Improving packed tower performance

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Since its introduction in the late 1970s, sheet metal structured packing has revolutionised low pressure distillation. The 1980s and early 1990s saw a proliferation in the number of different structured packing types on the market. The main difference between these packing types was the surface area they provided. However, this period saw no groundbreaking innovations in the field of structured packing. During the last decade several innovations increased the capacity and efficiency of towers packed with structured packing. This article highlights some of these advances.

Packing innovation

Realising that one of the major capacity limitations is at the interface between two successive layers of structured packing led to the development of FLEXIPAC® HC® packing in the mid 1990s. In this packing, a part of the flow channel is turned vertical where the layers rest on top of one another[1]. If these vertical pieces are too short, it offers very little capacity benefit. If these vertical pieces are too large a part of the overall element height, the efficiency of the element will suffer. FLEXIPAC HC structured packing was optimised to obtain the maximum capacity without sacrificing efficiency. This can be seen in Figure 1.

Since the introduction of FLEXIPAC HC packing, the geometry was further optimised. As Figure 1 clearly illustrates, the new generation of FLEXIPAC HC packing has significantly better efficiency and capacity than the original sheet metal structured packings.

Depending on the application, it is possible to achieve 15% higher capacity and 15% more theoretical stages than with the original sheet metal structured packing. In a close boiling separation running at high reflux ratios, replacing first generation structured packing with the latest FLEXIPAC HC structured packing could give a feed rate increase of approximately 30% whilst maintaining the same purity values. At the same time, the utility consumption and reflux rate would increase by only 10%.

Innovation in packed tower internals

Distributors

When sheet metal structured packing was introduced, the knowledge that was gained with the distribution of liquid onto beds of random packing was put to use. As a result of this approach, a certain number

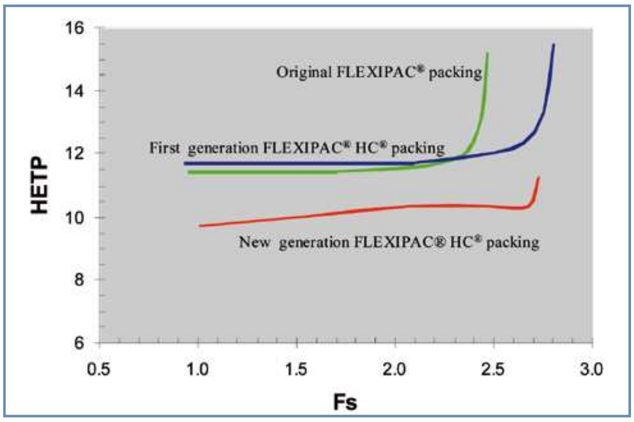

Figure 1. Total reflux efficiency and capacity of FLEXIPAC® structured packing (measured using a binary test mixture).

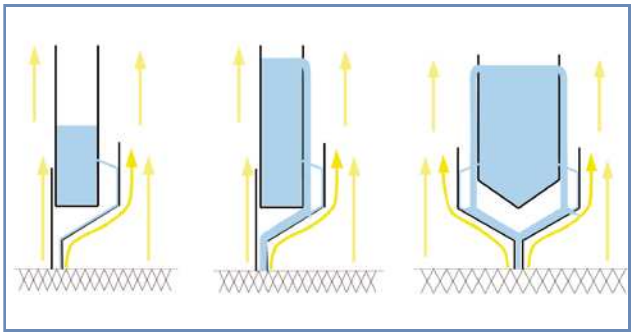

Figure 2. Schematic representation of the principle of operation of Koch-Glitsch's Enhanced Baffle Plate Distributor.

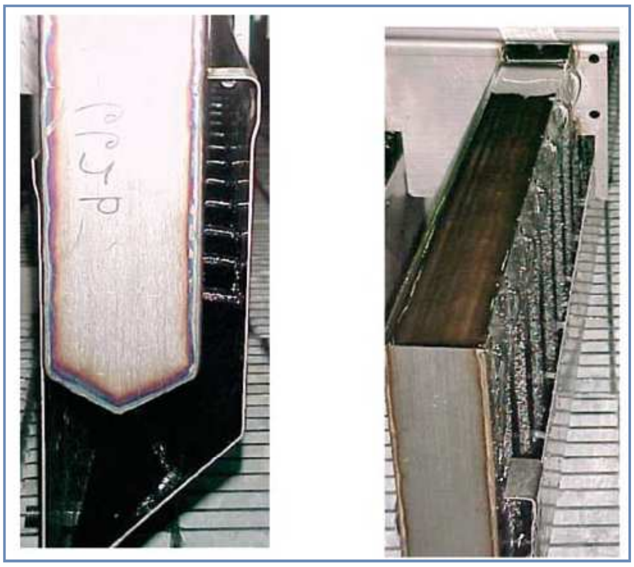

Figure 3. Enhanced Baffle Plate Distributor under normal operation (left) and overflow conditions (right).

