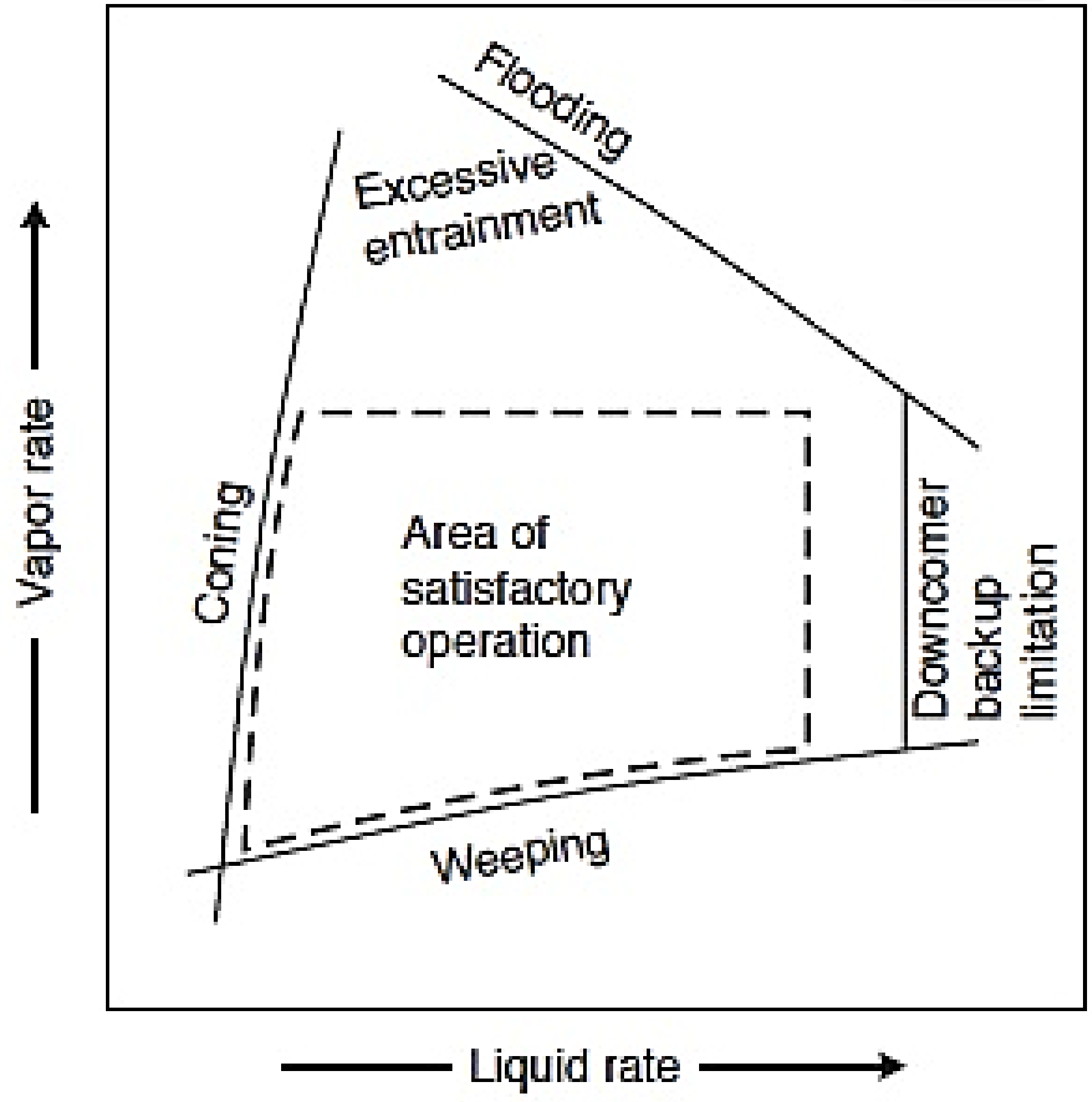
The upper limit to vapor flow is set by the condition of flooding.

At flooding there is:

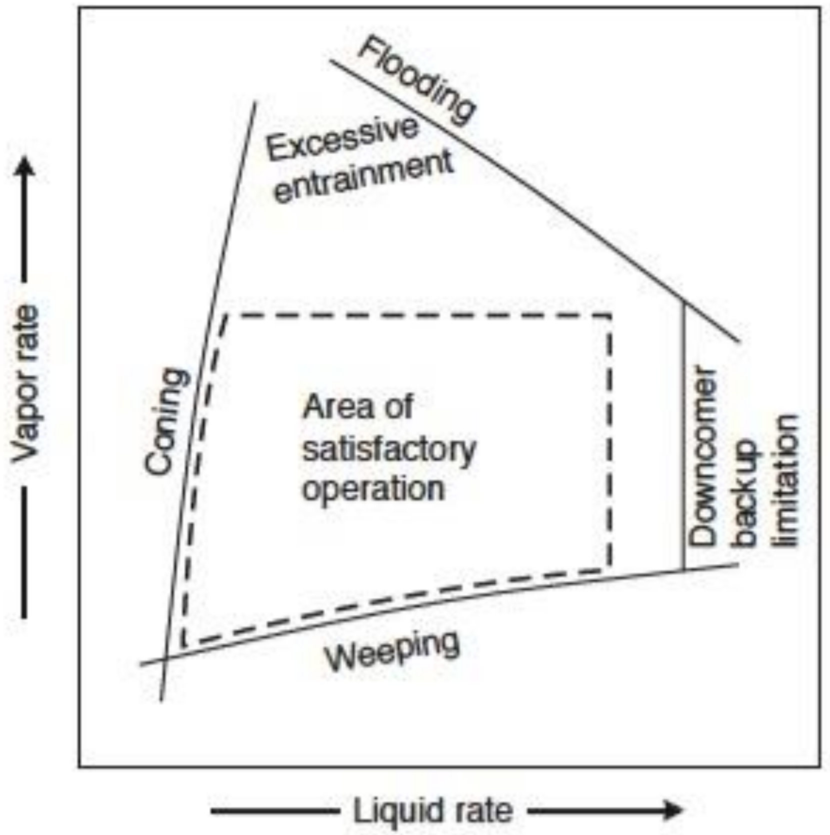
- A sharp drop in plate efficiency and
- Increase in pressure drop.

