



PICKING THE RIGHT WORKHORSE

Alessandro Ferrari, Izak Niewoudt, and Neil Sandford, Koch-Glitsch, evaluate the available tray technologies for pressure distillation towers.

In pressure distillation towers, the distillation tray is the workhorse of the mass transfer industry. Particularly for light hydrocarbon fractionation trains in olefins plants and NGL fractionating plants, the distillation tray is the device of choice to reliably and economically produce high purity products.

The available tray technologies fall into three major categories:

- Crossflow trays.
- Counter-flow trays.
- Cocurrent-flow or ultra-high capacity trays.

Crossflow trays

The first category, crossflow trays (Figure 1), are the most widely applied tray type. These include perforated or sieve trays, bubble-cap trays and floating- and fixed-valve trays. These devices demonstrate a good balance between investment cost, capacity and efficiency, and are typically used for newly constructed process plants, particularly in pressure distillation of light hydrocarbons.

Later in the life of process units, there is often a desire for an incremental capacity increase. If it is

possible to debottleneck the fractionating trains by only revising the column internals, the economic payback for such an incremental capacity increase is often very attractive. Random packing was, for a time, employed to increase the capacity of tray towers, but this is an expensive and time-consuming revamp strategy. Since the late 1980s, the mass transfer equipment companies have developed an array of improved higher capacity trays. Some of these are enhanced crossflow trays that maintain the crossflow configuration of standard trays, but use various enhancements to improve both the tray capacity and efficiency. Special downcomer shapes are employed to enlarge the bubbling area of the tray. Improved valve shapes are also employed to reduce entrainment and further increase capacity. Longer flow paths and/or more uniform residence time results in enhanced separation efficiency.

Counter-flow trays

The other main category of higher capacity trays are counter-flow trays which use a multitude of downcomers to reduce the liquid froth heights on the

tray deck. With counter-flow trays, the liquid flow path across the vapour/liquid contacting zone of the tray is relatively short, and less uniform than that which occurs on crossflow trays. This results in operation close to the point efficiency with little-to-no crossflow enhancement, so that this category of trays often exhibits reduced tray efficiencies compared to standard or enhanced crossflow trays.^{1,2}

The quality and uniformity of vapour and liquid contacting on the tray deck is largely responsible for the mass transfer efficiency of a tray device. Conversely, the capacity of a tray is determined by the ability to separate the liquid and vapour within the available tray

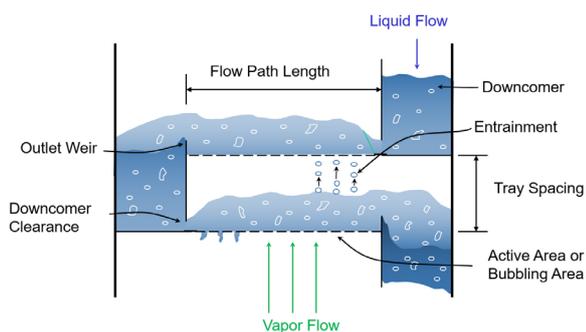


Figure 1. Crossflow tray terminology.



Figure 2. ULTRA-FRAC® tray by Koch-Glitsch.

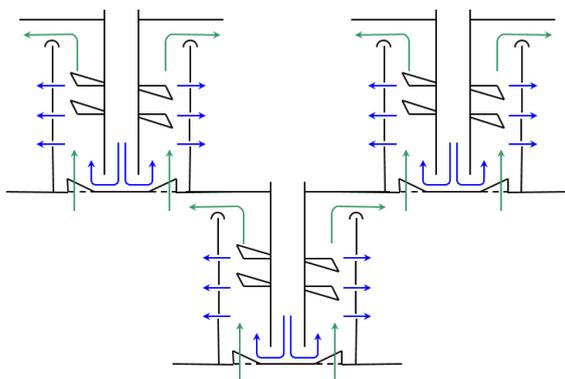


Figure 3. ULTRA-FRAC® tray operation.

