A photograph of a modern architectural interior. The ceiling is a light blue-grey color with three large, circular, recessed skylights. The walls are made of a textured, light blue-grey material. On the right side, there is a glass railing with a dark metal handrail. In the background, a dark wooden door is visible. The overall atmosphere is clean and minimalist.

MICHAEL SCHULTES,
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PRESENT A MODERN
LIQUID DISTRIBUTOR AND
REDISTRIBUTORS DESIGN.

ALL THE MOD CONS PART 2

High performance packings can provide their best efficiencies to gas-liquid mass transfer processes only if the liquid is distributed to the packing via a distributor that allows homogeneous liquid distribution and if the distributor is not overflowing. In the first part of this article design criteria had been described for a proper design of a distributor height and the liquid outflow performance.

The following part shows how a distribution quality can be determined and how the efficiency of a mass transfer tower is influenced by the distribution quality defined. Examples are discussed, where wrong distributor designs lead to severe failures in separation efficiencies mass transfer columns.

Defining the layout of the drip points and the distribution quality

When designing a liquid distributor, care must not only be taken to ensure that the liquid is distributed as evenly as possible over the column cross-section, but also that sufficient free cross-section is also provided to the gas countercurrent flow. With high gas loads, gas risers which are too narrow lead not only to a high pressure drop, resulting in a higher distributor design, but may also cause a deflection of the jets of liquid or even an entrainment of liquid with the gas flow. In addition, care must be taken at the layout procedure that drip points are not covered by beams or support rings.

Moore and Rukovena have developed a highly effective method for evaluating the quality of distributor designs.¹ According to these authors, each drip point is equipped with point circles whose total area is equivalent to the cross-sectional area of the column. Using the calculation procedure described by Moore and Rukovena, the quality of a distributor



design can be calculated according to Equation 1 with the aid of the distributor layout to determine factor A, B and C.

$$D_Q = 0.40 (100-A) + 0.60 B - 0.33 (C - 7.5) \quad (1)$$

- A = Cross section tower area not covered by point circles in %.
- B = least point circle area in 1/12 tower area divided by 1/12 tower area in %.
- C = area of overlap of point circles divided by tower area in %.

The method can be explained with the aid of two examples. Figures 1a and b show a deck type orifice

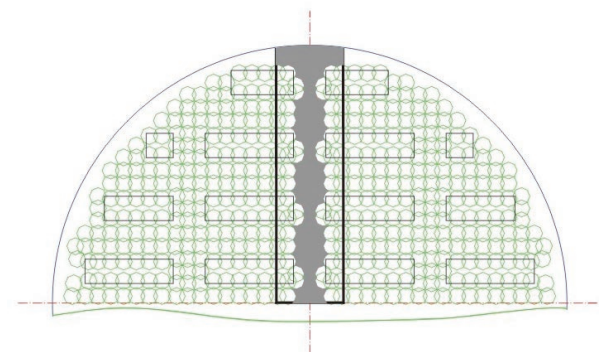


Figure 1a. Distributor layout with point circles for calculating distribution quality below beam location of a deck type distributor.

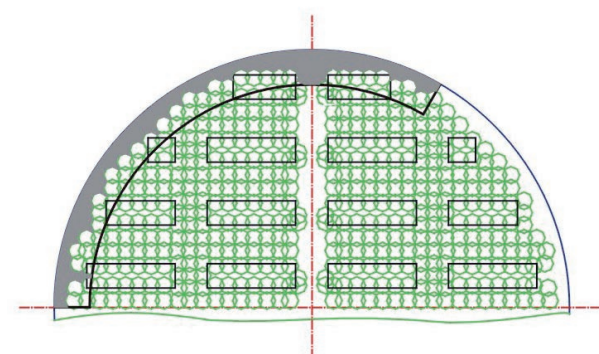


Figure 1b. Distributor layout with point circles for calculating distribution quality below support ring location of a deck type distributor.

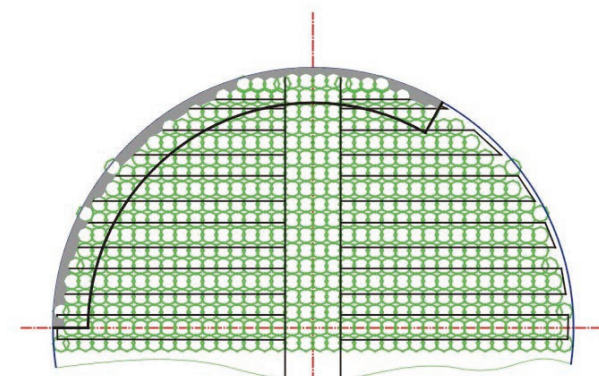


Figure 2. Distributor layout with point circles for calculating distribution quality below support ring location of a trough type distributor with enhanced liquid irrigation below support ring.

distributor, which has a centreline supporting beam, due to the large column diameter, and a support ring along the column wall. In order to calculate the distributor quality according to Moore and Rukovena, the most critical cross-sectional areas have to be detected. For Figure 1a, half of the support beam location is shown, and for Figure 1b, the 120° long segment of the support ring area is shown. The evaluation of the area portions recorded by Figures 1a and b yields a distribution quality of $D_Q = 63\%$ and $D_Q = 62\%$, respectively, since noticeable areas are not irrigated by the distributor.