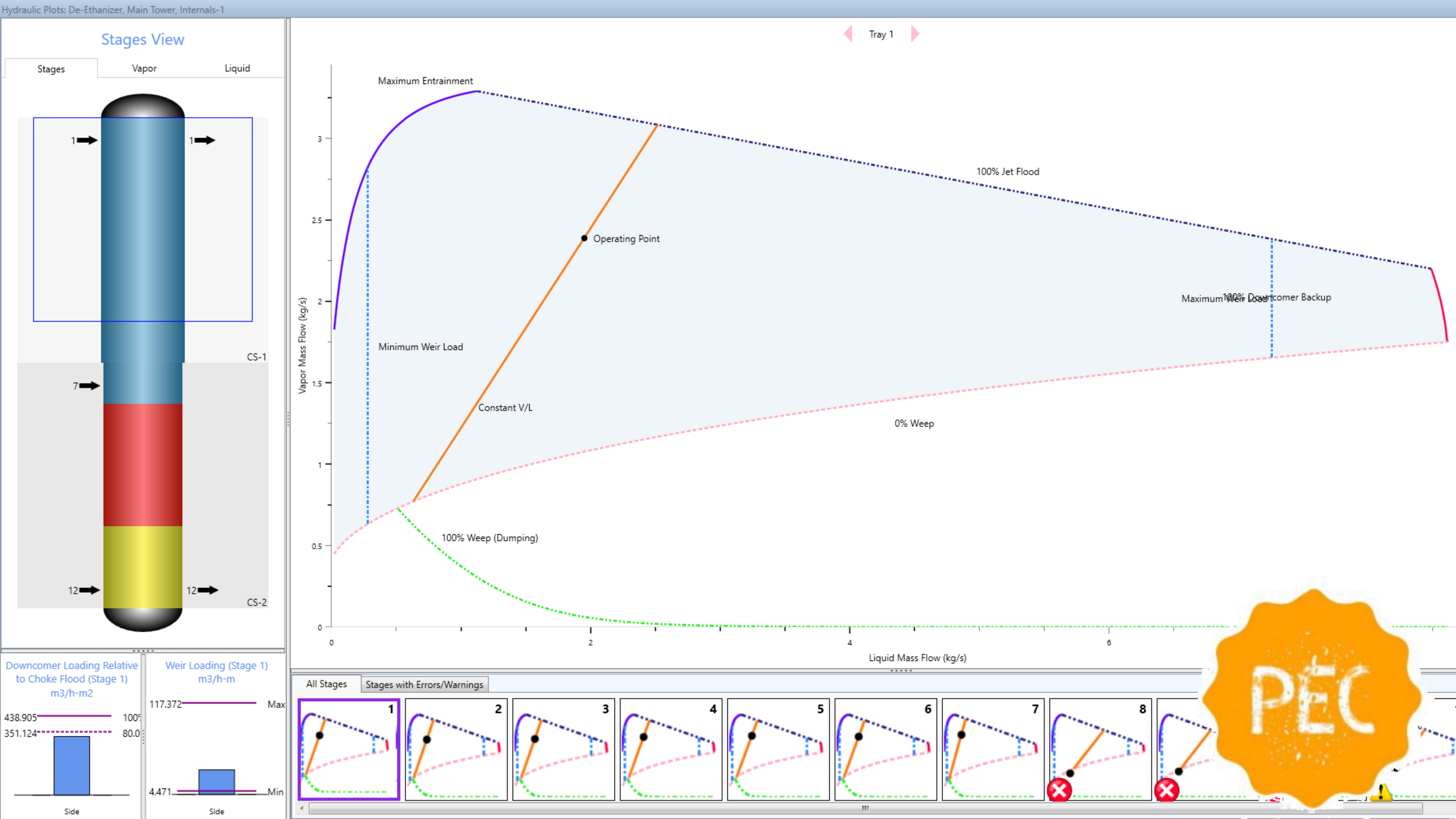
▶Flooding is caused by either:

- Excessive carry over of liquid to the next plate by entrainment, or
- Liquid backing-up in the down comers.



- The lower limit of the vapor flow is set by condition of weeping.
- Weeping occurs when the vapor flow is insufficient to maintain a level of liquid on the plate.
- "Coning" occurs at low liquid rates, and is the term given to the condition where the vapor pushes the liquid back from the holes and jets upward, with poor liquid contact.





Hydraulic Plots: De-Ethanizer, Main Tower, Internals-1
Stages View
Stages
Vapor
Liquid
CS-1
CS-2
Tray 1
Maximum Entrainment
100% Jet Flood
Operating Point
Maximum Weir Load
100% Downcomer Backup
Minimum Weir Load
Constant V/L
0% Weep
100% Weep (Dumping)
Vapor Mass Flow (kg/s)
Liquid Mass Flow (kg/s)
Downcomer Loading Relative to Choke Flood (Stage 1) m3/h-m2
438.905
351.124
Side
Weir Loading (Stage 1) m3/h-m
117.372
Max
4.471
Min
Side
All Stages
Stages with Errors/Warnings
PEC

Thank You

PEC