

Better feed entry ups debutaniser capacity

Points of transition, where streams enter or leave the tower, are some of the most common and severe tower bottlenecks. Combining hydraulic evaluation with field data and gamma scan analysis is key to identifying and eliminating such bottlenecks

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A debutaniser in BP's FCC unit (Figure 1) separates 57 000bpd of feed into a C₄ overhead product and a bottom debutanised naphtha product. The bottom product is purified to a Reid vapour pressure (Rvp) specification typically of about 7psi. The tower is 10.5ft ID and contains 30 trays, with the two-phase feed entering above tray 15.

For several years, the tower bottlenecked the gas plant. Raising the charge rate or the tower reflux would lead to tower flooding, and the flooding would lead to high tower pressure drops, instability and poor separation.

With an FCC turnaround scheduled for February 2003, work began in late August 2002 to troubleshoot and debottleneck the tower. The joint investigation identified the arrangement of the tower internal feed piping to be the primary bottleneck. Secondary bottlenecks marked for improvement were excessive liquid height on the bottom chimney tray and tight downcomer entrance areas below the feed.

The investigation was completed within one month with a full definition of the proposed modifications to tower internals. Vendor drawing checks were completed by the end of November 2002. The modifications were implemented in the February 2003 turnaround.

Upon return to service, the tower bottleneck no longer existed. Flooding, instability and high-pressure drops are no longer observed at the current plant rates. Product purity has improved, with the bottoms RVP 1psi lower than before the modifications. The debutaniser no longer bottlenecks the FCC gas plant.

Hydraulic evaluation

Based on normal operating data at unflooded conditions, a simulation was prepared and provided the basis for a hydraulic evaluation. Results of this hydraulic evaluation are shown in Table 1, which shows that none of the trays in

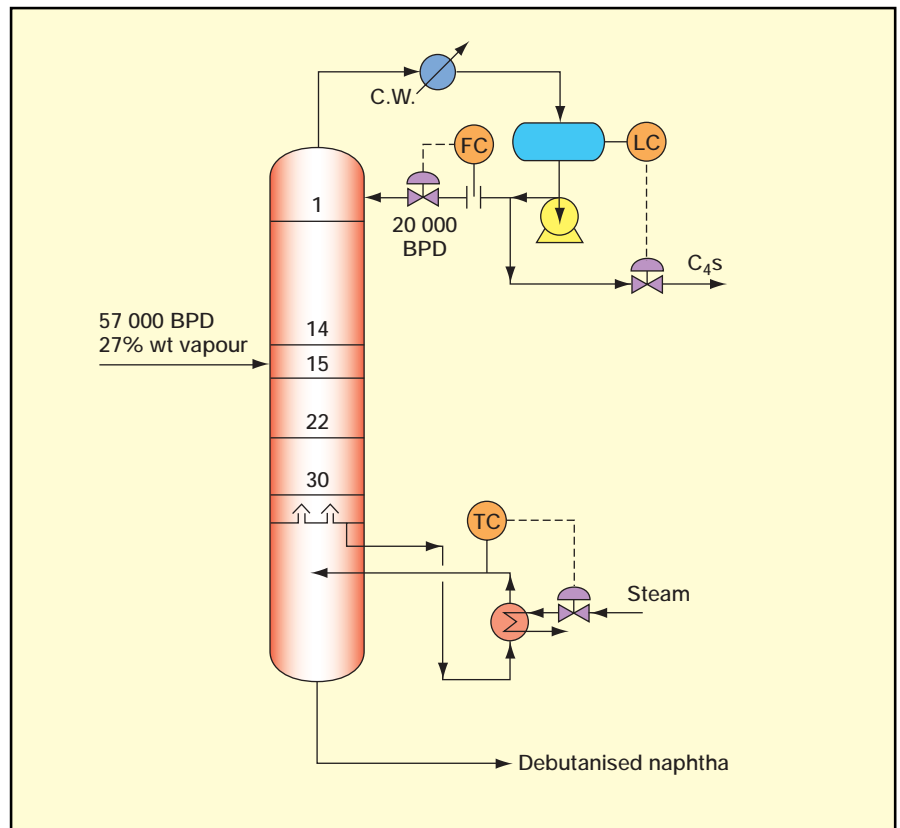


Figure 1 FCC debutaniser

the debutaniser approached either jet flood or downcomer backup flood.

