Troubleshooting Liquid Side Draw-off Trays

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Abstract. When a liquid draw is taken from the middle of a column, a side draw-off tray has to be used. Splitting ratio of liquid to the side draw and to the bottom section of the column is determined by process requirements. Two cases will be reported first where the flow rate of the side draw could not reach the design values. In the third case, the bottom section of the column starved. The commonality among all the three cases discussed in this paper is that liquid hydrostatic head was not adequate either over the draw-off nozzles or the internal overflow pipes of the draw-off trays. After corrections were made to address individually specific designs of the external piping, the elevation of the draw-off nozzle and the way of how liquid level was kept on the tray, the side draw-off trays functioned properly.

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Keywords Troubleshooting, Liquid draw-off, Tray

Introduction

Downcomer trapouts and chimney trays are two common devices to split liquid into side draw and internal column reflux, the choice of which is typically based on two main considerations, i.e. degassing requirement and inventory requirement for column control.

A trapout is integrated into a tray with perforations, hence, degassing of liquid is usually not complete. A side draw from a trapout can feed a side stripper or an external drum. The liquid hydrostatic head is more determined by the depth of the trapout than the tray outlet weir due to liquid aeration above the tray deck. In contrast, it is possible to fully disengage gas on a chimney type draw-off tray. The hydrostatic head on the latter type can be determined by the height of either overflow weir or overflow pipe. Alternatively, it can be controlled by a valve downstream of the draw-off nozzle.

A draw-off nozzle capacity can be restricted by various mechanisms, and two of them are related to vapor. Often cited in literature[1], one mechanism is that drop in static pressure of the liquid due to the flow friction and kinetic conversion etc. causes the saturated liquid to vaporize in the nozzle, which eventually triggers nozzle cavitation. The other mechanism, similar to tray downcomer choking, is that when the liquid level above a nozzle is not high, vapor could be dragged into the nozzle and then restrict liquid flow. There are certain criteria established to avoid the above mentioned two mechanisms.

Keeping the liquid level above the nozzle sufficiently high has advantages. The potential energy due to high liquid hydrostatic head suppresses liquid at boiling point from flashing, and also makes it difficult for process vapor to reach the nozzle. However, in case of turndown, these advantages may disappear due to decreased liquid hydrostatic head.

In sum, liquid draw-off can be designed either avoiding vapor or allowing self-venting by escaping from the nozzle counter currently. Robust practical design rules however may include both mechanisms. In addition, often overlooked, to a specific nozzle, there is an independent minimum hydrostatic head required in order to drive a certain amount of liquid out of the column. In the following paragraphs, 3 cases will be shared where the inadequate hydrostatic head causes diverse problems.

Case 1

In the first case, a distillation column of 7.8 m diameter was equipped with 4-pass high capacity trays, and a side draw was taken in the middle of the column. Since there was a degassing drum outside the column, simple trapouts were adopted. Traditionally, a trapout is positioned below a full downcomer, as if the trapout and draw-off nozzle are fully enclosed inside the downcomer (Figure 1). Thus, trapout is commonly called downcomer trapout. In our case, all downcomers were truncated to have extra bubbling area, which is a common strategy for modern high capacity trays. Thus, the trapouts were separated from the downcomers, and downcomers were dynamically sealed, no longer dependent on trapout design. For simplicity of external draw piping, 2 trapouts were applied to an intermediate tray

with 2 side and 1 center downcomers. The nozzle diameter was 300 mm with nozzle liquid velocity less than 0.8 m/s. The rest dimensions of the trapouts were fully specified by an engineering company. The depth of the trapout was 600 mm below the deck of the draw tray, its length was 900 mm, 3 times of the nozzle diameter, and its width was the same as the one of the downcomers above them (Figure 2).