spacing. If too much liquid is carried along with the vapour flow ascending to the next tray, this liquid entrainment may initially reduce the tray efficiency, and ultimately lead to flooding. Crossflow, or counter-flow, trays rely upon gravity to affect the vapour/liquid separation. Increasing the vertical distance between trays, or the tray spacing, can be a strategy to increase the tray capacity, but there are diminishing returns as the spacing is increased. Increasing the tray spacing when revamping an existing tower requires more careful consideration since the higher tray spacing comes at the cost of fewer mass transfer stages per unit of vessel height. A higher efficiency tray device is therefore required to at least maintain the same separation efficiency after the revamp. For practical purposes, the maximum capacity is usually reached as the tray spacing approaches 900 mm (35.4 in.). The Fractionation Research Inc. (FRI) System Limit defines a maximum vapour rate that is independent of tray type – applicable to all crossflow and counterflow tray types.

Ultra-high capacity trays

The final category of ultra-high capacity trays was developed specifically with the intention to overcome this system limitation. These trays use inertial separation by either centrifugal or impaction devices to perform the vapour/liquid separation and thus increase the tray capacity. Since they do not rely upon gravity to separate liquid and vapour, they can typically exceed the FRI System Limit by a significant capacity (more than 50%). Several of these types of trays emerged in the early 1990s, including the ULTRA-FRAC® tray (Figure 2).

The Koch-Glitsch tray in this category has been utilised in excess of 70 installations at the time of writing. The tray uses circular elements that are responsible for both the vapour/liquid contacting and separation. Figure 3 shows how each contacting element functions (the vapour path is shown in green and the liquid path in blue). Liquid enters the contacting element from the tray above via a circular pipe downcomer. Vapour enters from the tray below into the annular zone between the pipe downcomer and the circular contacting element. Devices inside the contacting element cause the vapour and liquid to rotate in cocurrent flow. After exiting the contacting zone, the liquid is forced to the inner circumference of the contacting elements from which it exits via a series of apertures. The liquid then drops down on to the tray deck where it flows towards the nearest pipe downcomer to feed the next tray down. Vapour, free of entrained liquid, exits from the top of the contacting elements and enters the next tray above.

A detailed understanding of both the capacity and efficiency characteristics of these high-performance devices is crucial to ensure a satisfactory outcome when revamping existing distillation towers.^{3,4} This aspect only becomes even more important when the tower is a superfractionator, as such towers are often designed close to their minimum reflux ratio in order to minimise energy consumption.

Case study – two tower C2 splitter revamp

A major olefins producer desired to increase the capacity of its ethylene fractionation train. This required the debottlenecking of a C2 Splitter that separates an ethane/ethylene feed. The fractionator consists of two vessel shells connected in series, as summarised in Figure 4. The lower part of the rectification section and the entire stripping section is within the first tower, which also includes two side reboilers to take advantage of heat integration within the plant. The remaining rectification trays are in the second tower, with the polymer grade ethylene product taken as a side draw, several trays from the top. Above the side draw is a pasteurisation section intended to reject light ends.

In spite of the fact that a recent revamp had been made using high capacity trays⁵, Koch-Glitsch was invited to study the performance of the existing towers to explore the possibility of a further revamp to increase the ethylene production rate. Koch-Glitsch process engineers specialised in olefins applications used a proprietary simulation model to benchmark the performance of the existing towers, and identified a possible path forward to achieve the aims of the customer. It was noted that while the fractionator was currently achieving the high purity ethylene required for polyethylene production, there was relatively high slippage of ethylene at the bottom of the tower, despite the unusually high number of trays employed.

The plant provided test run data that was used by Koch-Glitsch to model the existing operation of the C2 Splitter. This analysis confirmed that the reason for the high slippage of ethylene in the bottom product was due to the low tray efficiency of the existing devices, which was handicapping the overall performance of the fractionator.

A detailed revamp scope was evaluated considering various configurations and tray technologies. A solution was developed that involved a combination of enhanced crossflow SUPERFRAC® XT trays and co-current flow ULTRA-FRAC trays. In the majority of the tower, the new trays were installed using an increased tray spacing, taking advantage of the improved mass transfer efficiency of the new trays. By increasing the tray spacing, the trays were able to handle the increased internal vapour and liquid traffic while at the same time recovering more ethylene from the feed.

