

OVERCOMING CHALLENGES

PART ONE



Izak Nieuwoudt and Neil Sandford, Koch-Glitsch, USA, look at addressing the challenges involved with large diameter trayed towers.

Rising demand for polymers in developing markets such as India, China and the Middle East continues to drive strong growth in olefins production. Market projections for the most important intermediates, ethylene and propylene, indicate conservative growth rates of at least 4% until 2025.¹

In North America, the continued rapid expansion of shale oil and gas exploration and production have created an abundance of cost-advantaged ethane and propane to feed new ethane crackers and propane dehydrogenation (PDH) plants. Driven by economies of scale, the trend is for these new plants to target ever larger production capacities. An important separation step requires a large superfractionator tower to distil the ethylene or propylene to polymer grade purity. To handle the capacity of these mega plants, larger and larger diameter splitter towers must be designed and built. This first part of a two part article will review the design challenges of these large splitter towers.

In order to tackle these challenging operating conditions, Koch-Glitsch has developed a range of high-performance mass transfer devices including the SUPERFRAC® tray and ULTRA-FRAC® tray. Traditionally, SUPERFRAC trays were used to revamp existing towers for improved performance, but they are currently being specified for new grass roots installations to minimise equipment diameter, height and overall investment cost.

This increasing equipment size has brought new challenges for mass transfer equipment suppliers. To meet these challenges, new trays and tray support structure designs have been developed. With these new approaches, it is possible to build splitter towers of more than 33 ft (10 m) in dia. while achieving excellent tray efficiency and capacity.

The SUPERFRAC XT tray was developed specifically to meet the demands of the next generation of superfractionators. Combining hydraulic, separation and mechanical design expertise to maximise the tray performance

in the most demanding fractionation services and large diameter towers, often requires complex multiple flow pass designs.

Tray optimisation

In the design of trays for large diameter splitters there are a number of challenges that need to be addressed:

- High liquid rates often require an increase in the number of flow passes. The number of passes influence the capacity and efficiency of the tray. The challenge is to maximise both the efficiency and the capacity. The tray configuration, downcomer shape and valve type play a role in the performance.
- Feed, reflux and reboiler return arrangements can significantly affect the performance of the tower and must be optimised for the specific tray design. CFD studies (Figure 1) are used to do these optimisations. Optimised downcomer arrangements and tray layouts

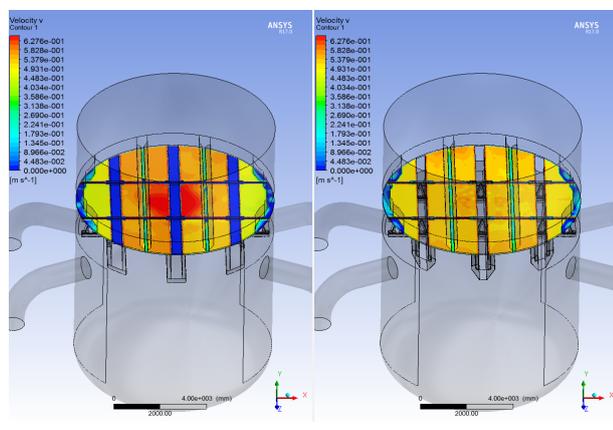


Figure 1. CFD study of complex reboiler returns in large diameter splitter column.



Figure 2. Koch Glitsch's 5.5 ft (1.67 m) pilot plant for distillation testing with hydrocarbon mixtures.

were developed for the trays and were combined with optimised valve selections and layouts to maximise the capacity and efficiency. These new trays were tested in the 5.5 ft (1.67 m) dia. tower (Figure 2) in the Koch-Glitsch R&D facility.

Optimised tray designs were used in the splitters covered in the case studies, yielding efficiencies of 92 – 100%. These high efficiencies have been used to achieve combinations of the following benefits:

- Reducing the number of trays, which would reduce the tower height.
- Reducing the reflux ratio. This will lower the energy consumption, including that of the heat pump compressor. The reduced reflux will yield a smaller dia. tower, or for a fixed dia., the capacity can be increased.
- By reducing the number of trays, the overall pressure drop of the tower can be reduced. This will reduce the energy consumption of the heat pump compressor.

Mechanical design challenges

Some of the mechanical design challenges that need to be addressed in these large towers include the following:

- How are the trays supported with devices that do not interfere with the hydraulic and separation performance?
- Can the deflection of the trays and support structures be limited to where it does not influence the tray performance?²
- What is the optimal tray arrangement to minimise the tower diameter and to effectively deal with the high liquid rates?
- Is it possible to achieve high tray efficiencies in these large towers that will allow a reduced number of trays to minimise the tower height?
- Can high tray efficiencies be realised that would reduce the tower pressure drop and reduce the energy consumption of the heat pump compressor?

