

Fractination Trays

Product Bulletin 401

For many years, column trays have been used in a wide range of separation processes in the petrochemical and chemical industries. Although trays have been replaced in part by random and structured packing, there are many mass transfer applications in which trays will be the preferred choice. Trays are essentially used when:

- ☐ Towers are very large in diameter (Multi-pass Trays)
- ☐ Compounds contain solids or foulants
- ☐ There are many internal transitions
- ☐ Liquid loads are high
- ☐ Lack of experience in the service
- ☐ Chemical Reaction/Absorption - use high weirs to provide greater residence time for absorption / chemical reaction.

The Raschig USA offers a variety of tray products which include conventional sieve, valve and bubble cap trays, and specialty trays such as dual flow trays, Nye trays, disc and donut and side-to-side baffle trays.

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Raschig USA, INC.

(formerly Raschig Jaeger Technologies)

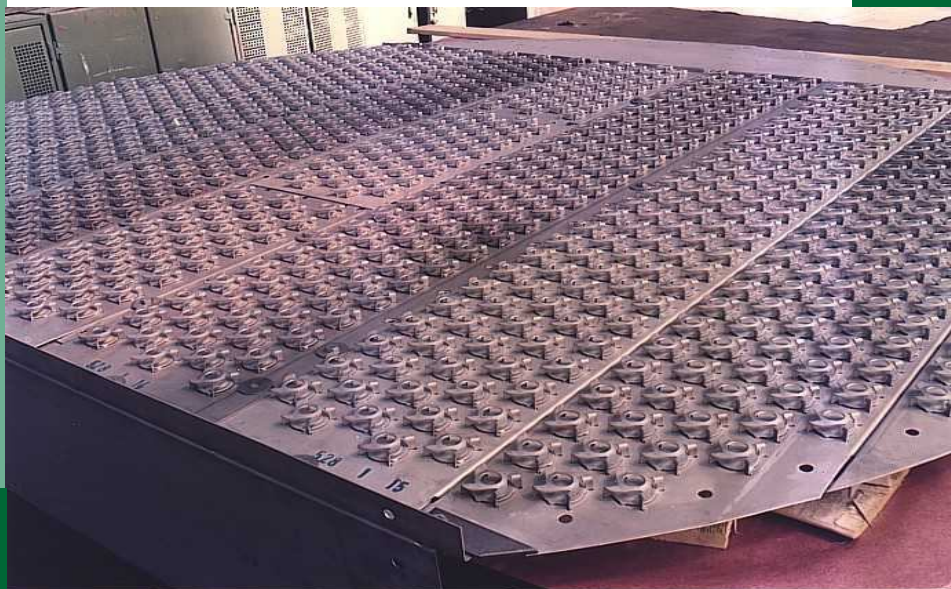




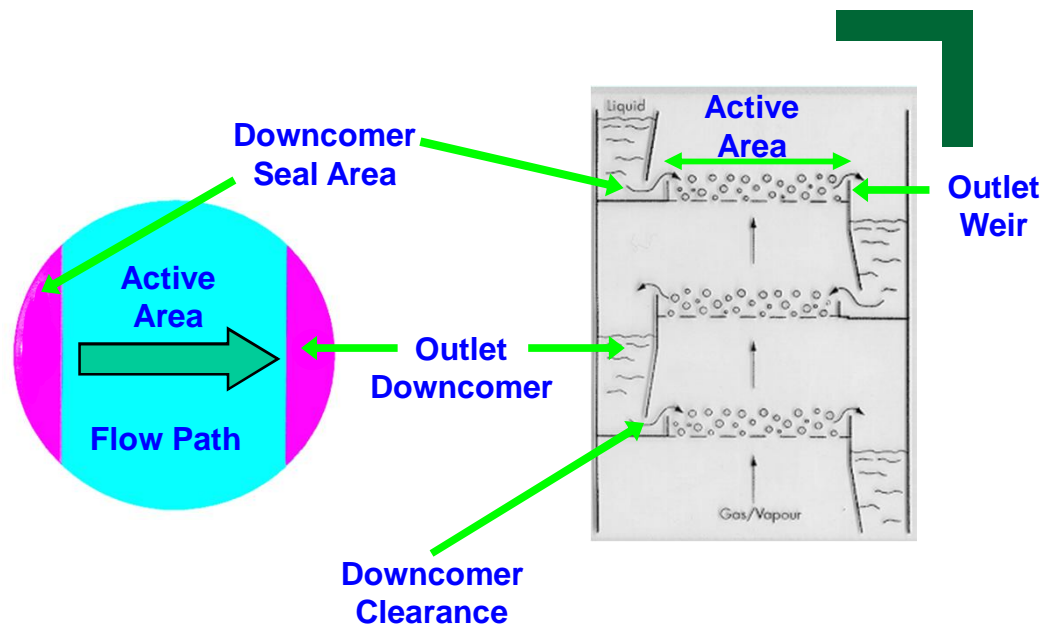
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Conventional Trays

