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THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Mass Transfer-I

Mass Transfer Equipment



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Mass Transfer Equipment

Equipment for gas-liquid operations

Common range of values of mass transfer parameters in commercial gas- liquid operations

Contacting equipment	Superficial gas velocity (m/s at normal condition)	Mass transfer parameters		
		$k_L \times 10^4$ (m/s)	$k_y \times 10^3$ (kmol/s.m ² .Δy)	\bar{a} (m ² /m ³)
Sieve tray	0.02–0.5	1–20	0.5–6.0	100–200
Packed column	0.1–1.2	1–20	0.03–2.0	10–350
Bubble column	0.1–0.3	0.4–3.0	0.5–2.0	50–600
Spray column	0.05–3.0	0.7–1.5	0.5–2.0	10–100
Mechanically agitated contactor	0.05–3.0	0.3 – 4.0		100–1000

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- The major gas liquid operations include absorption, stripping ,distillation, humidification and dehumidification.
- The main purpose of the equipment for interphase mass transfer to provide intimate contact of the immiscible phases.
- The mass transfer equipment operates in the batch or in continuous mode.
- For small production units batch operation is preferred/used.
- A high degree of turbulent mixing is desired/created to disperse one phase into other to provide a large interfacial area of contact which lead to increase the mass transfer coefficient.
- Mass transfer equipment are customarily designed and fabricated as per the specific requirements.

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- The gas is dispersed in liquid in form of bubbles.
- The liquid is dispersed in the form of droplets or discontinuous films in a continuous gas phase.
- Some times both gas and liquid phases are continuous.
- Tray and packed columns are most widely used for gas-liquid contacting for gas absorption, stripping, distillation.

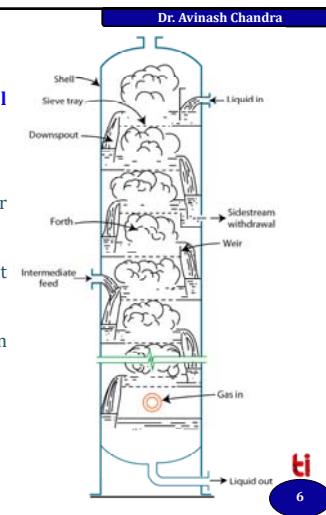
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Gas Dispersed	Liquid dispersed
➤ Tray/plate columns	➤ Venturi scrubber
➤ Bubble columns	➤ Wetted wall column
➤ Sieve-plate columns	➤ Spray towers
➤ Valve-tray columns	➤ Packed towers
➤ Agitated vessels	
➤ Sparged vessel	

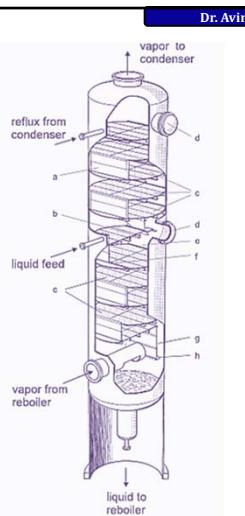
Tray / Plate Column

A tray tower primarily consists of a vertical cylindrical shell and a set of tower internals include:

- Trays or plates on which the gas liquid contact occurs.
- Arrangements for flow of the liquid from one tray to the lower one through the down comer
- Plate towers exhibit larger pressure drops and liquid holdup at higher gas flow rate.
- Plate columns are normally suitable for fouling liquids or laden with solids.