The reconfiguring of the mass transfer internals in these towers was accomplished during a planned 21 day plant turnaround. Of this period, only 17 days were available for the work inside the towers. Additionally, since the towers are both post weld heat treated (PWHT), it was necessary to perform the internal transformation without any welding directly on the pressure vessel envelope in order to meet the aggressive schedule. Fortunately, Koch-Glitsch has experience

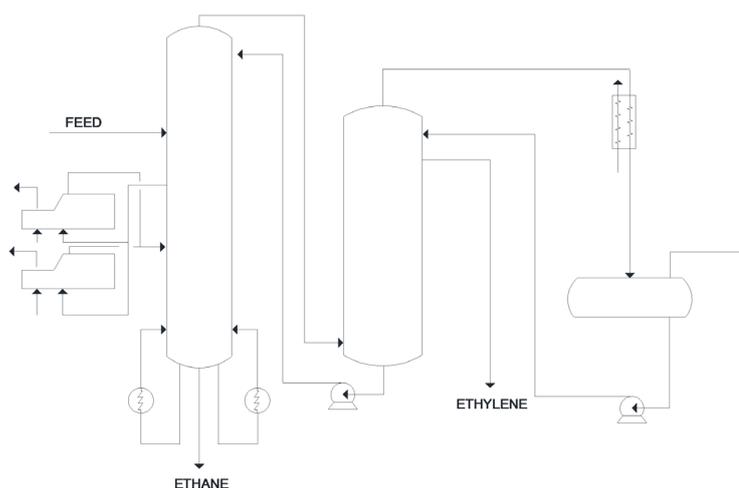


Figure 4. Two tower C2 Splitter flowsheet.

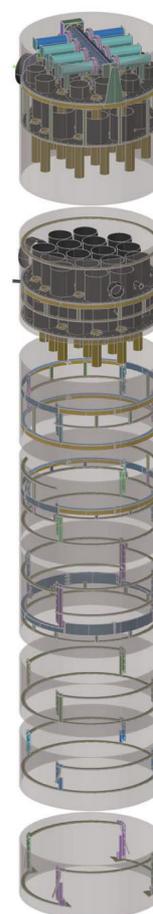


Figure 5. 3D model of OMNI-FIT® technology.

working under similar time constraints and complex tower revamps. OMNI-FIT® technology comprises special mechanical design techniques that have been specifically developed to allow the rapid and accurate installation of new higher performance devices. Changes of the tray type, the number of flow passes, the increasing or decreasing of the tray spacing and even conversion from packed internals to trays have all been accomplished using this technology without welding directly on the vessel shell.

The internal design phase used 3D modelling (Figure 5) to ensure accurate fit-up. Patented expansion rings and custom engineered support channels ensured accurate installation of the newly spaced trays. Additionally, since no new nozzles could be added, a detailed review of all feed and draw nozzles on the tower was performed to ensure these would be adequate for the future tower performance. This was of particular importance for the two side reboilers to ensure that the required heat integration was achieved.

Overall, the total number of trays installed in the two-tower fractionator was reduced by 14%. Even with this reduction, the ethylene losses from the bottom of the tower were reduced by more than 80%. Following the revamp, the ethylene production rate was increased by almost 8%. Currently, the C2 Splitter unit capacity after revamp is not limited by the new high-performance trays that were installed. There are external limitations within the plant, but once these other bottlenecks are resolved, the plant capacity will be further increased. In order to test the future potential capacity when more feed will be available, the plant temporarily routed some extra feed from another unit to this one and proved that ethylene production could be boosted by approximately 12%, while still maintaining the same high recovery.

Koch-Glitsch provided performance guarantees covering the ethylene product purity and recovery.

Additionally, there were two modes of operation with varying heat input to the side reboilers. For all operating modes, the specifications for the ethylene product capacity and recovery were achieved or exceeded.

As new higher performance mass transfer technologies are developed, it becomes more difficult for the non-expert in an operating company to verify the claims of the companies seeking their business. Pilot plant performance data does not always tell the complete story of how newly-developed equipment will function outside of a laboratory environment in the real operating world. It is therefore vital to partner with a company that has a demonstrated track record of scaling up from pilot plant data to achieve success in complex revamp projects. 

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