Conventional trays are cross flow trays. Liquid descending from the tray above emerges from the inlet down comer and flows across a rapidly diverging/converging open channel or tray active area to the outlet down comer. Vapour from the tray below is forced through the active area into the cross flowing liquid to produce a two-phase mixture of aerated liquid. The nature of the aerated liquid is dependant upon the relative vapour and liquid velocities and the vapour-liquid contact openings on the tray active area.

Below is a simple sketch of a single-pass cross flow tray. Two- or four-pass trays are used when the liquid load is much higher.



Sieve Trays

Sieve trays became a dominate tower internal for mass transfer columns in the 1950's owing to their simple shape and ease of manufacture. This made sieve trays a popular device for extensive research and as a result, a considerable amount of experience has been gained for tray design and it's application. Sieve trays are flat perforated plates in which vapour is forced through the holes into the cross flowing liquid. Vapour flow prevents liquid from leaking (weeping) through the holes. At low vapour velocities, liquid weeping through the holes occurs, which bypasses a portion of the tray active area and reduces efficiency, giving sieve trays relatively low turndown (approx. 2-2.5:1).

The Raschig Jaeger Group has the capability to design and manufacture virtually any type of sieve tray. Tray hole sizes down to 3.2 mm in diameter are offered.





Valve Trays

Like sieve trays, valve trays have been in use as far back as the 1950's but nowadays have become the more popular choice because of their greater operating range properties. Valve trays are essentially flat perforated trays with moveable or fixed valve units with or without a cage structure covering the holes. Moveable valves are disk-shaped type devices which are enclosed within a cage structure or contain legs formed out of the valve disk. Fixed valves are units with integral legs formed out of the tray deck.

The open or vertical curtain area of the valve, through which vapour issues in a horizontal direction is defined by the restrictive legs integral with the valve unit or the leg-rise of the cage structure attached to the tray deck. As the vapour rate is increased, the valve units rise and the upper limit of opening is controlled by the valve leg height. It is at high vapour rates that valves serve to deflect entrainment first before propagating upwards unlike sieve trays. Upon decreasing the vapour rate, the curtain area of the valves decreases or valves settle intermittently over the holes. This minimizes liquid weeping while maintaining good operation at low flow rates. It is a combination of the above that permit valve trays to perform over a wider operating range and thus a higher turndown compared with sieve trays.

The Raschig USA can offer several types of valve units depending on the hydraulic loadings and the application.

Movable valves:	RJ-V1, RJ-V4
Caged valves:	RJ-A1, RJ-A3, RJ-A4
Fixed Valve:	RJ-V0, RJ-SVG, RJ-MV

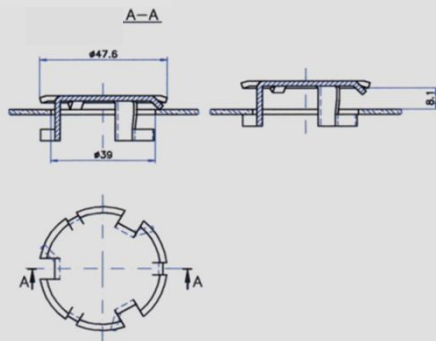
RJ-V1 Moveable Float Valve

The RJ-V1 valve is a general purpose moveable float valve unit used in various services. The valve lid is normally 1.5 mm thick from which three restrictive legs are formed integrally. Various valve lifts are possible according to the leg rise. To improve the valve activity in certain cases trays are equipped with light and heavy valves.