Figure 2 shows for the same column diameter as before, a trough type distributor which, owing to its rigid trough walls, can be designed to be self supporting. Furthermore, the surface area below the support ring is partially used effectively, due to angled drain pipes. The 120° long support ring segment is now used for the evaluation of the distribution quality. The evaluation of this area, shown in Figure 2, reveals a distributor quality of $D_Q = 86\%$. The quality of a distributor can be classified according to Moore and Rukovena in three categories, by Table 1.

Figure 3 shows the influence of the distribution quality number D_Q on the number of theoretical stages n_{th} that can be expected for various distillation or absorption systems. The curves are based on industrial performance data reported by Moore and Rukovena where distributors with D_Q values less than 70% (standard type) had been revamped to intermediate or high quality distributors.¹ Whereas for absorption and desorption processes with high liquid and moderate gas loads, a standard distributor quality is often sufficient, for more difficult distillation processes, an intermediate distributor quality or a high quality distributor should be used.

Distributor test

Once the design of a liquid distributor has been completed and the distributor has been built, it is advisable to carry out a distributor test. The test should not only check the empirical variables influencing the distributor design but should, in particular, reveal the influence of manufacturing tolerances and manufacturing errors (Figure 4).

Examples

The following three examples are to illustrate the importance of liquid distributors for the performance of mass transfer columns.

Example 1

A column was equipped with 50 mm ceramic Pall rings and, during the next shutdown time, it was discussed to be converted to a modern metal high performance random packing. For reasons of cost and time, the existing distributor had to be kept as used. During the technical discussion, both the packing revamp and the existing distributor situation were studied. Figure 5 shows the column sketch.

The column consists of an upper part with a diameter of 1.4 m and a lower part with a diameter of 2 m. The packed

Table 1. Distribution quality number D_Q categorised according to Moore and Rukovena¹

Commercial standard distributor	$D_Q = 10 - 70\%$
Intermediate quality distributor	$D_Q = 70 - 90\%$
High quality distributor	$D_Q = >90\%$

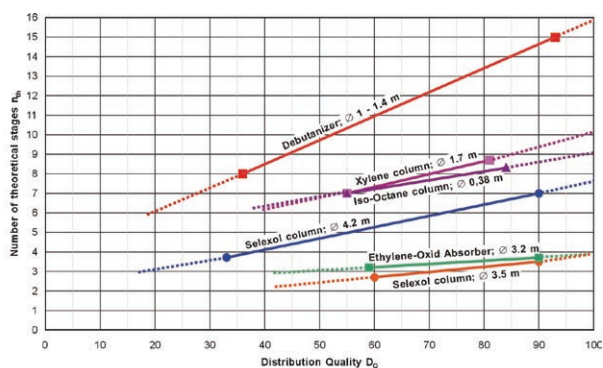


Figure 3. Influence of distribution quality number D_0 on the number of theoretical stages for various mass transfer systems.



Figure 4. Distributor test facility at Raschig workshop for distributor testing up to 12 m diameter.¹¹

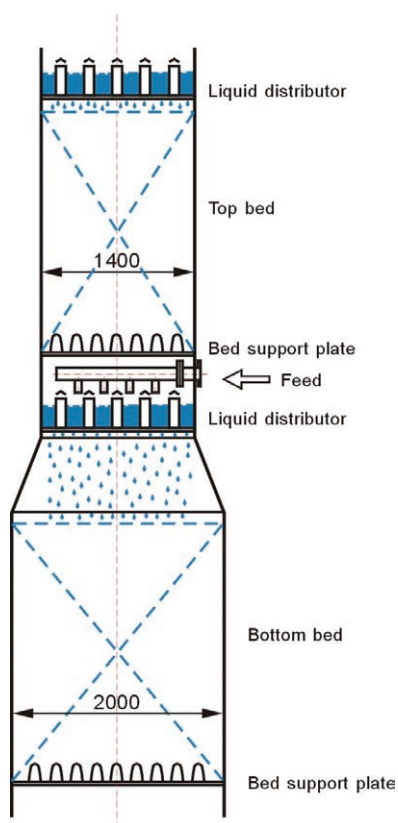


Figure 5. Principle column sketch with underirrigation of bottom bed by liquid distributor located in column top section.

bed that had to be replaced was in the lower part of the column. Unfortunately the liquid distributor for the lower section was located in the upper part. This means that an area roughly 50% of the lower total column cross sectional area had not been irrigated by the liquid distributor. Since ceramic Pall rings, with their significant wall flow tendency, rapidly bring the liquid to the column wall, the total column cross-section was wetted after a relatively short packing height so that the function of the column was ensured. If, in such a case, a modern metal random packing with only a very low wall flow tendency had been used, a considerable drop in mass transfer efficiency would occur, since the gas in the unwetted peripheral column area would not come into contact with the liquid. In the present case, a high performance packing was not used, but a 50 mm metal Pall ring.

