

Tray revamp restores crude column performance

Retrofitting the packed top section of a crude atmospheric tower with high capacity trays improved separation efficiency

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The existing crude distillation unit at Hindustan Petroleum Corporation Limited's (HPCL) Mumbai refinery is designed to process Bombay High and Arab Mix crudes. During an earlier capacity revamp of the crude atmospheric tower, 24 conventional trays with moving valves located in the top fractionating sections that separated light naphtha, heavy naphtha, and kerosene were replaced with an equal number of Superfrac trays equipped with fixed valves. The tower configuration after the first revamp is shown in **Figure 1**. With Superfrac trays, capacity and separation between naphtha, heavy naphtha, and kerosene cuts were satisfactory with a good gap between the 95% ASTM D-86 distillation point of one product and the 5% ASTM D-86 distillation point of the next product. **Table 1** shows the product quality of naphtha to kerosene following the first installation of Superfrac trays in the top section.

To take advantage of the opportunity to process lighter crudes, the refinery needed to overcome capacity limitations in the top fractionating sections. Plant personnel contacted an engineering company for a process study to evaluate the feasibility of achieving the 20% extra capacity needed to process lighter crudes. The engineering company recommended replacing the top section of high capacity trays with two beds of structured packing in addition to other modifications in the tower. With agreement to implement the recommended changes, the engineering company designed the structured packing and inter-

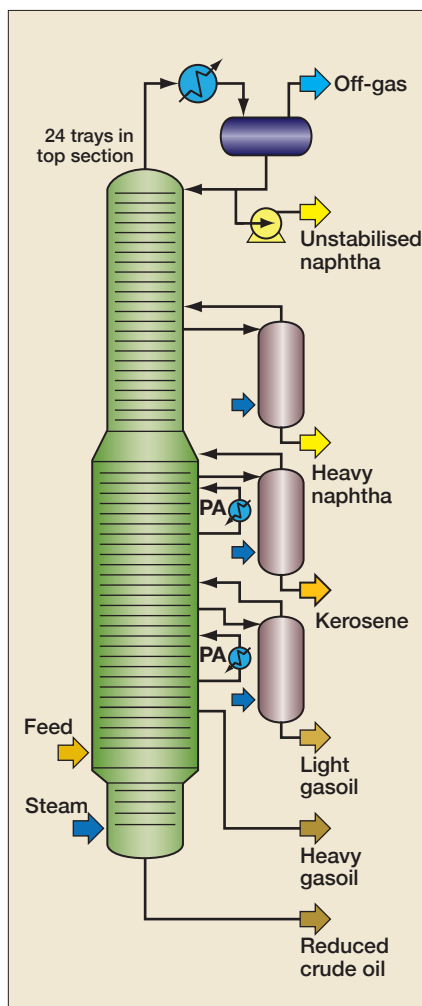


Figure 1 Original configuration after first revamp

nals, which were purchased from a local fabricator. During installation, the tray tower attachments were removed to accommodate the structured packing. The tower configuration with packing revamp is shown in **Figure 2**. The crude capacity after the modifications could be increased by 20%, but the separation between the three cuts (light naphtha, heavy naphtha, and kerosene) was very

| Results after first installation of 24 Superfrac trays in top section | | | |
|---|--------|---------|-------------------|
| ASTM D-86, vol% | 5%, °C | 95%, °C | Gap/(overlap), °C |
| Light naphtha | | 111 | 14 |
| Heavy naphtha | 125 | 148 | 20 |
| Kerosene | 168 | | |

Table 1

poor with a significant overlap in the ASTM D-86 cut points as compared to the gaps that were being obtained prior to the revamp. **Table 2** shows the product quality of naphtha to kerosene after the replacement of trays with packing in the top section.

Analysis of the existing tower configuration

Three different evaluations were conducted: gamma scan, physical inspection of packing and internals, and a process simulation to understand the possible causes for the underperformance of the packed bed.

Gamma scan

The refinery conducted a gamma scan of the top section of the tower. The results pointed to liquid maldistribution wherein one side of the tower received a larger proportion of the liquid flow compared to the other. Critical sections, such as the equipment between two packed beds, had significant external obstructions interfering with the scan results, and consequently the data were not sufficient to accurately determine the origin of the maldistribution.

| Results after packing installation in top section | | | |
|---|--------|---------|-------------------|
| ASTM D-86, vol% | 5%, °C | 95%, °C | Gap/(overlap), °C |
| Light naphtha | | 147 | (28) |
| Heavy naphtha | 119 | 193 | (26) |
| Kerosene | 167 | | |

Table 2

Physical inspection of the packing and internals

Two possibilities for the maldistribution were considered: the structured packing layers were not rotated at 90° angles during installation, and the tower internals may have been damaged during operation.