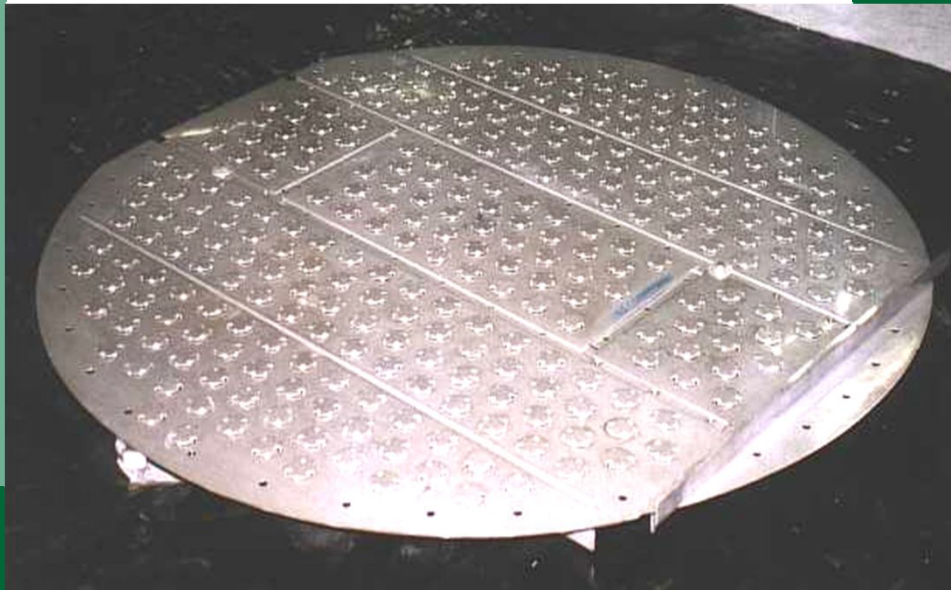
The valve unit contains anti-stick features with spacer tabs extending from the valve disk. When the valve unit is closed at low vapour rates, the spacer tabs provide a very narrow annular gap for vapour to escape radially into the cross flowing liquid. This promotes vigorous mixing while, at the same time, preventing the valve from sticking to the tray deck.

The RJ-V1 also has anti-rotating features in that the tray orifices each have an extension from the tray floor. This prevents continuous rotation of valves and material wear. Flush seating and multiple weighted valves are optional.

RJ-V1-Valve



RJ-V1 Moveable Float Valve

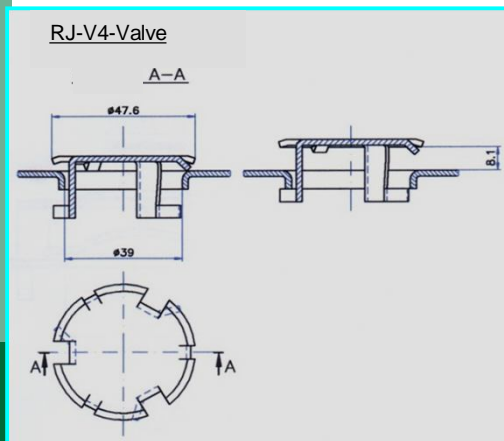


Tray with Moveable Valves (e.g. RJ-V1)

RJ-V4 Moveable Float Valve

The RJ-V4 valve is a low pressure drop general purpose unit in that the tray deck consists of a venturi-shaped orifice rather than a sharp-edge orifice. The venturi opening reduces significantly the pressure drop of the vapour at the deck entry and vertical curtain area. This leads to greater flexibility at lower vapour rates compared to that with a sharp-edge orifice. The RJ-V1 is used as the moveable float valve unit. It has the same restrictive legs bent downwards from the disk and anti-stick spacers.

If desirable, flush seat and multiple weighted RJ-V4 valves are available.

