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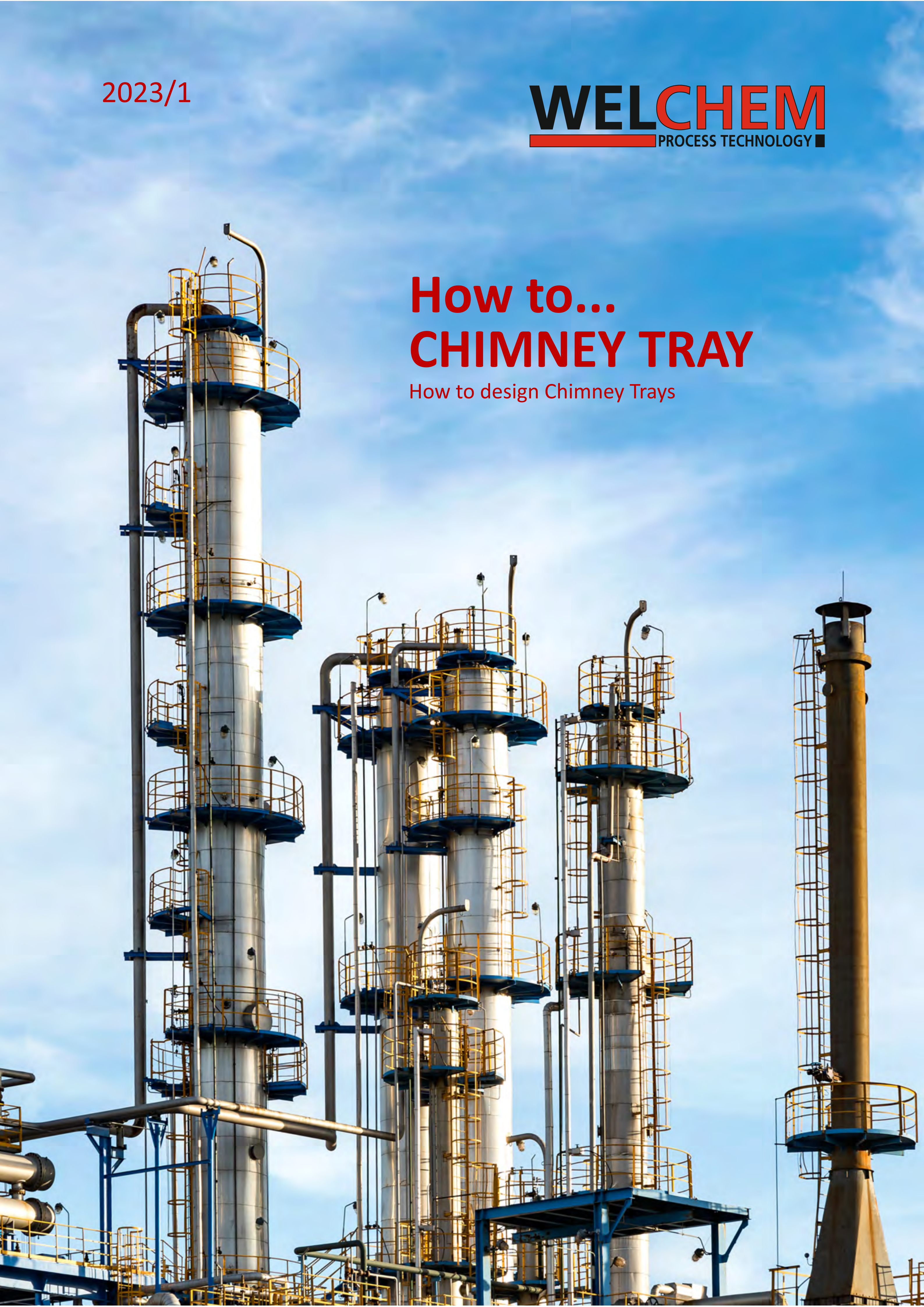
How to...
CHIMNEY TRAY

How to design Chimney Trays



How to... CHIMNEY TRAY

How to design Chimney Trays

Dr.-Ing. Volker Engel

Chimney Trays (also called „Collector Trays" or „Draw-Offs") are not used for mass transfer – but they are important and sometimes also critical components for the operation of columns. This article describes the functions, designs and leakage classes of these trays.