For prediction of downcomer choke flood, two methods were used: method 1, interpolation of FRI data, and method 2, a correlation that tends to be conservative. Since method 1 interpolates hydrocarbon test data, it is the most accurate. Table 1 shows that even with the more conservative predictions, trays 2 and 16 operated well away from downcomer choke flood. For Tray 28, while our interpolation method shows that downcomer choke flood is unlikely, the more conservative method raised concerns about flooding. These concerns were supported by the high downcomer entrance velocity of

0.52ft/sec on tray 28, which neared the good practice limit [0.5-0.6ft/sec, per p290 of Kister's *Distillation Design*, McGraw-Hill, NY, 1992]. The downcomer entrance velocities on tray 16 (0.44ft/sec) and tray 2 (0.31ft/sec) were well within the good practice limit.

Overall, hydraulic analysis argued against regular tray or downcomer flooding causing the observed tower bottleneck. However, it did raise concerns that the lower trays in the tower, especially near tray 28, may approach a downcomer choke flood.

With the hydraulic evaluation arguing against a regular tray/downcomer bottleneck, the investigation turned to tower gamma

chimney tray appeared quite sharp, and there was almost 2ft of entirely clear vapour above the chimneys. Trays 27 through 30 above the chimney tray were not flooded and appeared almost identical in the increased and normal reflux scans. The gamma scans showed no sign of a bottleneck in this region.

In summary, the analysis pointed at a premature, abnormal flood initiating just below the feed. This flood propagated via a downcomer mechanism.

Focus on feed entry

The previously discussed findings shifted the focus to the tower feed. Fluor's survey of malfunctions in refinery fractionators [see PTQ, Autumn 2003] identified feed entry issues as a prime source of bottlenecks and premature flooding in debutanisers.

To correctly simulate the feed, it was necessary to flash the feed stream by an outside flash step to the actual pressure of the feed tray. This yielded 27 wt% vapour. The two-phase feed entered the space above tray 15 via a 10" H-shaped pipe (Figure 3). The lateral arms of the "H" contained slots, pointed downwards towards the tray floor. The total slot area was 0.89ft², giving a huge downward slot velocity of 33ft/sec based on the average mixed phase density. The corresponding slot $p_m V^2$ was 6000, where p_m is the mixed phase density, and V is the slot mixed phase velocity, ft/sec.

The huge velocity pointed at the tray floor was identified as the prime bottleneck in this tower. The good design practice [Kister, Distillation Operation, McGraw-Hill, 1990] is to point the two-phase mixture towards the inlet downcomer at an angle of about 45 degrees downwards and to restrict the slot $p_m V^2$ to less than about 1000-2000. The lower $p_m V^2$ reduces the kinetic energy of the feed, and the downcomer wall spreads its momentum while minimising disturbance to the tray. The entry arrangement in Figure 3 is likely to cause excessive turbulence on the tray, re-entrainment of the feed, and penetration of the two-phase feed through the valves on the tray floor into the downcomer below. This penetration is likely to overload the trays immediately below the feed and to induce lights into the downcomer liquid of these trays. Both actions are likely to induce premature flood in the trays just below the feed, as observed in the scans.

A secondary bottleneck was caused by excessive mixture velocity at the feed entry. At the tower 10" feed inlet nozzle, and throughout the 10" pipe from the nozzle to the "H", the mixed two-phased feed velocity was 54ft/sec, giving