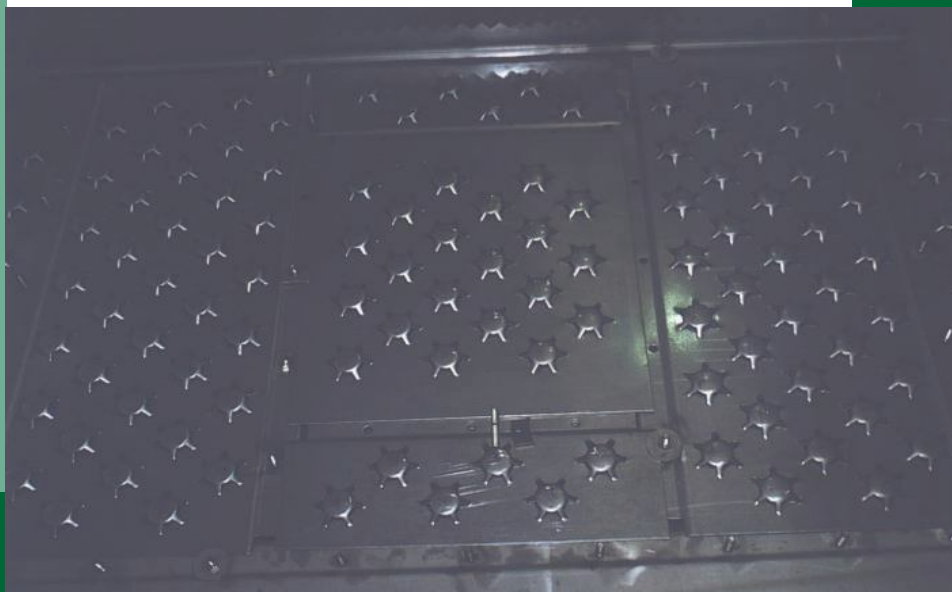


RJ-V0 Fixed Valve

The RJ-V0 valve is a fixed unit punched out of the tray deck at a fixed vertical curtain distance. The valve consists of 6 legs formed integrally with the tray deck. The fixed nature of the valve unit implies an operating range flexibility similar to that for sieve trays. The main advantage of fixed valves is that the high horizontal vapour velocity issuing through the narrow curtain area promotes intense radial mixing with the cross-flowing liquid and deflects entrainment sideways before being swept upwards. Furthermore the vapour flow creates a sweeping action along the tray floor which eliminates deposits of solid salts, and is therefore desirable for fouling applications. Also the RJ-V0 has no moving parts which makes it suitable for corrosive media.



RJ-V0 Fixed Valve



Tray with Fixed Valves (e.g. RJ-V0)

RJ-SVG Fixed Valve

The RJ-SVG valve is a fixed unit punched out of the tray deck at a fixed vertical curtain distance. The valve consists of 2 legs formed integrally with the tray deck. The fixed nature of the valve unit implies an operating range flexibility similar to that for sieve trays. The main advantage of fixed valves is that the high horizontal vapour velocity issuing through the narrow curtain area promotes intense radial mixing with the cross-flowing liquid and deflects entrainment sideways before being swept upwards. Furthermore the vapour flow creates a sweeping action along the tray floor which eliminates deposits of solid salts, and is therefore desirable for fouling applications. The advantage compared to the RJ-V0 valve is the fact that weeping is minimized because the leg facing the flow direction of the liquid phase prevents liquid entering the free area. Also the RJ-SVG has no moving parts which makes it suitable for corrosive media.



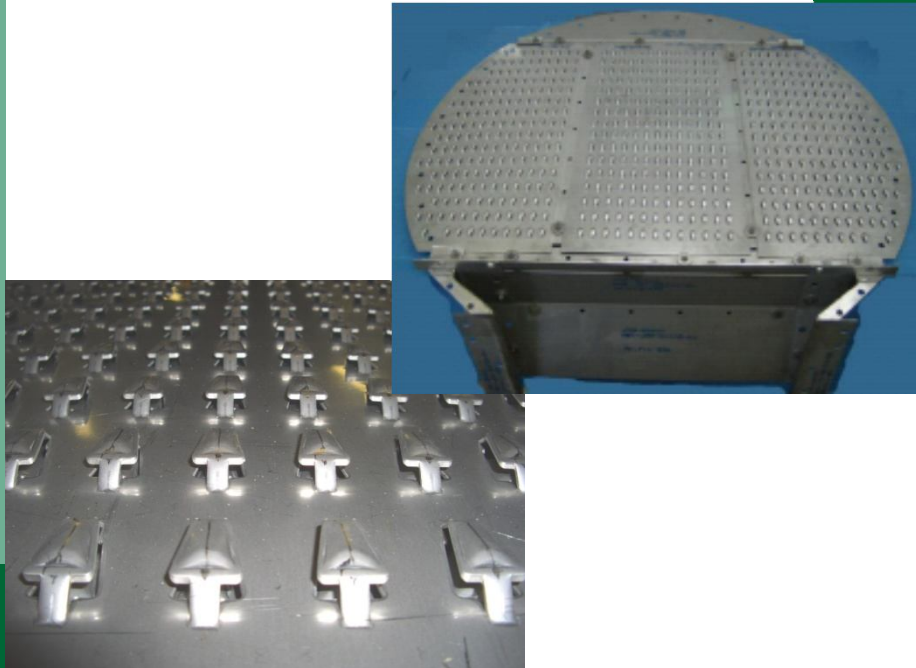


RJ-MV Fixed Valve

The RJ-MV valve is a high capacity fixed valve technology. It will provide higher capacity and lower pressure drop per theoretical stage compared to sieve or conventional valve trays. The magnitude of improvement will vary depending on the physical system but will generally be greater as the system pressure is lower or when the operation is in the spray regime. Capacity improvements over conventional trays can be up to 20%. The RJ-MV valves are extruded from the tray deck and generally oriented parallel to the liquid flow. The unique crowned head of the valve promotes improved lateral vapor release which reduces froth height and entrainment and increases hydraulic capacity. Other general advantages of the RJ-MV include: Improved mechanical strength due to added stiffness of the tray deck. Higher turndown compared to sieve trays due to improved vapor-liquid contacting.



