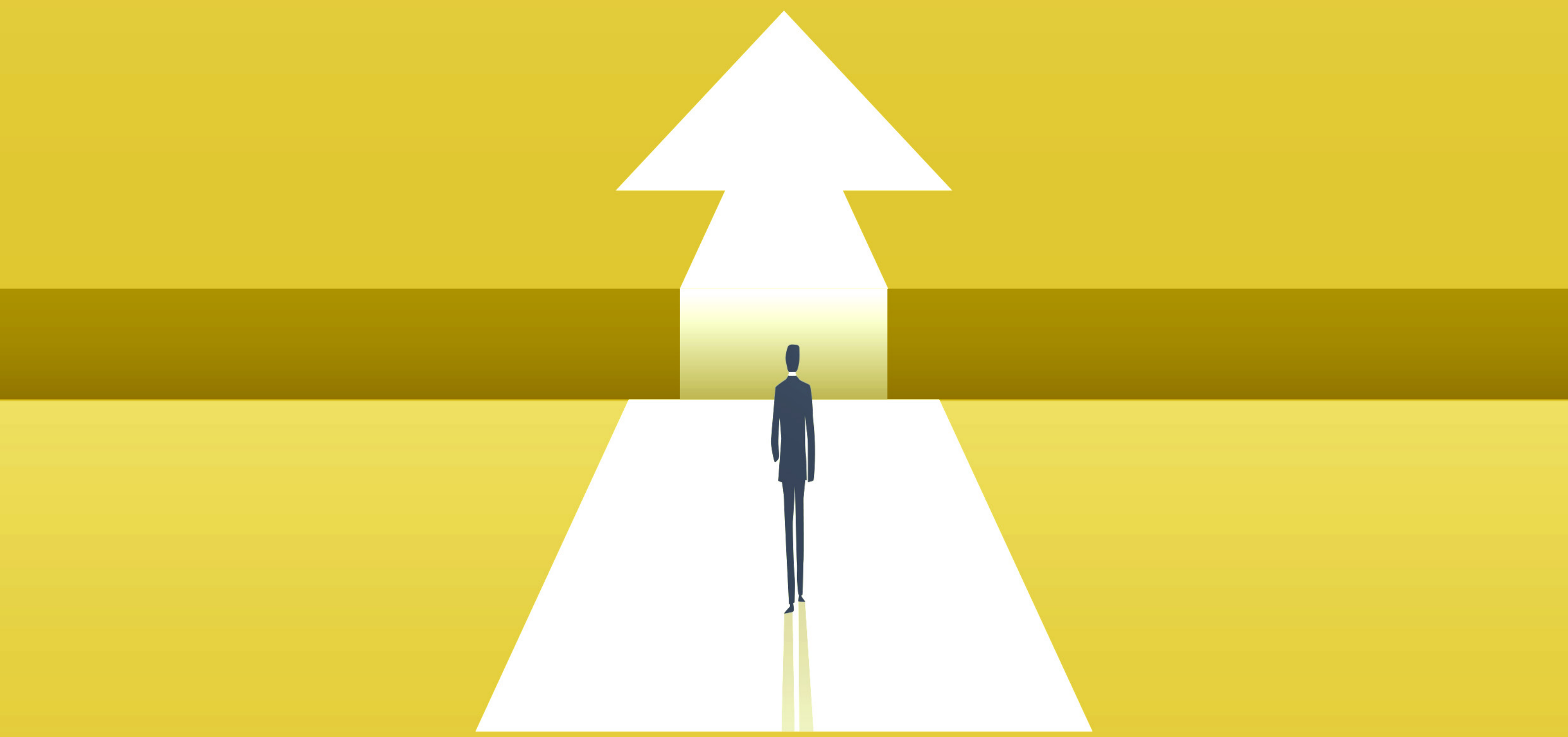
OVERCOMING CHALLENGES
PART TWO



In this concluding article, **Izak Nieuwoudt and Neil Sandford, Koch-Glitsch, USA,** use case studies to question whether there needs to be a trade-off between capacity and efficiency in large diameter trayed towers.

Part one of this article, published in the April 2019 issue of *Hydrocarbon Engineering*, reviewed the design challenges of large super-fractionator towers.[1] Areas of key importance were identified in tray design optimisation and the mechanical design challenges of large diameter distillation towers. The following process and mechanical technology solutions were also introduced:

- High performance SUPERFRAC® XT trays.
- The SECTIONALISED BEAM support structure.
- The PINNED-TRUSS beam.
- OMNI-FIT® technology for tower revamps.

This concluding second part will showcase the application of these technologies in time-sensitive splitter revamp projects, as well as a grassroots project.