Structured packing layers are installed with each layer rotated 90° with respect to the layer below. The rotation mixes and spreads both liquid and vapour phases in all horizontal directions to avoid local concentration variations at the same elevation. Figure 3 shows a properly rotated stack of structured packing layers.

Structured packing with a crimp angle of 60° from horizontal with an approximate surface area of 110-115 m²/m³ was used in the fractionation section. This type of packing is more typically applied in heat transfer and absorption services and may have been selected to meet capacity requirements.

The packing and internals were inspected during a scheduled shut-down. The packing layers were found to be rotated properly,

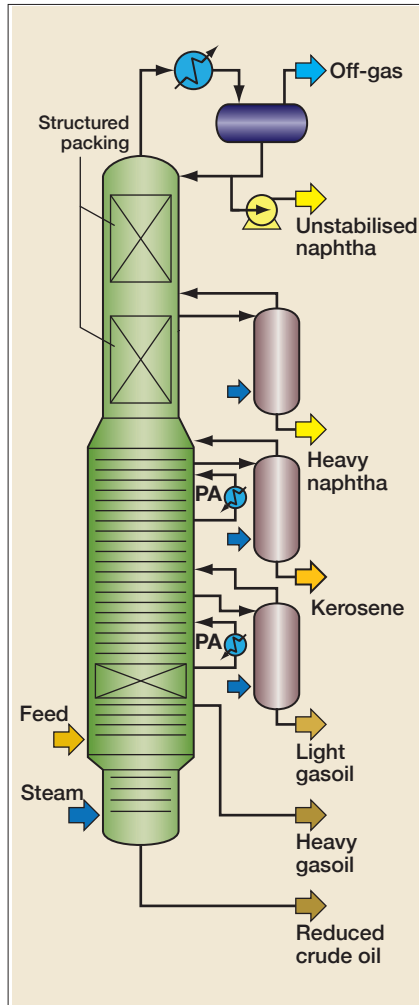


Figure 2 Tower configuration after packing installation in top section

and the internals were intact. Photographs taken during shut-down indicated corrosion on the packing (Figure 4), but severe damage was absent in the sections that were accessed.

The packed beds occupied most of the tower height, and the dis-

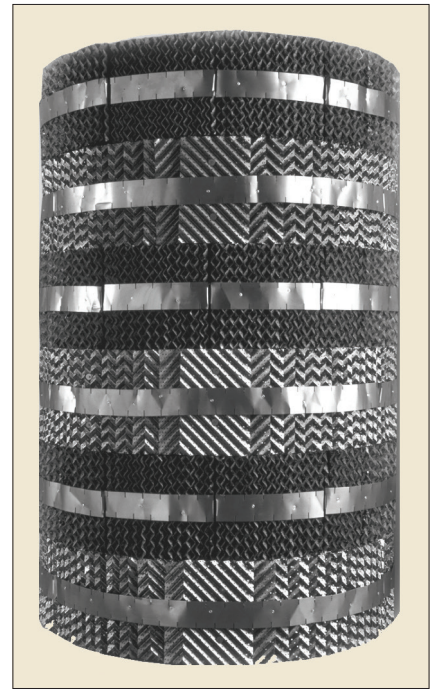


Figure 3 Typical stack of structured packing layers

tribution systems for liquid and vapour were fitted into a smaller vertical space. The need to maximise the packed bed height may have restricted the available space for the distribution systems. The distributor type selected by the engineering company was difficult to level and was designed to operate with a low liquid head in a multi-stage configuration. Using low liquid heads makes the distributor prone to the maleffects of liquid gradients formed by the flow and more sensitive to the levelness.

In this case, the reflux feed pipe feeding the distributor of the top bed was designed in a sub-optimal way without any significant flow restriction and could have additionally contributed to the non-uniformity of liquid distribution observed in the gamma scan. Feed pipes or pre-distribution systems are equally critical to the performance of the packed column as the liquid distributor. Obtaining the desired performance from a tower requires appropriate distribution devices for the column feeds. When designing feed or pre-distribution devices, consideration must be given to their spacing and orientation with respect to the type of liquid distributor below, expected distributor performance,



Figure 4 Structured packing after a few months of operations

flow rate, operating range, thermal condition (for instance, degree of sub-cooling), and whether mixing with overhead liquid is required. To achieve uniform liquid distribution, feed pipes should have a reasonable³ pressure drop. Restriction orifices within the pipe may be used to balance flow distribution in situations where fluid equalisation is non-ideal and it is difficult for the internals to correct for flow variations.