RJ-MV Fixed Valve



Tray with Fixed Valves (e.g. RJ-MV)

RJ-A1 Caged Float Valve

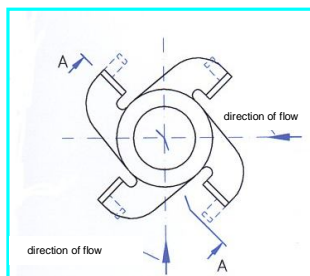
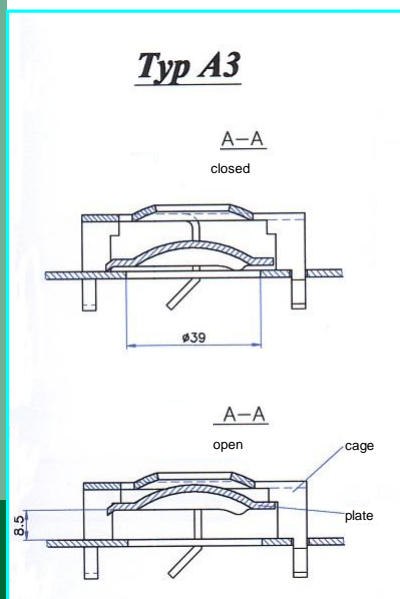
The RJ-A1 is a three-piece valve unit to maximize vapour rate flexibility. It comprises of a moveable light weight valve disk and a heavy weight valve disk which are enclosed in an open orifice cage structure with four legs that are attached firmly to the tray floor. Dependant upon the vapour rate, the light valve disk moves up first until the bottom of the second disk is reached. With further increase of vapour rate also the second disk will open. The maximum opening is controlled by the height of the cage legs. The light weight disk is normally flush seated with the tray deck but also RJ-A1 caged valves with anti stick spacer tabs can be offered.

Due to the relatively large operating range and the ability to perform satisfactorily at low liquid and vapor rates this valve represents an alternative for bubble cap trays.

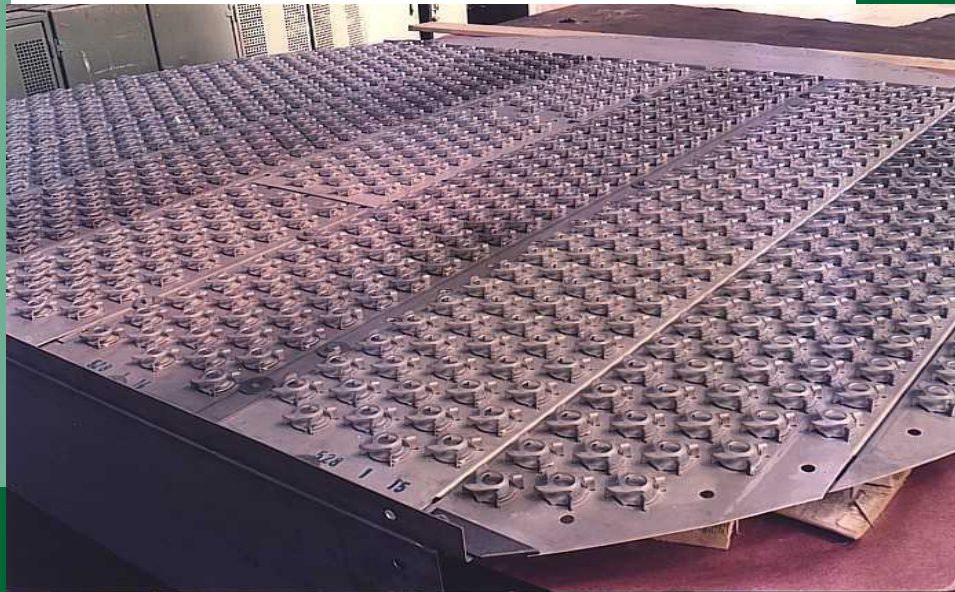


RJ-A3 Caged Float Valve

The RJ-A3 is a two-piece valve unit to maximize vapour rate flexibility. It comprises of a moveable light weight valve disk which is enclosed in an open orifice cage structure with four legs that are attached firmly to the tray floor. Dependant upon the vapour rate, the valve disk moves up or down within the cage structure and the maximum opening is controlled by the height of the cage legs. The light weight disk contains anti-stick spacer tabs such that when the valve is closed at low vapour rates, the annular space created by the tabs allows intense mixing of the horizontal vapour flow with cross flowing liquid. This prevents the valve disk from sticking to the tray floor. If desirable, flush seat RJ-A3 caged valves can be offered.