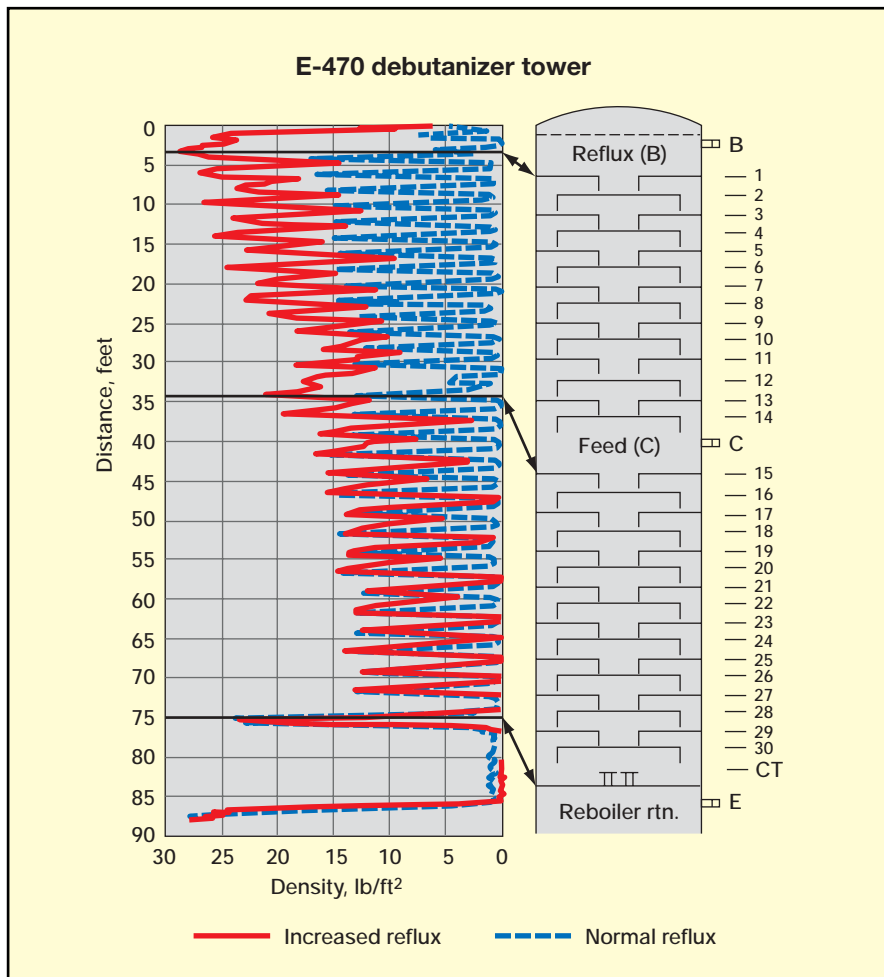


Figure 2 BP Texas City refinery E-470 debutaniser tower scan

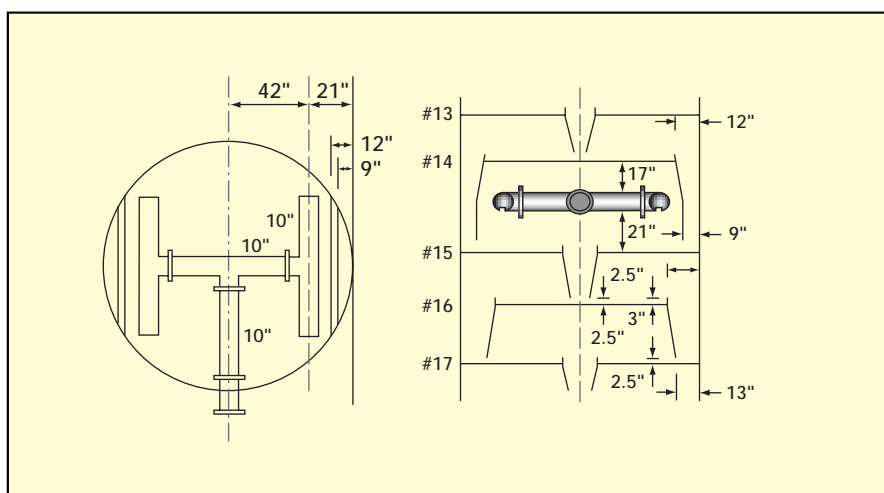


Figure 3 Feed entry before debottleneck

a $p_m V^2$ of 16 000. This is a huge number, an order of magnitude greater than good design practices. This high velocity is likely to generate high turbulence and lead to a poorly distributed feed. This high velocity is also likely to shatter liquid drops into tiny droplets, which are easily entrained, generate mist and can induce or promote premature flood. Poor distribution of the feed is likely to

raise some of the local slot velocities well above the 33ft/sec mentioned previously, thus aggravating the primary bottleneck.