Chimney Trays are used in all kinds of columns for collecting liquid (in order to feed or draw liquid; also called „Draw-Off Tray" or „Trap-Out Tray"), providing residence time for gas disentrainment, buffering liquid to counteract operational instabilities (also called „Holdup Tray") as well as for achieving a proper gas distribution (also called „Gas Distribution Tray"). Additionally they may be used for surge volume, buffer against upsets and for two-phase liquid draw.

Fig. 1 shows the set of main functions of a Chimney Tray (blue branch for liquid aspect, red branch for gas aspect).

Types of Chimney Trays

In principle a Chimney Tray consists of a sealed layer (base panels) with gas chimneys (normally called „risers"). Depending on the function of the trays, there will be additionally downcomers, troughs, boxes and hats for the risers.

In the following, different types of Chimney Trays are presented.

Total Draw-Off (Total Trap-out)

All liquid is drawn by one or more nozzles (*Fig. 2*). Due to static reasons and to minimize the total holdup of the tray, there are troughs or boxes at the nozzles for drawing the liquid. If not all liquid can be drawn by the nozzles, the Chimney Tray will flood and the liquid will drain down the risers. This must be taken into account in the design, both in terms of process and statics!

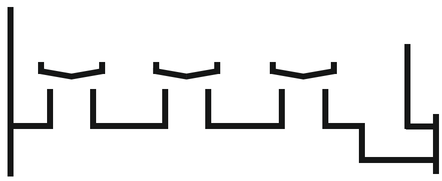


Fig. 2: Total Draw-Off Tray

Partial Draw-Off

Part of the liquid is drawn by one or more nozzles (*Fig. 3*). The rest of the liquid is transferred to the next stage by downcomer(s).

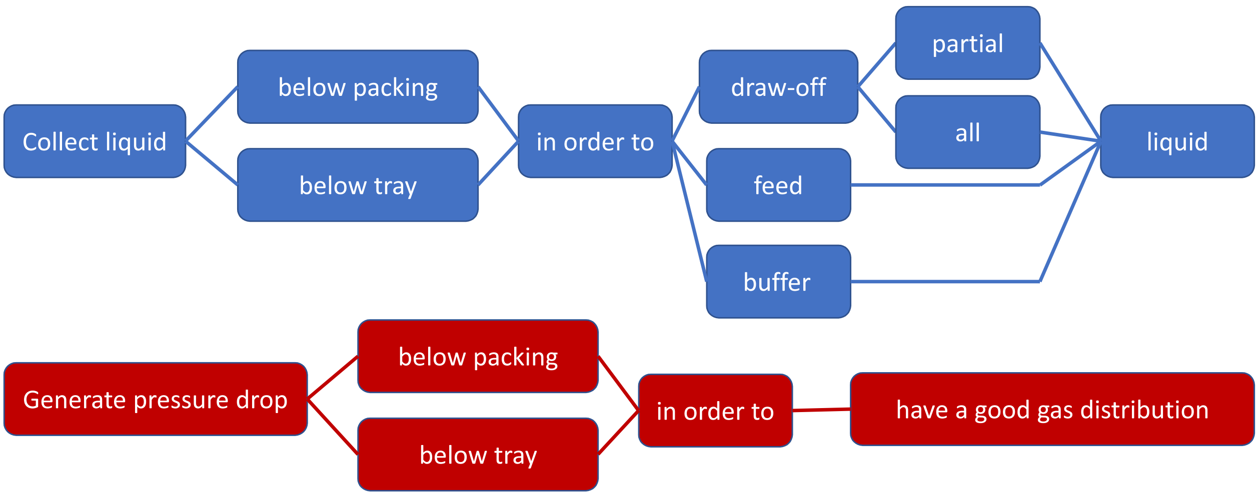


Fig. 1: Functions of Chimney Trays

Fig. 3: Partial Draw-Off Tray

No Draw-Off

All liquid is transferred to the next stage by downcomers (*Fig. 4*). These downcomers may be designed as classical downcomers for multi-pass trays or as multi-downcomers as boxes on the entire cross-sectional area. This type is used for improving the gas distribution as well as to add a feed and mix it with the liquid of the current stage.