Additionally, many existing producers have reconfigured their plants to utilise lower cost feedstocks and have taken advantage of the opportunity to make incremental improvements to the plant capacity, requiring improved performance from the distillation equipment. This has required the development of new revamp strategies to optimally reconfigure the fractionation tower internals in a timely manner. In some cases, this requires changes to the number of flow passes or tray spacings to be accomplished without major welding work in the tower.

To address these challenges, Koch-Glitsch has developed a number of novel solutions. When completing the detailed mechanical design for these large diameter towers, the company can utilise finite element analysis (FEA) to optimise the support structure for each tower.

The SECTIONALISED BEAM (Figure 3) and PINNED-TRUSS (Figure 4) support mechanisms are patented³ support structures that have been developed to enable supporting devices in large diameter towers without negatively affecting hydraulic performance. The SECTIONALISED BEAM support structure is split into two parts that can be passed through a tower manway, while the PINNED-TRUSS is split into

many parts. In either case, the pieces are bolted together inside the tower without welding being required, and the load is transferred between the pieces by large pins that are shop-welded to one of the pieces. The bolts are simply holding the two pieces together without having to transfer the load. Both mechanisms can be pre-cambered to allow

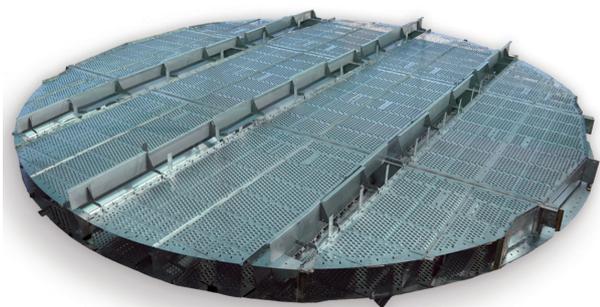


Figure 3. 8-Pass SUPERFRAC XT trays with SECTIONALISED BEAM support structure.



Figure 4. A PINNED-TRUSS beam used to support three levels of trays.

Table 1. Examples of splitter towers with SUPERFRAC trays

Splitter	New or revamp	Tower dia.	Tray type	Number of passes	Tray efficiency
C2 Splitter	Revamp	12.5 ft (3.8 m)	SUPERFRAC	2-pass	>96%
C3 Splitter	Revamp	16 ft (4.9 m)	SUPERFRAC	6-pass	100%
C3 Splitter	Revamp	28 ft (8.5 m)	SUPERFRAC XT	6-pass	94%
C3 Splitter	New	18.5 ft (5.6 m)	SUPERFRAC XT	4-pass	>95%
C3 Splitter	New	33.5 ft (10.2 m)	SUPERFRAC XT	8-pass	>90%

the trays to be flat under operating loads. Feedback from installation crews noted savings of up to 80% compared to field welded construction.

The OMNI-FIT® technology can be used to install trays without having to weld to the tower shell. This technology can be used in conjunction with the support technologies described above. This technology includes, amongst others, items such as:

- Downcomer adapters to change the size and shape of downcomers while reusing existing tower attachments.
- Boxed downcomers that allow the number, location and size of downcomers to be altered without having to do welding to the tower shell.
- FLEXILOCK® tray construction that allows panels to be snapped together, saving installation time and still creating a rigid assembly.
- Expansion rings supported from the existing tray ring in cases where the tray spacing was changed. The expansion rings eliminate welding to the column wall during the turnaround.

SUPERFRAC trays, combined with the mechanical design technologies described above, have demonstrated excellent performance in several large C2 and C3 splitter applications (Table 1).

Conclusion

The mega splitter towers in modern world scale olefins plants are pushing the boundaries of tray technology. To address the challenges in these towers, novel support mechanisms and tray arrangements were developed to extend the boundaries in excess of 40 ft (12 m).

This allows debottlenecking of existing splitters or a reduction in diameter and height for grassroots splitters. It also allows the energy consumption of these mega towers to be minimised. In the case of heat-pump splitters, the energy consumption and size of the heat-pump system may also be minimised. It is not necessary to find a trade-off between capacity and efficiency.

Co-current flow ULTRA-FRAC trays are now being used to further extend the capacity of splitter towers beyond even that of SUPERFRAC trays. This includes splitters already equipped with high capacity counterflow trays that consist of a multitude of criss-crossing downcomers.

Part two of this article will showcase the application of these technologies by delving deeper into the details of a complex, time sensitive splitter revamp project. 

References

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