Vapour distribution is another important aspect in packed tower performance. Unlike trays that have significant pressure drop, packing has much lower pressure drop and is not able to correct for vapour maldistribution. Therefore, initial distribution of vapour to the packed bed is very important. In this case, the chimney collector below the top bed was installed with little space between the top of the riser to the packed bed above (see **Figure 5**), possibly due to the desire to maximise the packed height. It is necessary to provide sufficient³ distance between the top of the risers to the bed above to create uniformity in the vapour flow into the packed bed. The distance between the riser hats was also restrictive, creating higher velocities that would hamper good vapour distribution. The overall result of the constrained arrangement of risers beneath the packed bed is increased vapour maldistribution and reduced separation efficiency.

Process simulation

HPCL requested Koch-Glitsch to assist in improving the column performance in the packed section. Koch-Glitsch developed a steady state process model of the tower using a steady state simulation soft-

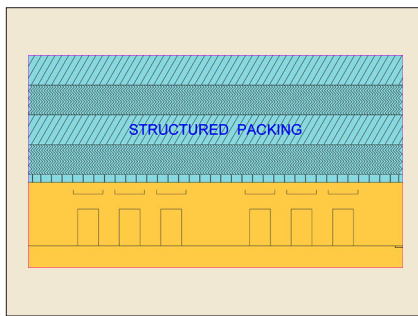


Figure 5 Chimney tray with low clearance to the packed bed above

ware. Ten theoretical stages were expected from the 12m of packing installed, based on efficiency data from similar size packings. However, the simulation results that matched the test run indicated that the number of stages achieved was actually less than half of the expected number.

When revamping towers from trays to packing, consideration must be given to the suitability of the packing to the service and to the liquid and vapour distribution

Inside-Out revamp approach

To optimise the tower's efficiency and capacity, Koch-Glitsch adopted the Inside-Out design approach.² This is an iterative method that combines process simulation with equipment selection, design, and hydraulic evaluation. The benefit of this approach is that it eliminates the guesswork needed to fit

the equipment design to the original simulation. For improving the packed bed performance, significant changes were envisaged for the feed pre-distribution, liquid distribution, packing selection, and vapour distribution. For the equipment design, different options were evaluated, which also included trayed options. The pros and cons of each option were identified and compared (see **Table 3**). Because the capacity requirement was now 20% higher than the earlier configuration of Superfrac trays, retrofitting with the original number of trays would reduce the capacity unless the tray spacing could be increased. Using higher spacing reduces the number of trays and, therefore, the number of contacting stages.

For the trayed option, Superfrac trays were selected because they offer the best combination of capacity and efficiency. Depending on the performance requirements, the Superfrac tray offers various design

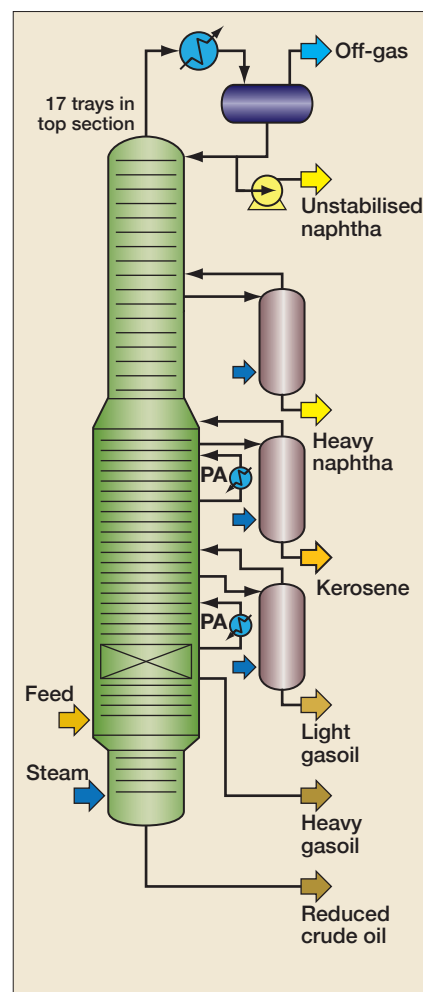


Figure 6 Configuration after second revamp (top section only)