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6**Cont...****Symbols**

<i>a</i>	Down-comer
<i>b</i>	Tray support
<i>c</i>	Sieve trays
<i>d</i>	Man way
<i>e</i>	Outlet weir
<i>f</i>	Inlet weir
<i>g</i>	Side wall of downcomer
<i>h</i>	Liquid seal
A_{dc}	Active area
A_d	Down-comer area
D_c	Column diameter
$d_{cap,v,h}$	Bubble cap, valve, hole diameter
$H, \Delta z$	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

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Source: A. Mersmann, M. Kind, J. Stichlmair: Thermal Separation Technology. Berlin, Heidelberg: Springer 2011
PPT of Prof. Dr. M. Reippich | Conceptual Design of Distillation, Absorption and Stripping Systems|

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- A tray column primarily consist of a vertical cylindrical shell and a set of 'tower internals' that include
- Tray or plates on which the gas-liquid contact occurs.
- Arrangement for flow of the liquid from one tray to the lower one through the down-comer.
- Inlet and out let nozzles for the two phases.
- In a gas absorption application, the liquid enters the top tray through a nozzle. It impinges on a baffle plate, moves across the tray and flows into the lower through a 'downcomer'.
- Mass transfer from the gas to the liquid phase occurs depending on the direction of the driving force.
- The liquid flows across a tray and then over a 'weir' to enter in to the downcomer.
- The downcomer is a region near the wall, separated by a 'downcomer plate', in which the bubble get disengaged from the liquid.
- The clear liquid flows to the next lower tray.
- Each tray acts as a stage in which the liquid flowing down from the upper tray and the gas flowing up from the lower tray come into contact; the tower as cascade.

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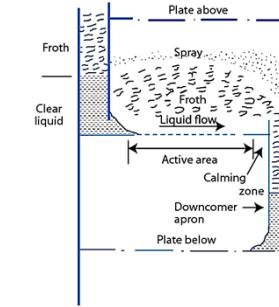
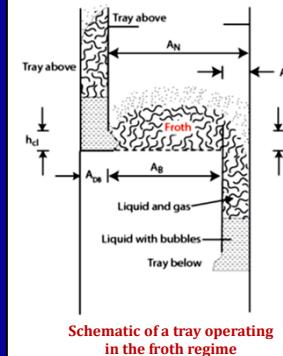
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- A **WEIR** on the tray ensures that there is always some liquid (**HOLDUP**) on the tray and is designed such that the holdup is at a suitable height, e.g. such that the bubble caps are covered by liquid.
- Being lighter, vapour flows up the column and is forced to pass through the liquid, via the openings on each tray. The area allowed for the passage of vapour on each tray is called the **ACTIVE TRAY AREA**.
- **Total tower cross-section area (A_T):** The empty tower inside cross-sectional area without trays or downspouts.
- **Net area (A_N) (also called free area):** The total tower cross-sectional area (A_T) minus the area at the top of the down-comer (A_{Df}). The net area symbolizes the smallest area available for vapor flow in the inter-tray spacing.
- **Bubbling area or active area (A_B):** The total tower cross-sectional area minus sum of the down-comer top area(A_{Df}) and down-comer seal area (A_{DB})and any other nonperforated areas on the tray. The bubbling area represents the area available for vapor flow just above the tray floor.
- **Hole area (A_h):** The total area of the perforations on the tray. The hole area is the smallest area available for vapor/gas passage.

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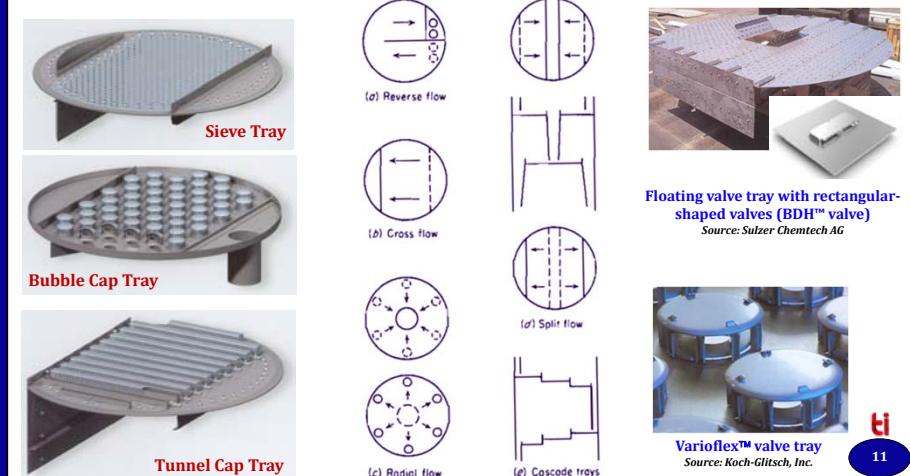
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Classification of plate types based on flow mode- side view shown:
 (a) Cross-flow plate
 (b) Counter-flow plate

