

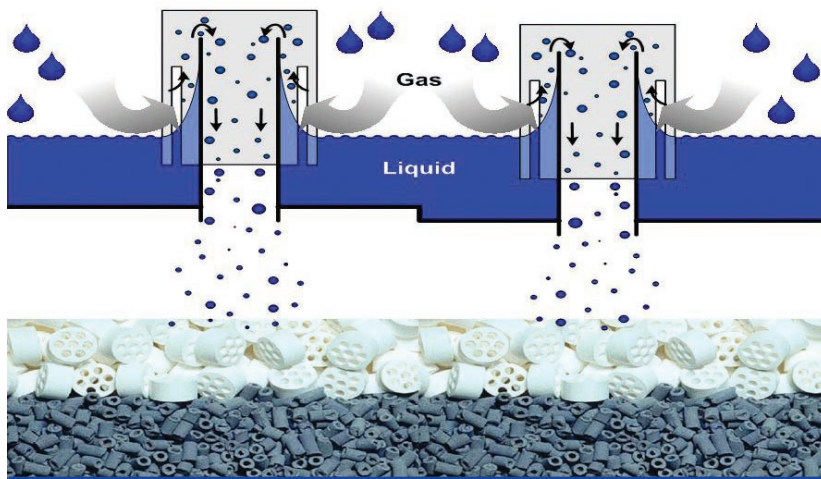


# Technology evolution for *liquid distribution*

**Dan Morton, Haldor Topsoe, Inc., USA, discusses the importance of even liquid distribution inside reactors.**

In a world with tight product specifications and evermore difficult feedstocks to process, efficiency losses due to imperfect reactor performance cannot be tolerated.

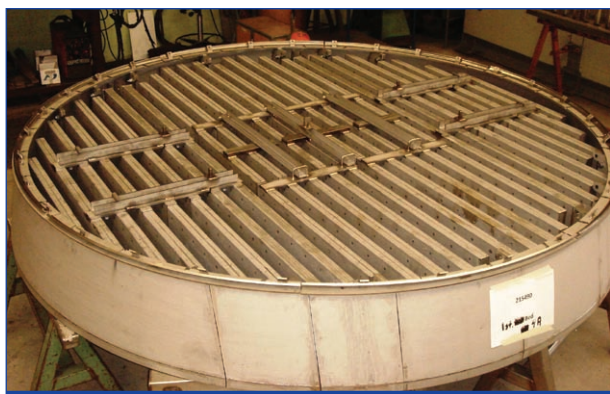
Maintaining uniform liquid distribution is essential in any hydroprocessing unit today. For example, if 1% of the feed that contains 1 wt% sulfur is bypassing the catalyst, it is impossible to make less than 100 wtpm sulfur product even if the remaining 99% is zero sulfur. In many cases, older technology distribution trays are no longer capable of meeting these new demands.



**Figure 1.** How the VLT distribution tray works.



**Figure 2.** VLT distribution tray.



**Figure 3.** The easy access manway is clearly visible.

## Distributor tray comparison

Haldor Topsoe's vapour lift technology (VLT) design distributes the vapour and liquid evenly across the entire cross section area of the catalyst bed. The VLT distribution tray operates on a 'vapour assist' principle, by which the vapour flows through a vertical slot on the side of the risers and thereby lifts the liquid through the nozzles and up through the risers and down the centre tube. During this path, the oil and the vapour are mixed completely and disperse onto the catalyst bed below the VLT distribution tray. The close spacing of the flow VLT nozzles on

the tray is a key parameter in the optimum dispersion of the liquid and vapour flow into the catalyst bed and in the resulting maximum utilisation of the catalyst. Each VLT is custom designed to meet individual requirements and is optimised to limit the overall space needed. Large diameter reactors and some older designs in revamped reactors take up more room. Topsoe's new internals reduce the required reactor height, thus making room for additional catalyst.