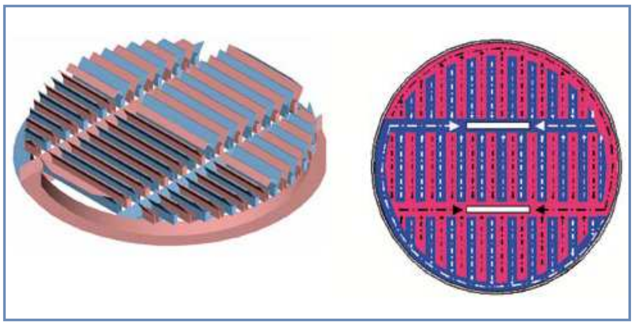

Figure 4. Mixing collector.

of drip points per unit area was specified for a certain packing. It was also important to ensure that these drip points were spaced in such a manner that even irrigation of the packing was obtained. Distribution quality indices were developed to guide designers in the placement of the drip points[2].

However, unlike random packing that spreads liquid in all directions, structured packing spreads liquid in one direction only. One may thus argue that, with a distributor with discreet drip points, the first layer of structured packing will spread the liquid in one direction and, that the next layer below, which is rotated by 90°, will spread the liquid in the other direction. Thus it will take the best part of two packing layers to get an even liquid distribution. If the liquid can be distributed as a curtain of liquid that runs 90° to the sheets of the top layer instead of discreet drop points, distribution in one direction is taken care of. The first layer of packing then only has to spread the liquid in the other direction. If these curtains of liquid are close enough together, it will take less than one packing layer to have an even liquid distribution. It may be argued that thin curtains of liquid can disintegrate into fine liquid droplets more easily than the thick liquid streams from discreet drip point distributors, and that these fine droplets will be entrained. These arguments led to the development of the patented Enhanced Baffle Plate Distributor[3] (Figure 2).

In the Enhanced Baffle Plate Distributor, the liquid from the troughs are metered onto a baffle plate with surface treatment. The parts are dimensioned in such a way that an even liquid curtain is obtained at the bottom of the baffle plate. Several measures are employed to ensure that the liquid curtain does not disintegrate. A shield plate can be put next to the baffle plate in such a manner that the vapour would not get in contact with the liquid as it is flowing down the baffle plate. In the case of higher liquid load applications, the shield plate can be replaced with a second baffle plate. This second baffle plate is irrigated from metering holes on the other side of the liquid trough. The disintegration of a liquid curtain is a function of the height of free fall it is subjected to. In the case of the Koch-Glitsch Enhanced Baffle Plate Distibutor, the edges of the baffle plates rest on the packing, which limits the free fall to virtually zero. In a recent air/water test of an Enhanced Baffle Plate Distributor (installed over a bed of INTALOX® 5TX structured packing), virtually no entrainment was observed at a C-factor of 0.158 m/s (0.52 ft/s). The troughs can be levelled independently from the baffle plates. This means that the baffle plates are allowed to follow the potential unevenness of the packing without affecting the level of the distributor. If the packing is out of level, liquid may track along the bottom edge of the baffle plates. To prevent this, the bottom edges of the baffle plates are serrated. The overflow notches drain onto the baffle plates, which means that even in upset conditions where the troughs overflow, the distributor will still function normally without excessive entrainment (Figure 3).

The Enhanced Baffle Plate Distributor was designed to maximise the performance of structured packing:

- The packed height needed to achieve an even liquid distribution is reduced, which means that more stages per height of tower can be realised.

- The open area of this distributor is high, which translates to low pressure drop.
- The liquid curtain is shielded all the way to the packing, reducing the risk of entrainment in towers packed with modern high capacity structured packing.

The performance of Enhanced Baffle Plate Distributors is discussed in more detail in the following case study.

Liquid collection and mixing

To ensure that the liquid composition and the L/V ratio is the same across the tower cross-section, the liquid from a bed is collected, mixed and sent to a distributor to be redistributed to the bed below. This is particularly true for a large diameter tower with tight composition specifications. A mixing drum is typically used to ensure a uniform liquid composition to the distributor below. This mixing drum takes up a considerable amount of tower height.

