RAISE THE GAME

A. R. S. Bhandari, Bharat Oman Refineries Ltd, along with R. Madhavan and Sandeep Yadav, Koch-Glitsch, India, recall a refinery stripper tower revamp project.

Product strippers remove light hydrocarbons and hydrogen sulfide (H_2S) from the reaction product of hydrocracker/diesel hydrotreater reactors. Live steam is typically used as a stripping medium and the towers are equipped with a reflux to control the quality of the top product. The product from the bottom of these strippers is further processed into naphtha, kerosene and diesel in the downstream product fractionator and other towers. Carryover of heavy hydrocarbons in the top product of the product strippers results in a high endpoint of the combined heavy naphtha stream from the downstream column. Therefore, good fractionation in this tower is essential for the overall performance of the unit.

A revamp to enhance internals for the trayed and packed sections of hydrocracker (HCU) and diesel hydrotreater (DHT) strippers in a refinery improved the naphtha endpoint and reduced the H_2S content of the light naphtha. The retrofit design philosophy involved studying each piece of equipment in detail, identifying possible bottlenecks and applying state-of-the-art technology to overcome these bottlenecks and achieve high performance from the tower. Performance testing before and after the revamp demonstrated the value of ensuring that tower internals are appropriately designed, fabricated and installed.

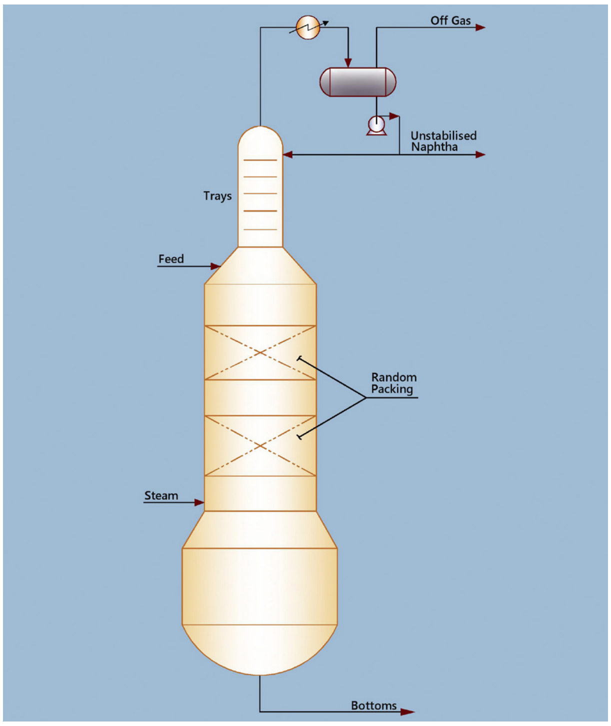

Figure 1. A hydrocracker/DHT stripper.

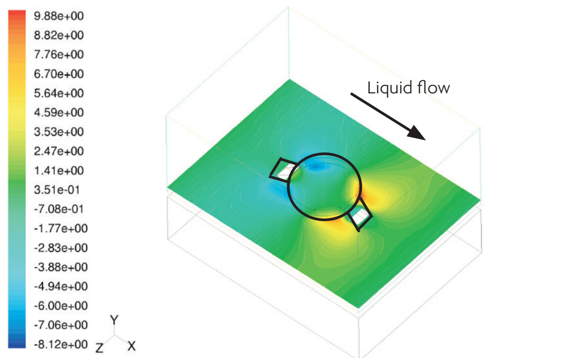

Figure 2. Liquid push towards the outlet weir is created by vapour.

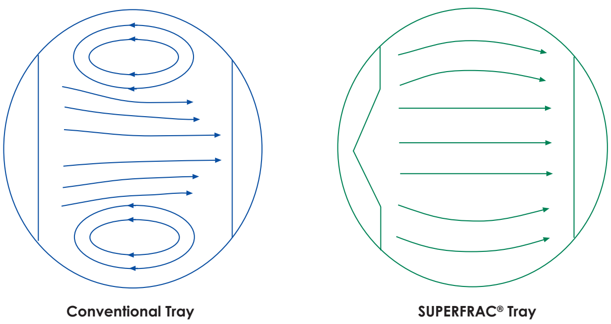

Figure 3. A comparison of the liquid flow pattern of trays.