Case study 1 - revamp of a C3 splitter propane dehydrogenation (PDH) plant

The tower shown in Figure 1 was originally installed with 4-pass fixed valve trays. On initial start-up the tray efficiency was poor, generating too few stages to allow the splitter to produce polymer grade propylene product. Despite one attempted fix, the trays were still plagued by low tray efficiencies, resulting in a significant shortfall in polymer grade propylene production. The plant eventually installed a prefractionation tower to make up for the deficit in stages being provided in the main propylene product splitter.

Following successful commissioning of the prefractionator tower, market conditions were favourable for another increase in capacity. The owner targeted a revamp solution that would ensure 100% of the propylene product to be polymer grade at a significantly higher feed rate. Though Koch-Glitsch did not supply the original equipment, given the history of poor tray performance in the C3 splitter, an extensive review of the tray technology to be used in the revamp was made by the plant engineering staff together with an independent third-party consultant. The review included a demonstration in Koch-Glitsch's 5.5 ft (1.67 m) hydrocarbon pilot plant distillation tower, which closely reproduced the hydraulic design conditions for the revamp. Following this review, a 6-pass SUPERFRAC XT tray design was selected. Several of the features discussed above were included in this design. This included extensive use of OMNI-FIT technology that allowed the flow path length and downcomer widths to be changed without welding to the tower shell. More than 150 existing 4-pass trays were removed and replaced by 6-pass SUPERFRAC XT trays (Figure 2) plus two dedicated distributor trays and new feed pipes at the reflux and feed entry points.

The installation work was completed safely and on time. It only took 38 working days from the initial tower entry to the completion of the new tray installation. Such a compact schedule was only possible through a close one-source solution working relationship between the Koch-Glitsch equipment design team and the Koch Specialty Plant Services installation project team. The installation team made several key inputs during the detailed design phase that helped to shape the final equipment scope, ensuring it would allow rapid and safe installation while working on multiple levels in the tower. During the installation work in the field, the design team was constantly available to assist with timely resolution of any issues that arose.

Figure 1. This 28 ft (8.5 m) dia. x 330 ft (100 m) tall propane/propylene splitter was retrofitted with SUPERFRAC® XT trays.

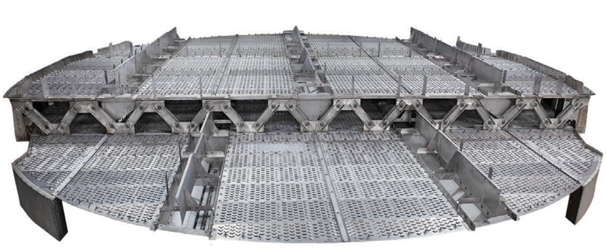


Figure 2. 6-pass SUPERFRAC XT trays with PINNED-TRUSS beams.

Following the revamp with SUPERFRAC XT trays, the overall tray efficiency increased from approximately 78% to 94%. The tower is now meeting the product purity goal at the higher feed rate. Propylene in the bottom product recycle is less than 50% of the design slippage, allowing the energy consumption (including heat pump compressor duty) to be optimised by reducing the reflux ratio. The new trays also have a lower pressure drop, which further reduces the energy consumption in the heat pump compressor.

Case study 2 – revamp of a C3 splitter

Due to an increase in the global demand for polymer grade propylene, the operating company embarked on a programme to increase its propylene production capacity.[2] It wanted the maximum possible capacity while maintaining recovery and purity specifications. The tower was equipped with 4-pass valve trays. Koch-Glitsch analysed the plant data and concluded that the trays were limited by jet flood and downcomer flood limitations. In an un-flooded state, these 4-pass valve trays were giving efficiency values of approximately 98%.

The operating company evaluated several alternatives before deciding on revamping the tower with 6-pass SUPERFRAC trays. The challenge was to get the same or better tray efficiency with trays that had flow path lengths that were approximately 33% shorter. To address this, the following features were used on these trays:

- Downcomer shapes and sizes that would maximise the downcomer capacity.
- Valves and valve arrangements that would maximise the entrainment flood capacity and efficiency.
- Features to regulate the froth flow pattern and froth heights to maximise the tray efficiency. Changes in the number of downcomers and the downcomer sizes could be accommodated using the OMNI-FIT technology.

After an initial upset caused by a faulty sump level transmitter, the tower was started up successfully. Upon ramping up rates it was found that there was not enough condenser capacity and feed to push the tower to the capacity limit of the trays. At a capacity increase of 24%, these limitations prevented a further rate increase. The propylene purity and recovery was maintained at these increased rates. Over the whole operating range of the tests, the overall tray efficiency of the SUPERFRAC trays was 100%.