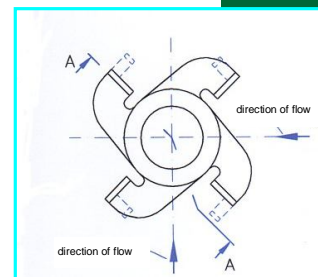
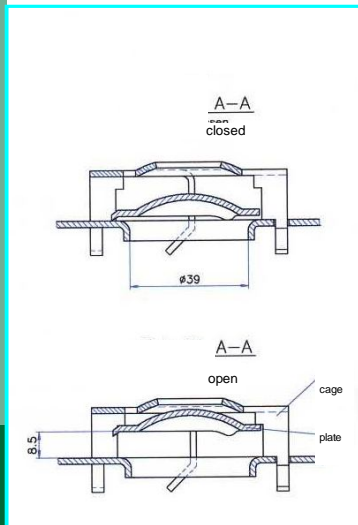
RJ-A3 Caged Float Valve



Tray with Caged Valves (e.g. RJ-A3)

RJ-A6 Caged Float Valve

This valve type is the same as the RJ-A3 caged float valve except that the tray deck consists of a venturi-shaped orifice rather than a sharp-edge orifice. The venturi opening offers lower vapour rate flexibility due to the lower pressure drop.



Bubble Cap Trays

Bubble cap trays were the work horse tower internal in the first part of the twentieth century until the late 1950's when it was superseded by sieve and valve trays. It consists of a flat perforated deck in which the holes are enclosed with vapour or gas chimney risers and caps in the form of inverted cups mounted on top of the risers. The caps can either be equipped with slots or holes, through which vapour escapes, or non-slotted where vapour is directed into the space between the bottom of the cap and tray floor (skirt clearance). Vapour is forced into the surrounding cross-flowing liquid such that aerated liquid is trapped on the tray floor to a depth at least equal to the weir height or riser height. This gives the bubble cap tray the advantage to operate at extremely low liquid and vapour rates.

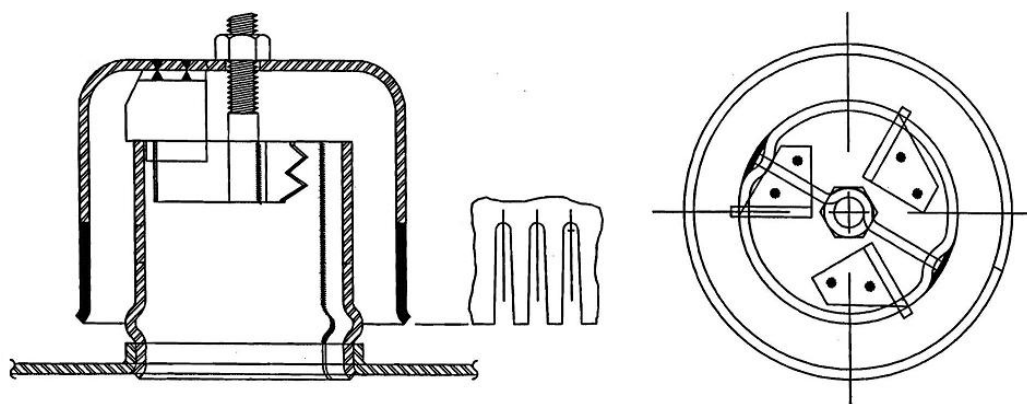


Bubble Cap Trays

The main disadvantage, besides cost, is that a large fraction of the vapour phase pressure drop is wasted as it occurs in the reversal area between the chimney riser and cap. Consequently it does not contribute to the mass transfer process.

Bubble cap trays, generally, have the ability to handle wide ranges of liquid and vapour flow rates satisfactory due to their leak proof properties. This advantage is exploited in special applications such as gas scrubbers where a large amount of vapour *must* be in direct contact with the low liquid flow.

Standard cap sizes of 75, 100 and 150 mm are available. Custom designs are also available.





Specialty Trays

Dual flow Trays

Dual flow trays are essentially sieve trays without down comers such that the entire tray active area is perforated with holes. Hole sizes range between 12.5 to 25 mm in diameter. Tray action occurs through the continuous counter current passage of vapour and liquid through the tray holes. As the liquid and vapour load are increased, the tray liquid head increases up to a point where a pulsating liquid seal is established at sufficiently high loads. At these conditions, liquid momentarily leaks through holes in areas of wave crests, while vapour surges through holes in the area between crests. As a result dual flow trays only have a very narrow efficient operating range. High open hole area dual flow trays have a higher capacity and lower pressure drop compared to conventional distillation trays at the same tray spacing and are best suited for processing fluids that form polymers or have a high solids content. The majority of commercial applications are common in small to moderate sized columns. They are seldom used in larger diameter columns because of difficulties in achieving the desired tray tolerances for levelness. Trays that suffer from out-of-levelness, are prone to segregation of the vapour-liquid flows which results in large scale liquid and vapour maldistribution.