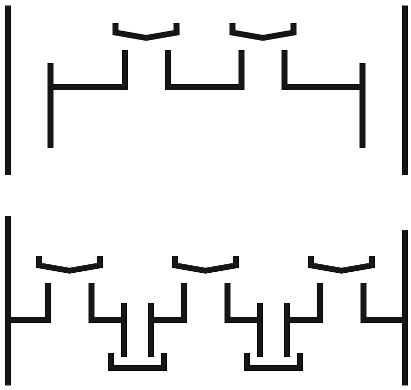


Fig. 4: No Draw-Off

Types of Risers

The design of the risers is adapted to the functionality of the Chimney Tray.

Number and size of risers: For gas distribution, there will be many small risers spread over the total cross-sectional area. When there is no issue for gas distribution, few risers are realized (*Fig. 5*). The dimension of the riser has to take care about the size of the manhole.

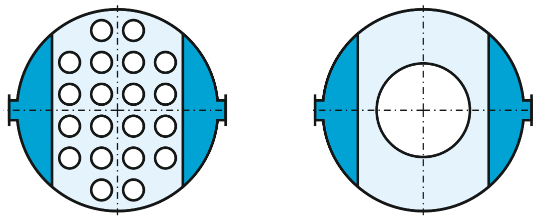


Fig. 5: Number and size of risers

Height of risers: Risers have to be higher than any weir on the Chimney Tray in order to have no overflow through the risers!

Shape of risers: When there is need for many small risers, normally round risers built from pipe material are used.

For static reasons rectangular risers are the preferred shape (*Fig. 6*). To utilize the entire area of a chimney tray, there may be trapezoid risers as well.

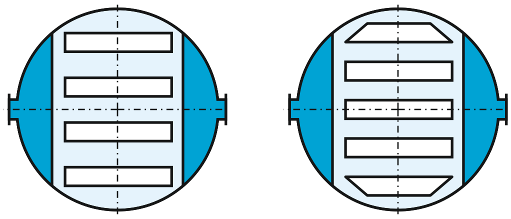


Fig. 6: Rectangular risers

Hats of risers: To prevent liquid falling through a riser (e.g. if a Chimney Tray is located below a packing section), the risers are equipped with hats (roofs). The hats are normally bended and protrude the riser area, so that the liquid from the hat can not run into the riser (*Fig. 7*).

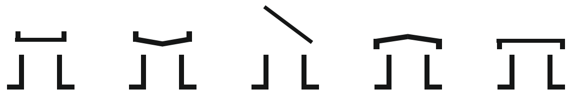


Fig. 7: Shape of risers' hats

To support the liquid flow towards the draw-offs, the rectangular hats can be sloped (*Fig. 8*). The construction has to ensure, that no liquid will flow in the riser.

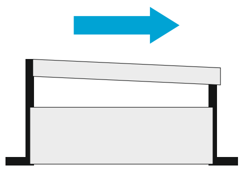


Fig. 8: Sloping of hats

For generating a certain pressure drop (in case of using the Chimney Tray as gas distribution device) one can reduce the outlet area by adjusting the distance of the hat to the riser. Because by this a high gas outlet velocity is induced (not helpful for optimal gas distribution), it is more practical to generate the pressure drop by inlays (*Fig. 9*). These inlays are slotted panels to achieve a certain pressure drop.

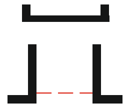


Fig. 9: Inlay in riser

Types of Downcomers

As for classical trays, there are single and multi-pass designs for the downcomers. Especially when the stage below is a trayed section, the downcomer positions and dimensions are set by this design.

For the case of a liquid distributor below the Chimney Tray, the liquid has to be transferred to the pre-distribution box(es). In this case, the downcomer position has to be harmonized with the pre-distribution troughs. For large-scale distributors, there may be used multi-DCs. In this case, sometimes inlays are used for reducing the liquid inlet impulse to the pre-distribution throughs.