Original design

The original internals in the HCU and DHT product strippers included valve trays, random packing and distributors, which were designed by an engineering company and supplied by a local fabricator. The original design basis was a heavy naphtha ASTM D-86 endpoint of 183 – 184˚C. Reflux was provided above the trayed rectification section and steam in the bottom of the column to control the naphtha endpoint and remove H_2S from the bottoms product. Figure 1 shows the typical arrangement of these strippers.

New requirement

When the hydrogen unit was commissioned, the combined naphtha from the HCU and DHT units was specified with an endpoint of 160˚C or less to maximise catalyst life in the reformer. At maximum achievable capacities, the naphtha endpoints were in the range of 175 – 185˚C, which is typically higher than the design basis. At lower rates and with some operational changes, a naphtha endpoint of 165 – 170˚C was possible on a consistent basis but required higher H_2S slippage into the bottoms product. The existing internals were not able to achieve the design reflux or steam rates.

The towers were inspected during a turnaround and the internals in the feed sections showed some mechanical damage. It was decided that these internals should be replaced in the subsequent turnaround and new designs evaluated to improve the quality of naphtha, reduce H_2S slippage and remove existing capacity bottlenecks.

Revamping the tower

Koch-Glitsch was requested to identify possible improvements to achieve a lower endpoint of naphtha and improve capacity. A systematic study revealed several areas that could be improved to achieve higher capacity and efficiency. These included the design of trays, packing, distributors, and the flashing feed device in the transition zone. Each of these elements were addressed in detail and the design was improved to maximise tower performance.

Trays

A review of the existing conventional moving valve trays in the rectifying section indicated a limitation in vapour handling capacity. A moderate increase in vapour handling capacity was required in the DHT stripper. Koch-Glitsch recommended the VG-0 type MINIVALVE® tray in this section for its ability to handle higher vapour loads with reduced entrainment, while providing higher efficiency than that of the conventional moving valves. VG-0 is a fixed valve and is smaller than the conventional moving valve. It creates a uniform frothing action on the tray deck due to its unique size and shape. Figure 2 shows a computational fluid dynamics (CFD) model of the VG-0 valve with higher velocity vapour at the front leg providing a slight pushing action to the liquid, which helps create a more uniform flow pattern across the tray.

In the hydrocracker product stripper, a significant increase in capacity was required. Koch-Glitsch proposed replacing the existing conventional trays with SUPERFRAC® trays equipped with VG-0 valves. These trays included features such as a multi-chordal downcomer, push valves and directional devices to maximise efficiency and capacity. Figure 3 illustrates the effect of both the multi-chordal downcomer shape and push devices to create uniform liquid flow pattern on the tray by eliminating the recirculating eddy-currents that occur at the sides of conventional trays.

Packing and internals

The existing packed beds in this case were equipped with conventional Pall ring random packing, which was replaced in this revamp project with IMTP® random packing.

The shape of the new random packing allows for improved wetting of the packing surface area, thus resulting in higher efficiency compared to Pall rings of similar size. Table 1 gives a relative comparison of Pall rings and the similar sized replacement random packing.

The existing liquid redistributors were designed with oversized hats (riser covers) with a small horizontal clearance between the hats resulting in localised, high vapour velocities, which could lead to entrainment that will negatively affect the capacity and efficiency of the packed bed. To overcome this concern, the liquid distributor and redistributor were replaced with INTALOX® liquid distributor and re-distributor, respectively. Salient features of these distributors that were essential to the revamp design included:

- Uniformly arranged orifices in the deck to provide optimum distribution quality.
- Deck type construction with small gas risers to provide good liquid cross-flow between risers, thereby minimising liquid gradients, especially important considering the high specific liquid load (>100 $m^3/hr/m^2$).
- An anti-migration feature on the liquid distributor below the gas risers to eliminate the need for a separate bed limiter and ensure no interference so a high quality distribution pattern is conveyed to the packing.

In addition to tall risers, orifice quantities and diameters were adjusted to increase liquid heads on the deck, improving both the distribution quality and operating range. The designs of the hats on the redistributors were optimised to remove bottlenecks for vapour flow. Figure 4 shows the arrangement of orifices, risers and hats on the new distributors after the revamp.

A pre-distributor was introduced above the INTALOX distributor to receive the feed and liquid from the top section and to convey these to the distributor with minimum turbulence.