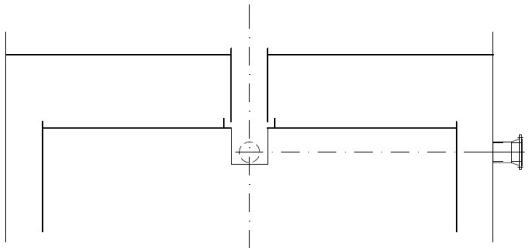


Fig. 1 A typical conventional downcomer trapout for a 2-pass tray

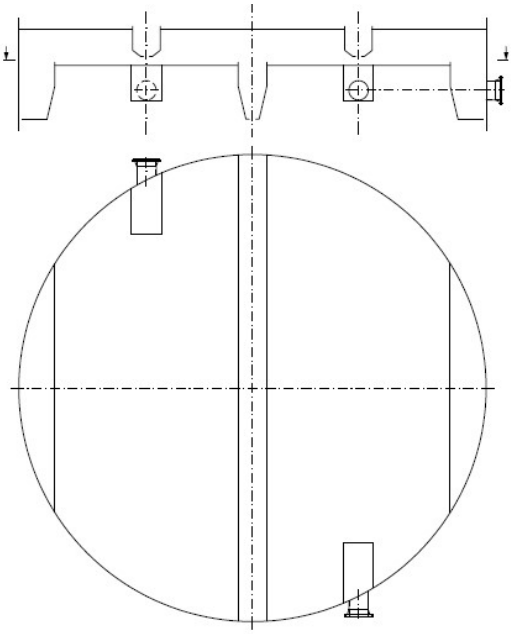


Fig. 2 The 4-pass tray with 2 draw-off sumps

As per process, 30% of the liquid reaching the draw-off tray was required to be taken out as a side draw, and the rest flowed down to the trays below via downcomers. However, during operation, the achieved flow rate of the side draw was far behind the target.

To troubleshoot the column, the specifications and the related drawings from the internal as well as the column vendors were retrieved and reviewed. It was first found that specifications were for conventional trays whereas the trays supplied were high performance trays with truncated downcomers. The consequential impact lies in that bubbling area. If the trapout is in the downcomer, there is no change in bubbling area, however when truncated downcomer is used, then this draw-off tray loses bubbling aera, hence the tray spacing for this draw-off trays should be compensated. Considering there was a lot safety in tray jet flood, it was concluded that the uncompensated tray spacing was not the reason for the trouble. Secondly, the trapout looked small in scale in the 7.8 m column. For 1 or 2-pass trays, trapout is usually a full segmental pan cross the whole column. For big columns like this, experience was not abundant to judge whether using small portion from the tray as trapouts would cause noticeable negative impacts, such as maldistribution of liquid.

When the column vendor drawing was reviewed, the main culprit was identified as shown in Figure 3. The elevation of the draw-off nozzle was wrong, and the distance between the deck of the draw-off tray and the centerline of the

nozzle was only 200 mm. As per calculation, the hydrostatic head was insufficient to drive the required liquid amount to the two draw-off nozzles.

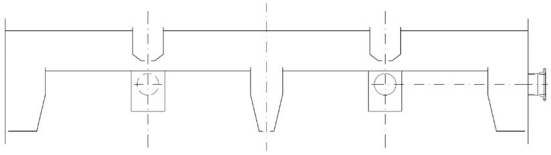


Fig. 3 Wrong elevation of the nozzles in the column drawing

Corrections were hence made including lowering the elevation of the nozzles and expanding the trapout dimensions to completely eliminate any concern associated with the liquid maldistribution on the draw-off tray.
The draw-off tray functioned after the corrections.

Case 2

The malfunctioning column was retrofitted using a new generation packing for capacity expansion. Soon after the plant started up, it was found out that the max achievable side draw flow rate was 30 % short of the design value.
The chimney type draw-off tray was thus fully examined. As shown in Figure 4, the 1-meter space of interest in the column not only accommodated the draw-off tray itself, but also a manhole of 500 mm. The riser height excluding removable hats was optimized to be 315 mm so that the liquid level on the chimney would not reach into vapor risers and installation of the draw-off tray via the manhole would be easier. For better utilization of the space in the column, no draw-off sump was adopted, but instead the draw-off nozzle was chosen flush with the tray deck. Accordingly, the overflow pipes were protruded 100 mm above the tray deck to provide necessary liquid head to drive the horizontal flow of liquid on the tray to the draw-off nozzle. To allow for possible gas carry-over to the draw-off nozzle, its diameter was increased from the existing 100 to 150 mm.

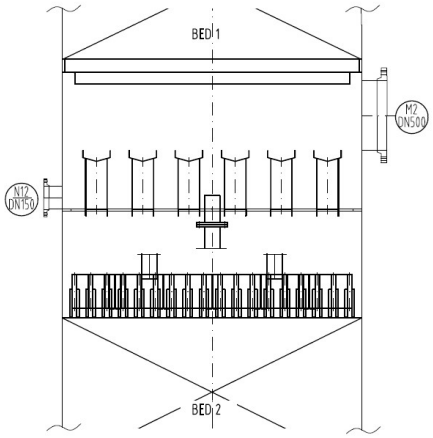


Fig. 4 The draw-off tray between the two packing beds

The examination showed that liquid flow in the two internal downpipes satisfied self-venting criterion, and no restriction of liquid to the bed below was foreseen.
Then the flow of liquid to the draw-off nozzle was inspected. The liquid crest over the pipe was marginal, less than 15 mm. Overall the level of the liquid was around 40 mm above the centerline of the draw-off nozzle, which was enough to drive the liquid flow to the draw-off nozzle, but perhaps a bit tight according to Sulzer experience.
The site inspection spotted an external pipe reducer which connected the newly expanded draw-off nozzle to the existing external draw-off pipe of 100 mm nominal diameter. It was at the same elevation as the nozzle. As shown in Figure 5, it reduced the effective liquid head by 25 mm, and aggravated the already tight liquid head required. It was also against recommended practices that piping fittings should be avoided on the draw-off line[2].