Hydraulics: Pressure Drop

For the Chimney Tray mainly acting as liquid collector, the open area of the risers should be large and therefore the pressure drop low. For those applications the pressure drop will be about or less than 0.1 mbar. If the Chimney Tray is located within a trayed section, the open area is normally about 10 percentage points larger than the open area of the trays.

When the Chimney Tray is built for gas distribution, the tray has to have a noticeable pressure drop. For good functionality, the pressure drop – even at minimum gas load – should be about 1 mbar (depends on the operational pressure of the tower).

The pressure drop is calculated by *Eq. 1*. It is the standard correlation (Darcy's law) for pressure drop through openings where the friction factors K_i describe the change of the velocity and direction of the gas by passing the riser.

$$\Delta p = C \cdot \rho_G \cdot w_G^2 \cdot \sum_i K_i \qquad \textit{(Eq. 1)}$$

Hydraulics: System Flood

Whenever the Chimney Tray is located below a packing and gas is flowing in counter current (e.g. to the liquid from the support grid), System Flood FFSF has to be checked.

The FFSF calculation checks, whether liquid droplets can fall down when gas is streaming upwards. When the droplets are carried upwards, no counter flow will be possible anymore and the column will flood. This flooding has to be checked for the least cross-sectional area, where gas and liquid have to pass. If there are hats on the risers, the open area between the hats is normally the smallest area. If flooding in this area is indicated, the tower may still work, because liquid can drain by the risers' hats. But one has to ensure, that this draining is optimized and without any contact with gas.

Hydraulics: Downcomer

On a Chimney Tray the classical Choke Flood (FFCF) calculation models are not applicable, since there is no froth layer entering the downcomers. There is no or only little degassing of liquid in the downcomer. Therefore the downcomer area is normally not checked for choke flood, but by criteria of self-venting flow.

Another flooding mechanism for downcomers is the Aerated Downcomer Backup Flood (FFAF). All contributing effects to the downcomer backup have to be calculated: (a) Pressure drop of the Chimney Tray, (b) liquid head by the clearance of the downcomers, (c) weir height and weir crest height of a seal pan. Since the pressure drop of a Chimney Tray is normally not high, there is no problem to keep the downcomer level within moderate values. But for gas distribution applications, the effect has to be considered very carefully (especially for maximum load).

If there is any risk of pressure surges from the section below the Chimney Tray, the liquid level in the downcomers has to be designed to be sufficient (sealing by high seal pan or inlet weir) to prevent gas channeling the downcomer.

Construction: Thermal Expansion

Chimney Trays are often welded-in in order to achieve a high degree of tightness. It is essential to ensure that the construction can absorb any thermal expansion that may occur!

This thermal stress occurs, when the column is heated or cooled because of the different thermal expansion by the very different material parameters (CS, SS, alloy) and different material thickness of tray panels and tower shell.

Fig. 10 shows a welded design for small diameters and ambient temperature, where no thermal expansion occurs.

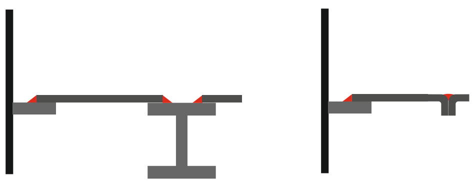


Fig. 10: Construction without thermal compensation

Fig. 11 shows an adapted design for compensating thermal expansion. This is done by using the structural properties of troughs (a) or bendings (b).

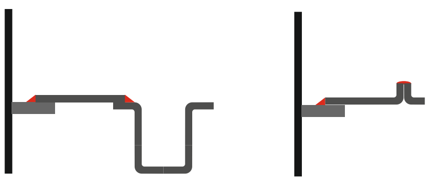


Fig. 11: Construction without compensation

Another common idea to structurally separate the Chimeny Tray from the column hardware is to use half pipes (at the support ring as well as at major beams).

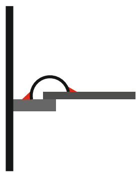


Fig. 12: Half-pipe for thermal compensation

For bolted and gasketed constructions (*Fig. 13*), the thermal expansion is normally not an issue. But those types will not achieve a high leakage class due to remaining openings. It is important to have a narrow clamp spacing and to use gasket washers for all boltings.