The VLT distribution tray is capable of handling wide ranges of operating conditions and turn down ratios due to the vapour assist principle. At a steady state of conditions, the liquid level will reach approximately halfway up the vertical slot as shown in Figure 1. If the operating conditions are changed by, for

instance, a reduced feed rate, the liquid level of the tray will drop momentarily thus exposing more of the vertical slot to the egress of vapour. The vapour velocity through the slot will obviously decrease, which means that less droplets of oil will now be 'pulled' with the vapour up through the riser. Consequently, the liquid level in the VLT distribution tray will increase until the liquid level again is covering about half of the vertical slot and a steady state is established.

The VLT distribution tray has now readjusted to the new set of operation conditions and will perform perfectly at these new operating conditions. This ability to self adjust to new operating conditions is essential for a tray design that needs to function optimally throughout the catalyst cycle. As an example, the liquid vaporisation is low at SOR temperatures and quite high at EOR temperatures resulting in large changes in the liquid level of the tray, but again the vapour assist principle is able to compensate for this difference completely and will continue to perform as intended. This ability to self adjust also means that the Topsoe VLT distribution tray is not very sensitive to being out of level. This is an important consideration when installed in an existing vessel with less than perfect symmetry. Haldor Topsoe's trays are designed for typical operating range, for liquid and vapour rates of 50 – 125% of design feed rate. These ranges can be adjusted even more depending on design considerations.

The Topsoe VLT distribution tray is designed to prevent flow distribution problems caused by deposition of particulate material on the tray surface. The positioning of the vertical slot on the distribution nozzles is designed so as to prevent plugging by particulate material, because the vapour velocity through the slot is so high that it is impossible for any material to block up the slot during operation. Furthermore, the VLT risers are designed with as much as 5 in. of clearance from the tray plate to the bottom of the vertical slot to allow for more than enough space on the tray plate for deposits to precipitate out.

## VLT distribution tray

The VLT nozzles are designed with a very small footprint, which results in the ability to fit many VLTs per square foot, and it allows for placement of the VLTs very close to the vessel wall. This is important because as much as 20% of the catalyst volume in a 10 ft ID vessel is located within 1 ft from the vessel wall. A 10 ft distribution tray contains approximately 1000 VLTs, resulting in an unmatched number of drip points.

## New box VLT tray design and quick release manway system

Haldor Topsoe's newest tray, the box VLT, incorporates the large number of drip points of the 'vapour lift' tubes themselves into a beam support system, thus eliminating the need for beam supports below the tray. This is a key advantage, especially in larger reactors where the tray support beam sizes can be very tall and take up lots of space inside the reactor. By integrating this design with fewer parts and a new 'quick release' manway system, the new trays are self supporting, lighter, take up less room and allow for faster installations. The vapour lift principle is still the basis for the box VLT distribution tray's functionality. The new box VLT is faster to install and the new manway system takes only seconds to unfasten, therefore reducing downtime during turnarounds.

By removing the beam support system below the tray plate, an additional 6 – 10 in. of catalyst can be loaded into the reactor that was not possible before. Also, the leveling of the top layer of catalyst is much easier as there are no beams in the way. As the beams are part of the box VLT distribution tray itself, fewer parts means fewer bolts and quicker installation times.

The new design is very rigid, and as little as 1 mm of deflection is seen over as much as a 14 ft tray diameter. Less deflection means more consistent liquid level on the tray, regardless of the span diameter. Also high liquid level and pressure differential is not as much of a concern, and less consideration is needed when hanging added thermometry from the trays.

The trays are sealed on the top side of the outer skirt. This has some additional advantages: levelling is much faster and accurate; trays can be shimmed up to level on top of support rings/bracket system; the trays do not seal to the ring support. So even if the support system is out of level, the skirt compensates without sealing issues. By combining this with new techniques for raising the top of the tray above the tangent line in revamped reactors, several additional feet of catalyst can be added.

The new compressed box VLT distribution tray design averages approximately 1 ft in total height. Within a quench zone between catalyst beds, the total quench zone height for a box VLT and a quench mixer is typically 3 - 4 ft, depending on reactor size.