Specialty Trays

Nye Trays

Nye trays were developed to provide a cost effective way to significantly increase the capacity of existing distillation towers. Compared to a conventional valve or sieve tray a significant higher capacity can be achieved. The general design of Nye trays can be compared to conventional valve or sieve trays containing the same three general regions: the active area (contact zone), the disengagement zone of vapour and liquid above the active area and the down comer.



Compared to a conventional tray the inlet panel is modified. The Nye insert consists of an elevated inlet panel with perforations in the vertical face to the tray above.



Specialty Trays

Nye Trays

With this design, on the one hand the active area is increased by the perforated vertical face which lowers the pressure drop. In addition to that the disengagement zone above the tray deck is increased. With those advantages, Nye trays consistently provide a higher capacity than conventional valve or sieve trays. A further advantage of the Nye tray is the fact that for a revamp only minimal tower modifications have to be made and the existing supports can be reused. For new column, considering the same capacity than conventional trays, the column diameter can be reduced and so the initial investment will be reduced.



Specialty Trays

Side-to-Side Baffle Trays and Disc & Donut Trays

These two tray types are located inside a column in such a manner that the liquid and vapour are brought in to direct contact by forcing vapour through falling liquid. Liquid descends from one tray to the next either as a curtain of liquid raining down or as liquid rivulets passing through holes in the tray deck. Tray panels are flat or slightly inclined decks that occupy 40-60 % of the column cross-sectional area. Designs containing panels with holes are usually 40% open so that there is sufficient overlap between plates stacked one above the other. At a given tray spacing, both tray types offer a higher capacity and lower pressure drop compared with conventional sieve and valve trays, and in some cases dual flow trays. The trade-off is a considerably lower contacting efficiency. With both baffle trays and disc & donut trays having an extremely high open area, they are most suitable for dirty service and heavy fouling applications. Examples are heavy oil refining and petrochemical heat transfer services having a petroleum coke / high solids content. The Raschig USA can supply these trays on request.

Comparison of Common Conventional Tray Types

TRAY TYPE	BUBBLE CAP	DUALFLOW	SIEVE	VALVE (Moving / Non-Moving)
Capacity	Moderate	Very High	High	High to very high
Pressure Drop	High	Low to Moderate	Low to Moderate	Moderate. Older designs were somewhat higher. Recent designs same as sieve trays.
Efficiency	Moderate (0.6 – 0.8)*	Lower compared to others (0.5 – 0.7)*	High (0.7 – 0.9)*	High (0.7 – 0.9)*
Turndown	Very high Can handle very low liquid rates	Low. Not suitable for varying loads	Approx. 2:1. Unsuitable for varying loads operation	Approx. 3-5:1 Higher turndown designs can be provided on request.
Maintenance	Relatively high	Low	Low	Low to moderate
Fouling Tendency	High. Tends to accumulate solid particles	Extremely low. Best choice for Severe fouling	Low	Low to moderate
Main Application	Very low flow conditions Where leakage needs to be minimized	Capacity Revamps Where efficiency and Turndown not Critical High fouling and corrosive services.	Most columns where Turndown not important	Most Columns Services where turndown important
Cost	High - approx. 2-3 times that for sieve trays	Low	Low	Marginally higher than sieve trays

* Within optimum operating range.

Below is a summary of the tray geometry and layout for the different conventional tray types at different operating pressures.

	Vacuum Distillation	Normal Pressure Distillation	Pressure – Distillation and Absorption
Tray Spacing, m	0.5-0.8	0.4-0.6	0.3-0.4
Weir length, m	$(0.5-0.6) D_S^*$	$(0.6-0.75) D_S^*$	$(0.85) D_S^*$
Downcomer Clearance, m	$0.7 h_W^*$	$0.8 h_W^*$	$0.9 h_W^*$
Bubble cap tray			
Tray diameter, m	0.3 - 8	0.3 - 8	0.3 - 8
Bubble cap diameter d_{GI} , m	0.08-0.16	0.08-0.16	0.08-0.16
Distance between bubble caps, m	$1.25 d_{GI}$	$(1.25-1.4) d_{GI}$	$1.5 d_{GI}$
Outlet weir height h_W in m	0.02-0.03	0.03-0.07	0.04-0.1
Sieve tray			
Tray diameter, m	0.3 - 8	0.3 - 8	0.3 - 8
Hole diameter d_h , m	0.003-0.015	0.003-0.015	0.003-0.015
Hole pitch, m	$(2.5-3) d_h$	$(3-4) d_h$	$(3.5-4.5) d_h$
Open hole area, %	10-20	6-15	6-10
Outlet weir height h_W , m	0.01-0.02	0.02-0.05	0.04-0.08
Valve tray			
Tray diameter, m	0.3 - 10	0.3 - 10	0.3 - 10
Valve diameter d_v , m	0.038-0.05	0.038-0.05	0.038-0.05
Valve lift, m	0.008-0.02	0.008-0.02	0.008-0.02
Valve open Slot Area, %	22-32	16-24	12-16
Distance between valves, m	$1.5 d_v$	$(1.7-2.2) d_v$	$(2-3) d_v$
Outlet weir height h_W in m	0.02-0.04	0.03-0.05	0.04-0.07