Bottom chimney tray bottleneck

Liquid from the bottom tray of the debutaniser is collected on a chimney tray just below it, from where it flows to

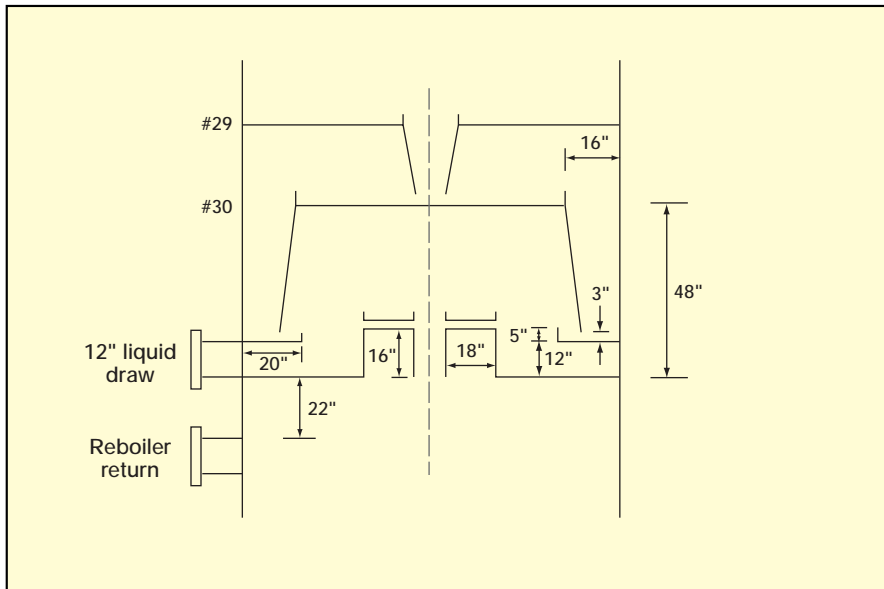


Figure 4 Bottom chimney tray

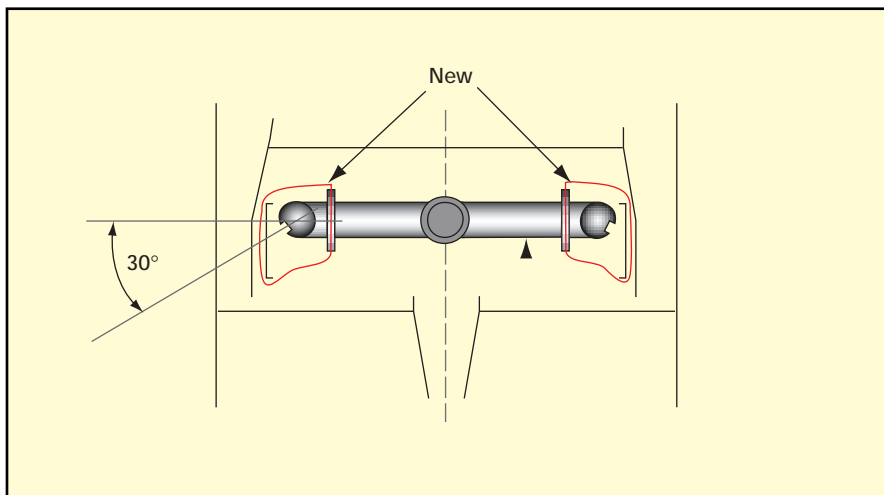


Figure 5 Feed entry modification

a once-through thermosiphon reboiler (Figure 1). There were concerns that the bottom chimney tray may be another bottleneck due to its non-standard design. These concerns were supported by the gamma scan observation that the liquid level on the tray approached the top of the chimneys. The fractionator malfunction survey [see PTQ Autumn 2003] lists reboiler-draw arrangements as a major trouble spot in debutanisers. It was therefore imperative to investigate these concerns.

Figure 4 shows this non-standard design. The top of the outlet draw nozzle from this tray is elevated 12" above the tray floor, with the chimneys only 16" tall. Liquid velocity in this draw nozzle was extremely high (9ft/sec) and it is badly undersized for self-venting flow. It is therefore conceivable that the liquid level on the chimney tray may exceed the top of the chimneys. Liquid level rising above the

top of the chimneys can lead to entrainment and premature flooding in the section above. Also, some of the tray liquid can descend down the chimneys, starving the reboiler of liquid.