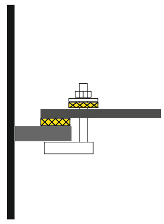


Fig. 13: Bolted design

Construction: Statics

The maximum level of liquid results from the risers' height or from the weir height of the downcomers (if there are any). This level of liquid has to be taken into account for statics.

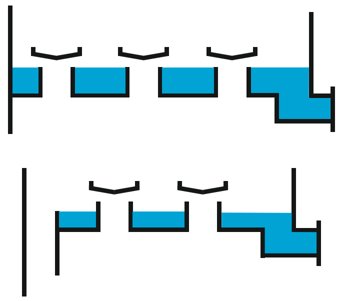


Fig. 14: Level of liquid

For total draw-off designs with small risers the maximum level might be even higher (e.g. when the risers are not able to drain the total amount of liquid in case of draw-off failure).

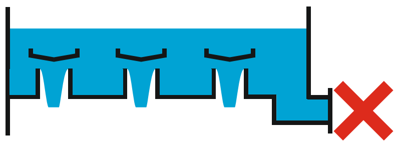


Fig. 15: Overfilling of trays

To achieve proper statics, troughs are often used as base. In this case, the troughs are fabricated as tower attachments.

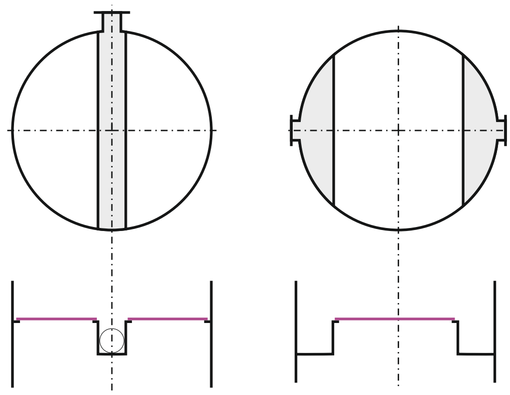


Fig. 16: Statics of Chimney Trays

In case of a classical tray construction setup, the construction is based on a support ring and major beam(s).

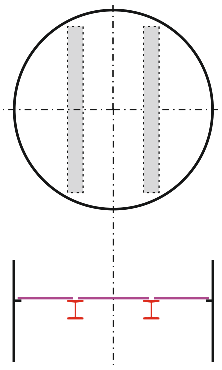


Fig. 17: Statics by major beams

Leakage Classes

Depending on the function of the Chimney Trays, a certain leakage class has to be achieved. Although there is no official set of rules, the following classes are used internationally:

Tightness class 1: For low process requirements max. leakage rates of 0.13 $m^3/m^2/h$ are accepted (Drop of liquid level < 130 mm/h).

Tightness class 2: For medium process requirements (e.g. Chimney Trays in vacuum towers) a leakage rate of less than 0.06 $m^3/m^2/h$ has to be achieved (Drop of liquid level < 60 mm/h).

Tightness class 3: For high process requirements (Chimney Trays above packed distillation section, above packed or trayed flash and scrubbing section in vacuum and atmospheric towers) leakage rates of less than 0.02 $m^3/m^2/h$ are necessary (Drop of liquid level < 20 mm/h).

Note 1: The cited „drop of liquid level“ depends on the total level of filling. Due to Toricelli's law the liquid through an opening depends on the liquid head of the outlet! For measuring a certain leakage class, a proper test scenario has to be defined!

Note 2: It is difficult to have bolted and gasketed manways in the deck at high tightness classes.

Note 3: The best way to achieve a manway in a liquid tight design is to use risers as passage way.

Conclusion

As the Chimney Tray is not used for mass transfer, its importance is sometimes underestimated. The failure of a Chimney Tray normally stops the operation of the column. Accordingly, the correct and robust design of these trays is very important.

About the author

Volker Engel studied process engineering at the Technical University of Munich and did his Ph.D. thesis on packed columns with Prof. Johann G. Stichlmair. Since 1998 he has been the managing director of WelChem Process Technology GmbH and head of the TrayHeart software. TrayHeart has developed into a state-of-the-art design tool for trays and internals in process technology.

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