## New quick release manway

Since welding is usually not allowed or a preferred method for tray installations, Topsoe's internals are completed assembled with bolts and no welding is required. Bolting poses a problem during shutdowns as most stainless bolts tend to seize up after long service, causing them to have to be cut or torched completely out in order to access the beds below. One of the

key problems with shutdown maintenance is the time spent removing the internal manways inside the reactors after numerous hours in service. Early on, Haldor Topsoe's answer to this issue was a wedge pins system specifically designed to be hammered manually through brackets on the manways. While the rest of the tray is typically never disturbed during service life, the manways are capable of being removed and reinstalled quickly by simply removing the wedge pins. No bolts are required so downtime is shortened.

The newest principle, the 'quick release' manway, uses a top access beam system that seals the manway from leakage while eliminating the need for wedge pins. Instead of being fastened from below at the tray level, the upper beams are accessible from the top side. This is advantageous in that workers no longer need to reach down between the nozzles to access the wedge pins, and unfastening the quick release system takes only a few seconds. By adding these features, shutdown times are dramatically decreased and more time can be spent inspecting other areas of the vessels.

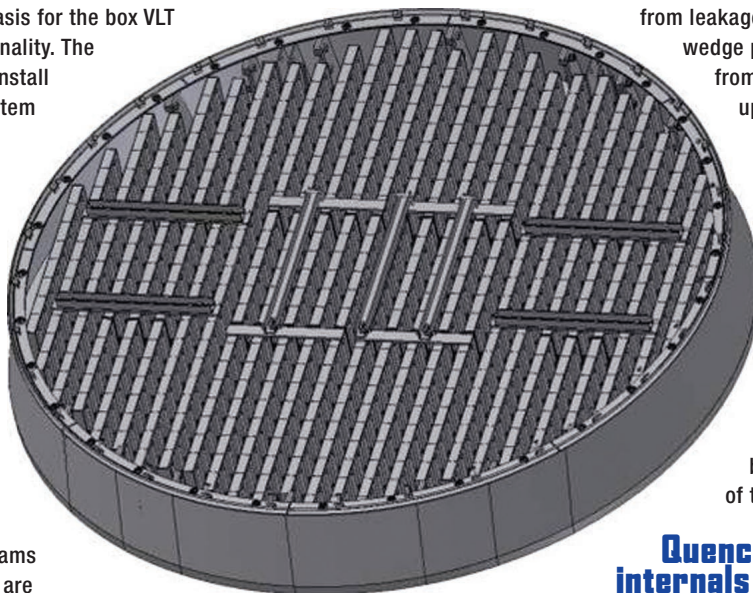


Figure 4. Topsoe's box VLT model.

## Quench mixer and other internals

In multibed two phase hydroprocessing reactors with interbed quench, a mixing device is required between the catalyst beds in order to contact the quench fluid with the vapour and liquid effluent from the above catalyst bed for efficient temperature equalisation.

The purpose of the mixer is to obtain a uniform mixture regarding temperature and composition before the two phase mixture is redistributed over the next catalyst bed. Any non-uniformity in the temperature will propagate through the catalyst bed and result in additional radial temperature spread.

The Haldor Topsoe vortex type mixing chamber receives the gas and oil equally from all quadrants of the quench collection tray through two or four slide nozzles. There, like a stationary fan blade, the gas pressure and liquid flow are forced into a swirling motion and efficient mixing of oil and gas is achieved. The mixed gas and oil interchanges with each other until it reaches the centre of the mixer, where the mixture is reaccelerated, reaching the dispersed flow regime, again ensuring that it is blended sufficiently to reach an even temperature before it is redistributed onto the next catalyst bed.

Compared to prior quench pipe designs, Topsoe's ring system does not block the manway opening allowing access during turnarounds without having to remove any internal quench piping.

## Cutting edge technology

Even liquid distribution and proper mixing is vital for maintaining longer and more profitable life cycles for catalysts. The use of Topsoe's state of the art reactor internals is an efficient option to ensure compliance with today's very stringent product specifications. **TE**