This drawback of the mixing drum was overcome by rolling the function of the mixing box into the collector[4]. Schematic representations of the patented mixing collector are shown in Figure 4. The key is to get the same amount of liquid from all parts of the tower to go to each of the drain points. This is accomplished by sealing off the ends of the flow channels of the vane collector in an alternating pattern. The liquid from the drain points in the vane collector can be piped directly to the parting boxes of the distributor below. As Figure 5 shows, this new mixing collector saves approximately 1 m of tower height at each redistribution point compared with the case where a mixing drum is used. In a new tower, this can be used to reduce the tower height by approximately 15% (depending on the bed heights and number of beds). In the case of an existing tower, the mixing collector can be used to increase the number of stages by approximately 15%. The increased number of stages can be used to increase product purity, to reduce the energy consumption, or to increase throughput.

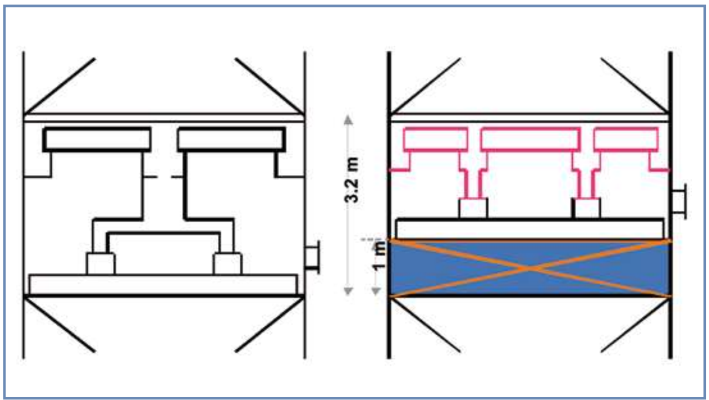

Figure 5. Height savings of mixer collecter.

Table 1. Comparison of test results (first generation FLEXIPAC® HC® packing)			
	Wichita test tower o/p-xylene	**FRI test tower o/p-xylene**	**Ethylbenzene/ styrene splitter**
Packing	FLEXIPAC 1.6Y HC	FLEXIPAC 1.6Y HC	FLEXIPAC 1.6Y HC
Total packed height (m)	3.19	3.48	> 40
Number of beds	1	1	6
Diameter (mm)	387	1213	10060 / 8380
Distributor	Pan type 59 drip points/m^2	110 drip points/m^2	Enhanced Baffle Plate Distributor
Redistribution			Mixing collector
HETP (mm)	310	305	316
Measured overall pressure drop (mbar)			92
Predicted overall pressure drop (mbar)			98

Case study

An ethylbenzene/styrene splitter was recently revamped with first generation FLEXIPAC HC structured packing, Enhanced Baffle Plate Distributors and mixing collectors. The same packing was tested in the Koch-Glitsch test tower and at the FRI using the o/p-xylene test system. The results from these three towers are summarised in Table 1.

As the properties of the ethylbenzene/styrene system are very similar to that of the o/p-xylene test mixture, direct comparisons are possible. The HETP values are remarkably close considering the differences in tower diameter. This may be attributed to the quality of liquid distribution that was obtained with the Enhanced Baffle Plate Distributor. The pressure drop models in the Koch-Glitsch in-house hydraulic program are based on results from the Wichita test tower. The quality of these models is evident from the excellent agreement that was obtained between the predicted and experimental pressure drop values.

Conclusion

Over the last decade significant improvements were made to structured packing and column internals. These innovations offer the following benefits:

- The latest generation of FLEXIPAC HC structured packing offers approximately 15% higher capacity and 15% more theoretical stages than the original sheet metal structured packing
- The Koch-Glitsch Enhanced Baffle Plate Distributor minimises entrainment and pressure drop, and maximises the separation performance of towers with structured packing.
- The Koch-Glitsch mixing collector can be used to reduce tower height of large diameter towers, or to increase the packed height per bed by approximately 1 m. This translates to approximately 15% more stages in the tower.

Notes

FLEXIPAC®, FLEXIPAC® HC® and INTALOX® are registered trademarks of Koch-Glitsch. Available exclsuively from Koch-Glitsc, LP, FLEXIPAC® HC® structured packing is protected by US Patent 5,632,934 and other patents worldwide assigned to Praxair Technology Inc. Koch-Glitsch, LP is the exclusive worldwide licensee of Praxair Technology, Inc. for the manufacture and sale of this packing in all markets except for industrial gas separation.

References

1. US patent No. 5632934.
2. MOORE, F., RUKOVENA, F., Liquid and gas distribution in commercial packed towers, Chemical Plants and Processing (European Edition), August 1987, p.11.
3. US patent No. 6722639.
4. US patent (pending) 20040195707 A1.