Table 1. Comparison of random packing

	Pall ring 2 in. random packing (%)	IMTP #50 random packing (%)
Void fraction	96.2	98.2
Relative capacity	100	125
Relative efficiency	100	112.5
Relative pressure drop	100	80

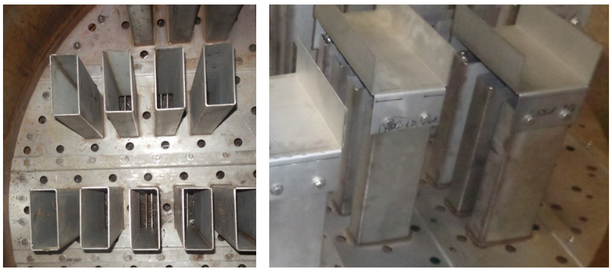

Figure 4. The deck distributor and redistributor (post-revamp).

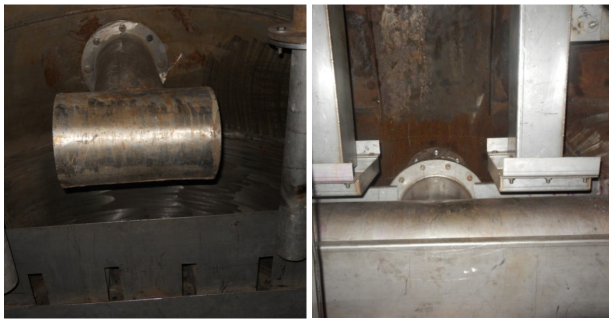

Figure 5. The feed section before (left) and after (right) modification.

Transition zone

The two-phase feed to the strippers entered the transition zone between the trays and packing. The transition zone comprised seal pans, downpipes and a non-ideal feed pipe arrangement in a congested space. The flashing feed was introduced above the distributor using an open-ended T-pipe, which resulted in liquid being directed towards the walls of the tower rather than down on the distributor given the high feed nozzle velocity and momentum.

The transition zone was simplified using a collector tray and downpipe arrangement to feed a pre-distributor trough above the main deck-style liquid distributor. The flashing feed pipe was expanded from the nozzle to reduce pipe velocities and introduce the feed onto the baffles of the pre-distribution trough to enhance disengagement of liquid from vapour. Figure 5 shows the feed section before and after the revamp.

Results

After revamping the product strippers, the additional capacity of the high performance trays, packing and

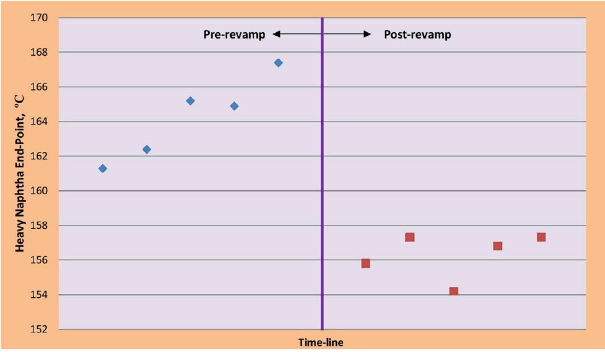

Figure 6. Combined HCU/DHT stripper heavy naphtha endpoint.

internals allowed the reflux rates and stripping steam to be increased significantly. Comprehensive test runs were undertaken to provide a comparison to pre-revamp performance data. The naphtha endpoint was lowered to below the specified maximum of 160˚C, and H_2S slippage in the bottoms product was significantly reduced.

Post-revamp, in the DHT product stripper, the reflux rate could be increased 2.85 times, from 4 tph to 11.4 tph, which helped improve the naphtha endpoint. Also, the stripping steam rate could be increased by 19%, which reduced the slippage of H_2S in the bottom. The high performance VG-0 type MINIVALVE trays used only 67% of the pre-revamp pressure drop to achieve these results.

Similarly, the feed rate to the hydrocracker product stripper could be increased by 6 – 7%, while the steam rate could be increased by 10 – 11%. This resulted in improved bottom product recovery and reduced slippage of H_2S in the bottom. The reflux rate was maintained at the pre-revamp values even at higher feed rates indicating that the SUPERFRAC trays provided improved separation efficiency. This was achieved at a reduced pressure drop of 70% of the pre-revamp values across the trays.

Figure 6 shows a comparison of the pre-revamp and post-revamp results for the HCU/DHT strippers' combined heavy naphtha endpoint.

Conclusion

Selecting the appropriate tower internals and designs is critical in order to achieve the desired process performance in both new towers and revamps of existing columns. State-of-the-art high-performance internals offer high capacity and efficiency compared to conventional mass transfer equipment. Engaging an experienced internal supplier with a complete portfolio of tower internals to advise on the most suitable equipment for a particular application will help achieve optimal tower performance.