The gamma scans, as well as operating experience, however, showed that even at the increased reflux rates the chimney tray bottleneck had not been reached yet. The chimney tray draw provided the only path of liquid from the tower to the reboiler, and the reboiler did not show any limits. This means that not much liquid descended down the chimneys, and most of the liquid actually went into the liquid draw. According to the gamma scans, the liquid level does not rise significantly above the chimneys and does not produce significant entrainment.

With the draw nozzle undersized for self-venting flow, the draw could handle most of the liquid flow rate only if the

chimney tray was effectively degassing the liquid. The total degassing time on this chimney tray was about 20 seconds, which is on the low side [30–60 seconds is good per Kister, Distillation Operation, McGraw-Hill, 1990]. However, considering that the tray 30 downcomers provided an additional four seconds of degassing time, and that there was no "waterfall" from the seal pan overflow to the liquid level (such waterfall produces froth), it is conceivable that the liquid drawn was sufficiently degassed. Accordingly, the chimney tray was identified as a secondary bottleneck, which was not encountered at the current operating conditions.

Debutaniser debottleneck

The previous analysis identified one primary bottleneck, which was theorised to be the root cause of the premature flood in the tower, and three secondary bottlenecks, which appeared not to have been reached yet.

The primary bottleneck was the downward pointing of the distributor slots towards the tray deck and the high velocity (33ft/sec) at which this feed hit the tray deck (a twentieth of a second after it left the distributor slots). It is likely that some of this feed penetrated through valves on the tray floor into the trays below, inducing excessive hydraulic loads and forcing lights into downcomers. Since the side downcomers on the trays below the feed were wider than those above the feed, and the feed pipe was close to the wall of one of the narrow downcomers, some of the feed penetrating the tray deck was directed right into the downcomer below. The lights and vapour entering these lower downcomers were likely to have induced premature downcomer choke in them.

To debottleneck the feed entry, the distributor slots needed redirecting away from the tray floor and the slot velocity needed to be lowered. This was achieved by replacing the slotted arms of the "H" shown in Figure 3 with new pipes equipped with slots that were directed at 30 degrees from the horizontal towards the downcomer wall (Figure 5). This angle was slightly flatter than the conventional 45-degree angle in order to assist vapour disengagement from the mixed feed. The total slot area was increased from 0.89–2ft², which reduced the mixture average slot velocities to 15ft/sec and the slot $p_m V^2$ to about 1200. These numbers are well within good design criteria. Impingement baffles were installed to prevent direct impingement of the feed on the downcomers from tray 14.

Three secondary bottlenecks were identified. Although none of these

appeared to bottleneck the tower at the current rates, each could become a major bottleneck once the primary bottleneck was eliminated. Budgets and economics favoured modification to address the secondary bottlenecks as long as costs were not prohibitive. The secondary bottlenecks, and corrective action taken, were:

— Lower trays in the tower approaching a downcomer choke limit. To address this bottleneck, the trays below the feed were replaced by new trays with 38% greater downcomer entrance area, at the expense of 5% reduction in the bubbling area, steeper downcomer slopes and weir-type change from swept-back to chordal. At the tray supplier initiative, clearances under the side downcomers were opened to reduce downcomer backup. Details of the modified trays are in Table 1. Besides alleviating concerns about downcomer choke flood, this modification brought the downcomer inlet velocities to within recommended design criteria. The tray changes were relatively inexpensive, using commercial adapters (Z-bars) to avoid hot work on the tower shell.

— Liquid level on the chimney tray approaching the top of the chimneys. This bottleneck was eliminated by raising chimney heights by 18in. The top of the chimneys is now 34in above the tray floor, well above the liquid level.

— Excessive two-phase mixture velocities at the feed nozzle and the pipe from the nozzle to the “H”. The modification needed to alleviate this bottleneck is to cut a larger nozzle at the tower shell. Due to metallurgical requirements, this modification was expensive and could not be economically justified. This bottleneck, therefore, was not modified.

Results

The process design for all the modifications was by the Fluor/BP team. Detailed drawings and fabrication were by a major tray supplier. The modifications were implemented at the February, 2003 turnaround.

Upon return to service, the debutaniser no longer experienced premature flooding, instability and high-pressure drops at the current plant rates. No limits were observed, although the tower feed rates have not been pushed far beyond the normal 57 000 BPD. Product purity has improved, with the bottom RVP consistently 1psi lower than previously. The debutaniser no longer bottlenecks the FCC gas plant.

Acknowledgement

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