Example 2

A customer ordered modern plastic packings in order to restart operation of an existing ammonia stripper, which was previously equipped with ceramic random packings. After commissioning, the customer observed that the mass transfer efficiency of the ammonia stripper was practically nil.

During the technical discussions, the design of the existing distributor, which consists of a trough system with a parting box and a feed pipe, was discussed. Figure 6 clearly shows that only three narrow distributor troughs had been installed in the existing column, which had a diameter of 2 m. The feed pipe had a discharge funnel which had to feed the liquid into the parting box, which was also narrow.

It was clear that the high liquid load from the feed pipe only partly reaches the parting box and a noticeable portion of flow would pass the trough. Furthermore, it could be seen that the three narrow distributor troughs below were, by far, not able to distribute the liquid evenly over the modern random packings across the entire column cross-section. After a new feed pipe and a new liquid distributor were installed, the function of the column was ensured.

Example 3

A large distillation unit was designed for using mass transfer trays at the top of the column and modern random packings in the lower part of the column. The customer ordered the trays, random packings and deck type liquid distributors at the packing supplier, but left the designing of the column to the column manufacturer. Figure 7 shows the original column layout which displays the following failures.

From Figure 7, it can be seen that the liquid leaving the tray section was not mixed with the lateral feed entering the column below, which means it was fed uncontrolled onto the deck distributor. Since the quantity of liquid from the tray section was relatively large, a markedly different liquid head, followed by significant cross flow behaviour with wave formation on the distributor, was expected. Because the residence time on the distributor was not sufficient to level out the difference in liquid head or to achieve a homogeneous mixture of both liquids, a maldistribution of the liquid and a reduced mass transfer efficiency of the bed section lying below was presumed.

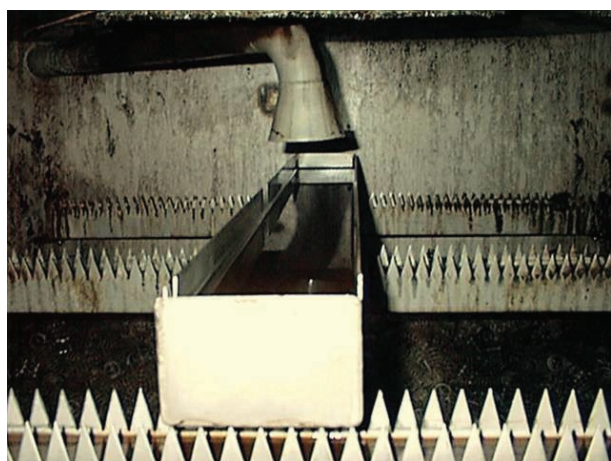



Figure 6. Underirrigation of packed bed by trough type distributor with V notches.

In addition to the described effects, the column manufacturer cancelled a feed pipe design so that the liquid was fed only via the column nozzle. In order to save column height, the feed nozzle was located directly above the support ring of the liquid distributor. The consequence of this would have been that the incoming liquid would have impacted directly onto the first gas risers of the deck type distributor and partly flowed into them. Since the faulty design was recognised before the columns had been erected, it was possible to avoid malfunction by modifying the column design.

Conclusion

The above shows that a modern distributor design depends on several factors. When designing a distributor, not only the fluid dynamic behaviour of liquid flowing out of orifices, but also system related conditions, such as foaming and degassing, have to be taken into account (Part 1).² A modern distributor design also reflects that the drip points have to be evenly distributed over the column cross-section. It is shown, with the help of three examples, what negative effects faulty distributor design can have on the function of mass transfer columns. 

Nomenclature

D_Q	Distribution quality number
n_{th}	Number of theoretical stages

Acknowledgements

Sadly Michael Rink passed away after the writing of this article.

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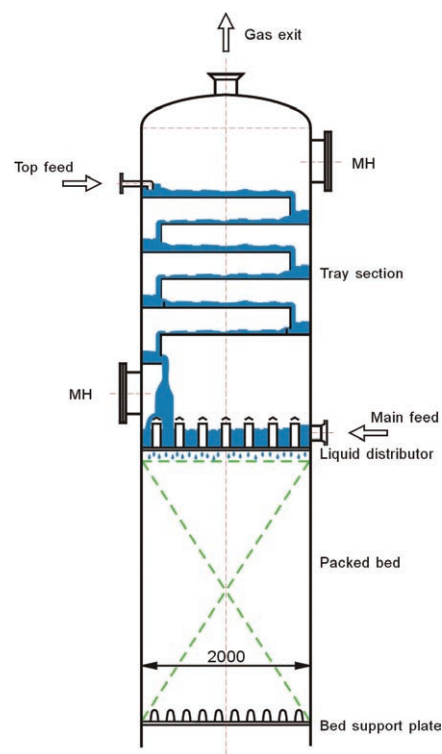


Figure 7. Principle column sketch with trayed top section and packed bottom section; maldistribution of liquid by liquid overflow from tray section and main side feed.