*DS = column diameter in m
hW = outlet weir height in m



Beyond a certain liquid rate the tray flow path needs to be split in to two or more paths. The following table shows recommended minimum diameters for trays with multiple flow paths

Number of flow paths	Recommended minimum diameter in m
2	1.7
3	2.4
4	3.2

Special Tray Design Accessories

The Raschig USA offers a range of tray accessories to produce an optimal solution to almost any fractionation tray problem. Mechanical and / or process considerations will indicate when special features are needed.

Down comer Designs

Down comer designs offered by the Raschig USA include multi-chordal, circular, envelope, and pipe styles. These down comer types can be supplied in addition to the straight segmental down comers.

Swept-back Weirs

Swept back weirs are essentially used for high liquid loads. They are an extension of the chordal weir length, such that it lowers the tray liquid flux (volumetric liquid flow per unit length of outlet weir), without changing the down comer area. For 3- and 4-pass trays, swept back weirs are used to extend the length of side down comers. This enables the balancing of liquid weir loads between the side and off center or side and center down comers. Swept back weirs lower tray pressure drop and down comer backup.



Circular or Downpipe Down Comers

Pipe down comers are only used for extremely low liquid load applications where standard segmental down comers are unsuitable. Segmental weirs are used with pipe down comers to ensure a good liquid distribution on the tray which helps lower the tray pressure drop.

Envelope Down Comers

Envelope down comers are used in only low liquid rate applications in which a minimum down comer width or minimal liquid leakage criteria has to be met.

Sloped Down Comers

Sloped down comers offer the best use of column area for down flow. They provide adequate volume for vapour-liquid disengagement at the down comer top without sacrificing tray active area on the deck below. Sloped down comers are very useful when vapour disengagement from the liquid flow in the down comer is difficult (e.g., high pressure applications, foaming systems) and when down comers occupy a significant part of the tray area (e.g., high liquid loads). The extent of down comer sloping is such that the bottom down comer area is no less than 50 % of the top Down comer area.

Anti-jump Baffles

When operating at high rates, solid vertical panels known as anti-jump baffles are installed at the center and off center down comers of multi-pass trays. Operating problems may arise with aerated liquid jumping across the center and/or off center down comer from one tray panel to an opposing tray panel resulting in excessive liquid buildup near the tray outlet. Anti-jump baffles deflect liquid directly in to the down comer. They are used when the width of the center or off center down comer is narrow and the tray loading is high.



Picket-Fence Weirs

Picket fence weirs are typically used at very low liquid rates ($< 8.94 \text{ m}^3/\text{h}/\text{m}$) in which there is a need to 'artificially' increase the tray liquid head to achieve performance. By using a continuous metal plate with rectangular notches or a number of equally spaced attached splash plates, the effective weir length is reduced. This in turn increases the liquid flux over the outlet weir and thus increase the liquid head on the tray active area.

Splash Baffles

For extremely low liquid rate services a splash baffle can also be provided and is similar to the picket fence weir. This is a metal plate set up parallel to the outlet weir set at a short distance above the tray floor. The splash baffle serves as an underflow weir for the liquid, is positioned in the near vicinity of the outlet weir and serves the purpose of increasing the liquid retention time on the tray.

Recessed Seal Pans

Recessed Inlet seal pans distribute liquid on to the tray in an upward vertical motion rather than horizontally through the inlet down comer clearance. The result is better aeration at the tray active area entrance which can increase the tray capacity. They are used to provide a down comer seal in cases where there sealing problems and when the clearance under the down comer is limited according to standard methods.

Recessed inlet pans are used together with sloped down comers. The bottom of the down comer extends about 25 – 38 mm below the tray floor to ensure a good liquid seal. Slope down comers with recessed inlet pans are used primarily in high liquid loaded services that suffer from down comer flooding.



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