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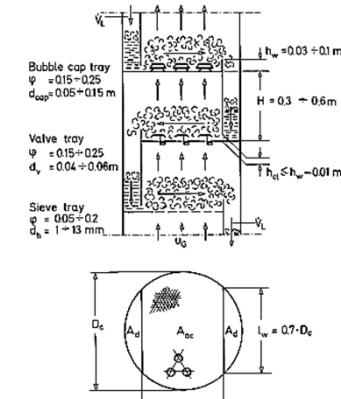
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Tray type and arrangements

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Cont...**Characteristic dimensions of industrial tray designs**

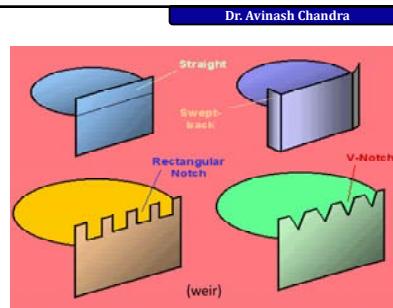
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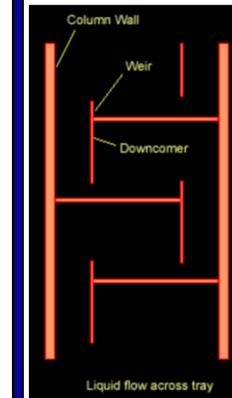
Weir

- The function of a weir is to maintain a desired liquid level on the tray.
- Typical weir height is between 2 to 4 inch.
- Low weirs are frequently used in low pressure column.
- Notched weir are commonly used for low liquid loads.
- The higher the liquid level, the higher the tray pressure drop. Higher liquid level also imply more liquid hold up on the tray, which may be undesirable if the liquid is toxic or hazardous.
- The weir length may vary from 60 to 80% of the tower diameter.



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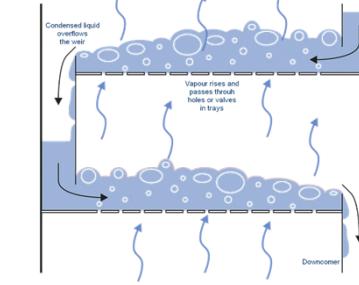
Downcomer



http://www.wermac.org/equipment/distillation_part2.html

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- Downcomer are used to guide liquid flow from an upper tray to a lower tray.
- The liquid, alongwith some dispersed gas or vapour bubbles, overflows the weir and enters the downcomer.
- The Downcomer must provide sufficient residence time for gas-liquid disengagement.
- The 'clear liquid' velocity in the downcomer normally ranges between 0.3 to 0.5 ft/s.
- The down comer plate may be straight or inclined.



Nozzle

- A tower for contacting a liquid and a vapour should be provided with a few nozzles for feed entry, entry of reflux at the top and of the reboiler vapour return at the bottom, and for product withdrawal from the tower.
- Primary criterion of a feed nozzle design is to ensure that the feed is introduced with minimum splashing or jetting. The feed should be evenly distributed and mixed with internal liquid or vapour.

Mist Eliminator

- Even under normal operating conditions, a little entrainment of liquid in the up-flowing vapour may occur.
- In order to prevent entrainment in the vapour leaving the top tray, a pad made of wire mesh or a pack of suitably bent and spaced thin sheets is fitted above it.
- The droplets are retained after they strike the surface of the pad. Such a device is called 'mist eliminator'.

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References



- Lecture notes/ppt of Dr. Yahya Banat (ybanat@qu.edu.qa)

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