Comparison of options

| | Replace with Flexipac structured packing and Intalox high performance internals | Restore to original configuration with Superfrac trays and original tray spacing | Replace with Superfrac trays with increased tray spacing (fewer trays) |
|--------------------|---|--|--|
| Capacity | No change | Reduction | No change |
| Efficiency | Better | Significantly better | Better |
| Fouling resistance | Low | High | High |
| Cost | High | Low | Lowest |

Table 3

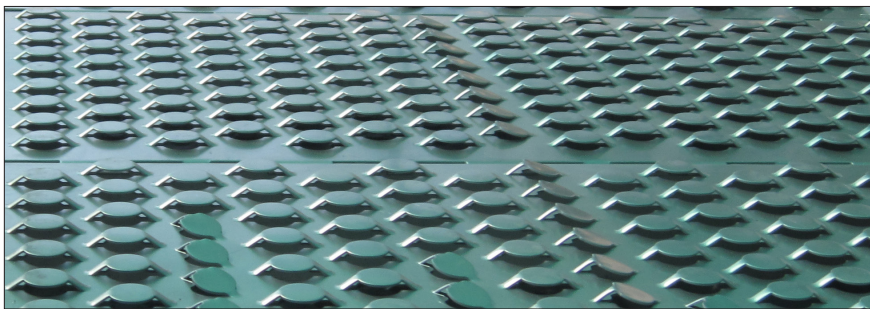


Figure 7 Superfrac tray deck with push valves

options.¹ This includes high capacity VG-0 type Minivalve valves in combination with specially shaped downcomers that maximise the flow path and contacting area. The efficiency of a Superfrac tray is maximised by eliminating stagnant zones and retrograde flow on the deck. This is done by strategically placing proprietary push valves and other directional devices on the tray deck. This feature was employed in this case as well. Koch-Glitsch has patented several downcomer arrangements for the Superfrac tray. For the light naphtha section, a vapour tunnel downcomer was used. For the slightly higher liquid loaded heavy naphtha section, a truncated vapour tunnel downcomer was used.

HPCL had experienced improved separation and capacity with the previous revamp from conventional trays to Superfrac trays. Replacing the packing with redesigned Superfrac trays was considered more reliable even if the retrofit used fewer trays. As hydraulic loads were different for different sections, different tray spacings were employed to get optimal capacity and to maximise the number of trays; 17 trays could thus be accommodated in the available space. It was expected that the separations would not be as good as the original Superfrac tray configuration which had 24 trays, but it would be significantly better than the separation provided by the existing packing (see Figure 6). Process simulations were refined to reflect the expected number of stages with this configuration. The calculated product qualities were significantly better than what was achieved with the existing packing.

After discussion between Koch-

Glitsch and HPCL, the Superfrac tray option was selected. New tower attachments – support rings and bolt bars – were welded to the column shell to support the trays, and the tower was retrofitted with Superfrac trays (see Figure 7).

After tower start-up, the required capacity was achieved with very good separation between the cuts. Gaps in ASTM D-86 curves rather than overlaps were observed. Table 4 shows the details of the separation between lighter products achieved post-revamp with the trays.

Superfrac trays, with their combination of high capacity and efficiency, offered the most reliable high capacity option and improved product qualities significantly

Conclusion

When revamping towers from trays to packing, consideration must be given to the suitability of the packing to the service and to the liquid and vapour distribution. In general, it is considered that packing provides higher capacity compared to trays and thus is a good option for revamps. Although the high open area of packing allows it to handle higher hydraulic loads compared to trays, packing is also more sensitive to liquid and vapour distribution because of a lower resistance

Results post-revamp with 17 Superfrac trays in top section

| ASTM D-86, vol% | 5%, °C | 95%, °C | Gap/(overlap), °C |
|-----------------|--------|---------|-------------------|
| Light naphtha | | 118 | 5 |
| Heavy naphtha | 123 | 157 | 8 |
| Kerosene | 165 | | |

Table 4

to fluid flow. Superfrac trays, with their combination of high capacity and efficiency, offered the most reliable high capacity option and improved product qualities significantly.

SUPERFRAC, MINIVALVE, INTALOX and FLEXIPAC are marks of Koch-Glitsch, LP.

References

- 1 Nieuwoudt I, Penciak J, Best of both, *Hydrocarbon Engineering*, Jul 2007, 85-89.
- 2 Remesat D, Krela M, Customised tower design, *PTQ Q2 2013*.
- 3 Kister H Z, *Distillation Operation*, McGraw Hill Publishing Company.

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