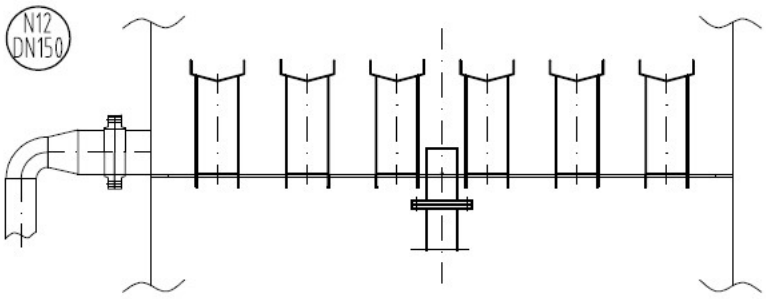


Fig 5. The reducer connecting the new nozzle and external piping

To restore the require hydrostatic head, the first correction was to move the reducer downwards to the vertical part of the draw-off pipe (Figure 6). Careful checkup found that the safety reserved between the top of liquid and the top of the riser was more than sufficient, hence the height of overflow pipe increased to 200 mm to ensure sufficient reserve. Either measure could be adequate to solve the problem, however being conservative is often the approach during troubleshooting. After two measures were taken, the draw-off flow rate increased above the design value.

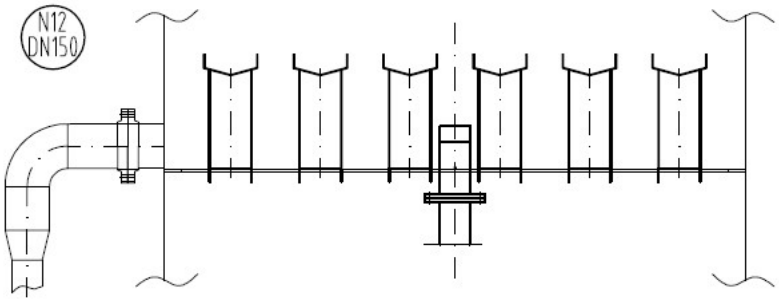


Fig. 6 Modifications made to the draw-off tray

Case 3

Unlike the previous two cases, the last one in this paper experienced liquid starvation in the bottom sump of a column. In this 8 m diameter column, besides taking a side draw, the chimney type draw-off tray also served as a transition device between a section of high capacity trays above and a section of baffle trays below (Figure 7).

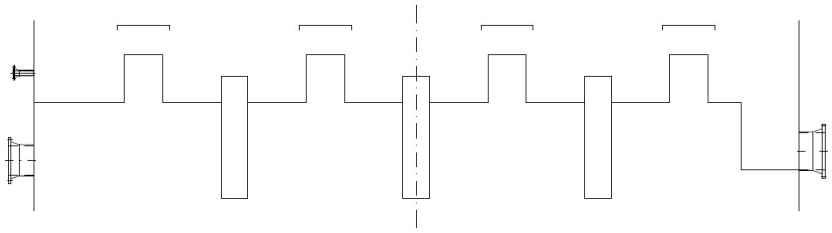


Fig. 7 The transit chimney tray

The side draw would remove 0.15 m^3/s liquid out of the column, and the remaining 0.11 m^3/s was flowing to the baffle trays in the lower section of the column via 3 rows of overflow pipes of 280 mm nominal diameter. In addition to the internal reflux from the tray above, the baffle trays were also fed with a large liquid flowrate. During commissioning, it was observed that the liquid level in the column sump was unstable and difficult to control. The side draw was more than 0.15 m^3/s. Therefore, the chimney tray design was examined.

The depth of the draw-off sump was 700 mm, and the 16-in nozzle was flush with the bottom of the sump. The draw-off nozzle was fully submerged, and there was sufficient hydrostatic head above the draw-off nozzle. As observed, the draw-off design was proper. Hence, the focus was shifted next to the design of the overflow pipes.