Case study 3 – revamp of a C2 splitter

This tower was producing only 76% of the desired ethylene production rate.[3] When the tower was pushed higher, the ethylene purity and recovery suffered. It was clear that both the capacity and efficiency of the trays were limiting the operating rates of this plant. The engineering company/licensor considered several alternatives, including trays with a large number of downcomers at a lower tray spacing. Due to the lower efficiency of such trays, the number of trays would have had to be increased by 23%.[4] The trays would have had to exhibit an increased capacity that would overcome a 23% reduction in tray spacing and give the customer the extra 24% capacity it was targeting. The amount of work needed to reduce the trays spacing would also have raised hot work issues and would have extended the shutdown.

The owner of the plant decided to use optimised SUPERFRAC trays for this revamp. The number of trays and tray spacing in the different zones of the tower were adjusted to achieve the maximum capacity and recovery given the purity constraints. This study showed that a one-for-one tray replacement with optimised trays would meet the objectives. Changes in downcomer arrangements could be accommodated using the OMNI-FIT technology. This approach removed the need for welding and significantly reduced the duration of the shutdown. In addition to the tray features discussed in case study 2, this revamp configuration also optimised the feed arrangement, reboiler return, side reboiler draw, and return and reflux distribution. Based on Koch-Glitsch calculations, the new tower arrangement would increase the ethylene production to 25% above the target set by the operating company. At that point the capacity would be limited by the reboilers, condenser and the pumps, and not the trays.

The tray installation and piping modifications were successfully completed within the allotted turnaround time. The tower was then started up without any issues and the product purity and recovery was reached quickly. Test runs were conducted to assess the separation performance and capacity of the revamped tower. At 96% of the desired rate, the upstream units reached their maximum capacity and it was not possible to push the tower to its limit. Even with the limitation of the upstream units the plant was able to increase its ethylene production capacity by 26%. Over the whole operating range of the tests, the overall tray efficiency was higher than 96%.

Case study 4 – a new C3 splitter in a grassroots PDH plant

An even larger propane/propylene splitter has been in service for over two years with the first ever 8-pass SUPERFRAC XT trays.[5] The 33.5 ft (10.2 m) dia. column has exceeded design capacity and product purity requirements from the initial start-up.

This grassroots PDH plant has a capacity that called for one of the largest C3 splitters in the world at just over 10 m in dia. and over 100 m tall. The plant owner selected SUPERFRAC XT trays based on criteria including proven performance, minimum tower size and ease of accessibility. Minimising the pressure drop was also an important factor since the splitter has a heat pumped reboiler driven by the compressed overhead vapours. The reliably high tray efficiency allowed fewer trays to be specified, resulting in a shorter vessel height, and lower pressure drop, requiring less compressor horsepower.

Koch-Glitsch worked closely with the owner's subject matter experts and their chosen engineering contractor to define the scope of the splitter tower internals. An 8-pass SUPERFRAC XT tray design with several of the features discussed above was selected for this application. With this being a new tower, the tray design, tower diameter and tray spacing could be optimised. Sectionalised beams were used to support the tray decks, with tray levelness being an important factor to ensure that the maximum performance would be achieved.

To minimise fit up errors, OMNI-FIT technology was used to significantly simplify the design of the supporting tower attachments that had to be welded inside the tower by the vessel fabricator. This provided greater flexibility to the tray installer to ensure an accurate installation was achieved. Even with the much-simplified tower attachment scope, several deficiencies in the fabrication of the tower had to be overcome during the installation.

On all towers the support rings must be levelled within a manufacturer-specified tolerance. The support ring level should be checked at the vessel shop before customer acceptance. A final check of the support rings should be made prior to beginning installation of the trays. If any of the rings exceed the specified tolerance for level, the tray manufacturer should be contacted immediately to agree upon a plan for rectification. For the PDH splitter, Koch-Glitsch sent a Certified Tower Specialist to the site to verify the tray installation, and he and the project team worked with the tray installers to ensure a quality outcome.

The PDH unit started up in November 2015 and by February 2016, it was running at full capacity, delivering polymer-grade quality propylene from the initial startup without any issues. The tower is meeting all capacity, purity and recovery expectations. The overall tray efficiency is above 90%, which is higher than what the engineering company assumed during the design phase. This allows the owners to adjust the reflux ratio to optimise the production and minimise the energy consumption.

Conclusions

The case studies presented in this article show that high tray efficiencies and capacities can be obtained with optimised SUPERFRAC XT trays. In C2 and C3 splitters, efficiencies of 92% to 100% have been obtained. 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.

References

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