The liquid velocity of the pipes was slightly less than 0.3 m/s, as such, no gas would be carried down to the pipes and choke them. The height of the overflow pipes was found 270 mm in comparison with 500 mm height of the vapor risers. The rectangular risers were parallel to liquid flow on the tray, and the sufficient distance between them eliminated possible obstruction of liquid flow to the draw-off sump and forming hydraulic gradient, which would potentially provoke liquid descending into some risers upstream of liquid horizontal flow. Thus, the overflow pipes were found adequate too. Eventually, the examination of the control scheme revealed the cause of the trouble.
The side draw flow rate was on liquid level control, and the upper span of the level was 310 mm, only 40 mm above the overflow pipes. As per calculations, this liquid head was not sufficient to transport 0.11 m^3/s to the baffle trays and subsequently to the column sump, leading to constant change in liquid level there. A temporary solution was setting level manually controlled until the next turnaround. Finally, as shown in Figure 8a, a few vertical slits added to the existing overflow pipes solved the problem. The slits applied to overflow pipes (notched tube) not only provided a higher hydrostatic head, but also brought high control sensitivity as the liquid level changes greater with flow of side draw-off. In fact, notched overflow tube is a recommended standard design if the side draw-off tray is on level control. This issue could have been prevented by a critical review of the control scheme during the design.

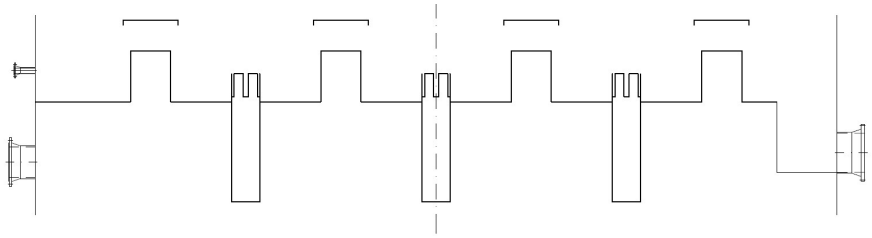


Fig. 8a Slits applied to the transit chimney tray

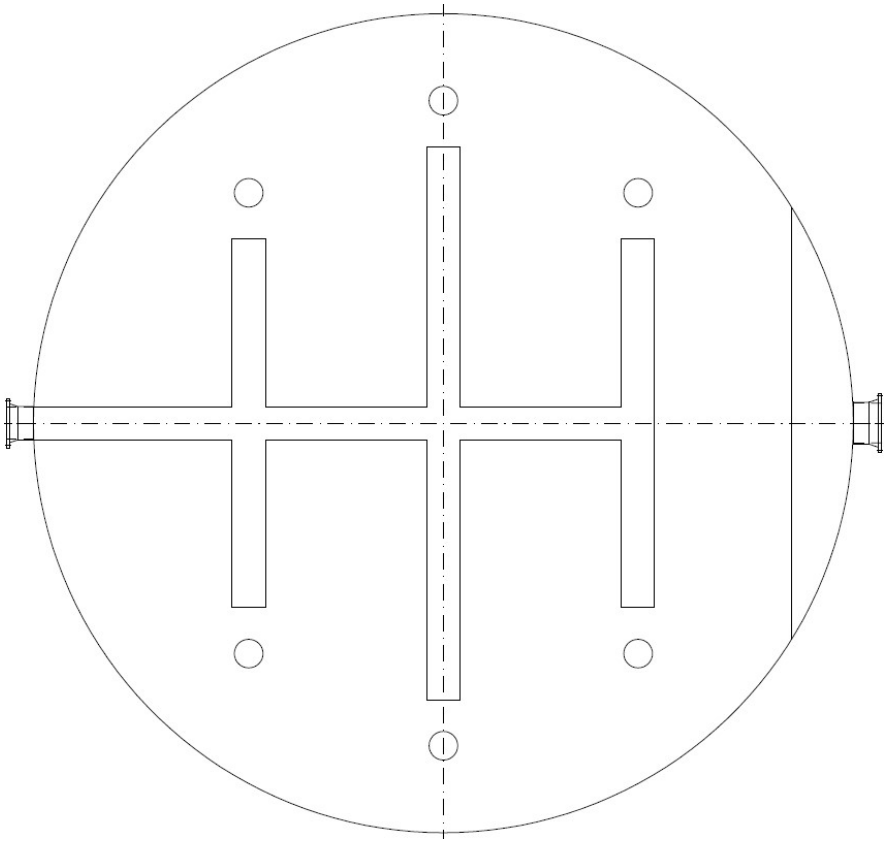


Fig. 8b The liquid inlet spider below the transit tray

Conclusions:

For a side draw-off tray, liquid hydrostatic head provides necessary driving force for liquid to flow to both draw-off nozzles and internal overflow pipes. Insufficient head leads to reduced flow as demonstrated in the three cases reported in this paper. Design of a side draw-off tray varies in detail despite that there are only two broad categories, i.e. trapout and chimney tray. The design must be based on process requirement and the portion of the liquid being drawn-off. In addition, to prevent similar failures in the future, the impact of modifications of the external pipe and other seemly minor features must be properly clarified, including the consultation of the supplier of the column and internals.

References:

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2. N. Lieberman and E. Lieberman, *Working Guide to Process Equipment*, McGraw-Hill Education, 2014, 182-195.