MANAGING WASH BEDS

Gregory Cantley, Marathon Petroleum Company LP, USA, and Lowell Pless, Johnson Matthey Process Technology – Tracerco, USA, discuss a method to optimise the wash bed in crude vacuum towers.

The crude unit of today's modern refinery is where it all starts. Good, clean fractionation from the crude atmospheric and crude vacuum towers greatly impacts the operation of downstream units.

The wash bed in the crude vacuum tower is one of those so-called evil necessities. When it operates well, it does not seem to garner much attention. However,

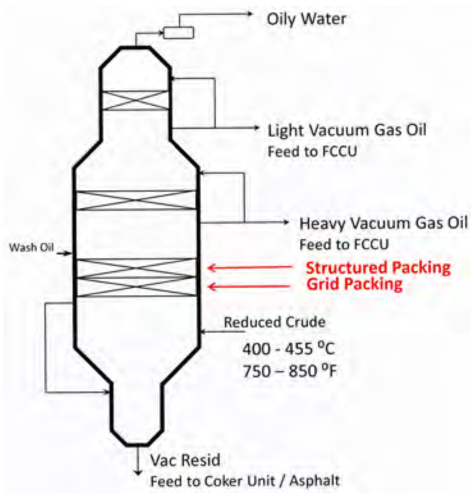

Figure 1. General process diagram of crude vacuum tower.

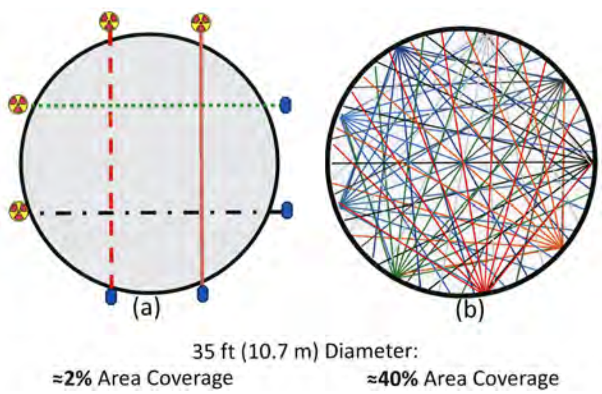

Figure 2. (a) A 4-way grid scan typically used to scan the entire height of the tower for troubleshooting; (b) a tomography scan completed at one elevation for a detailed cross-sectional density profile.

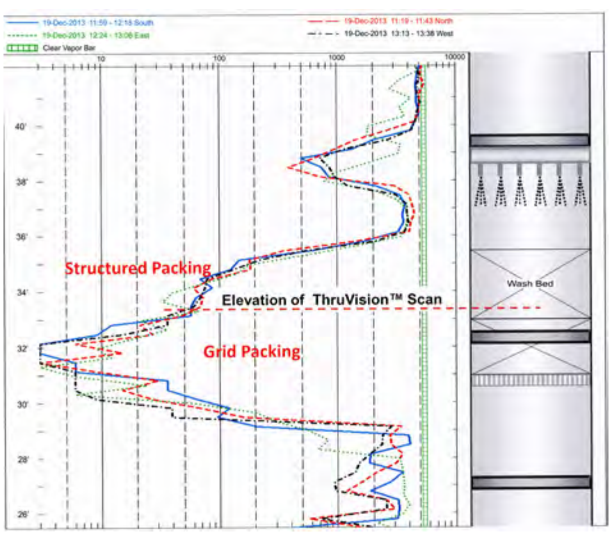

Figure 3. Baseline Tru-Grid™ scan results of a crude vacuum tower. The four scan lines matched, indicating the same process density along each scan line, suggesting good liquid distribution. One can see the shift in radiation counts, from right to left, due to the heavier bulk density of the grid packing.

when things go wrong, challenges can occur. The wash bed of the crude vacuum tower is prone to coking/fouling due to the low liquid rates, along with high vapour rates and temperatures. Generally, the wetting rate at the top of the wash bed is minimised to prevent high value product loss, but lower wetting rates lead directly to coke formation in the bed. The operating effectiveness of – or the rate and severity of coking in – the crude vacuum tower wash bed is one of the key variables determining the cycle time or run length between turnarounds. Therefore, a typical refiner works to balance the economics of heavy vacuum gas oil (HVGO) product recovery vs unscheduled or premature downtime to replace a coked bed.

Novel strategy

Marathon Petroleum Company's (MPC) approach towards the operation of the vacuum tower wash bed is based on a novel approach. The company regards the packing in the wash bed as a consumable item. The goal is to fully consume the useful life of the packing by the end of the operating cycle to maximise operating profit, by maximising HVGO yield. MPC uses Tracerco's ThruVision™ technology to routinely monitor the wash bed density to help manage the wash bed's useful life during the operating cycle. The technology provides a detailed density map, at a specific vertical elevation, that can pinpoint specific areas of liquid maldistribution or solids/liquid build-up.

The challenge was two-fold: first, what operating variables could be manipulated to control the coking rate? And second, what could be used to monitor the coking rate in the packing?

Case study: monitoring coking rate

This case study demonstrates the learning process over short operating cycles, and provides an example of the operating stratagem to manage the operating life of the vacuum column wash bed over a multi-year operating cycle.

MPC's objective is to manage the vacuum tower operating conditions in order to complete the required cycle run without completely coking the wash bed while maximising HVGO yield. In fact, the ideal scenario would be that the wash bed packing would reach the end of its useful life right at the end of the cycle run. The objective is not to save the packing from coking but to tolerate coking of the packing at a 'controlled' rate over time, as long as the desired operating rates and HVGO quality can be maintained until the end of the cycle run.

Figure 1 shows the general process schematic for one of MPC's crude vacuum towers. The wash bed consists of two sections of packing: layers of grid packing on the bottom and layers of conventional structured packing on top of the grid packing. This arrangement was thought to better sustain a longer cycle run length than a bed of all structured packing. The grid portion would wash most of the solids out of the vapour stream and provide enough heat transfer (cooling of the vapour feed) to minimise fouling and coking in the structured packing. It has been MPC's observation that despite the best intentions, the structured packing is still prone to coking.

In order to monitor the presence and rate of coking in the wash bed, gamma scanning was selected. Gamma scanning is a proven diagnostic technique used to troubleshoot the operation of separation towers. The gamma scan process is all external and one key feature is that it is carried out with the tower in operation. Using a small radioactive source and a sensitive radiation detector on the outside of the tower, the scan data provides a density profile of the internal hydraulics at the current operating conditions.

To monitor the wash bed, two scanning techniques are available. One method is the conventional vertical scan, typically called a grid scan as shown in Figure 2(a). The four scanlines measure the overall density through the packing within four quadrants. This method is best suited to looking for internal damage, flooding, liquid maldistribution, etc., but can be used to monitor the overall density of packed beds over time. A second method to use is a tomography scan, depicted in Figure 2(b). The advantage of the ThruVision tomography scan is that it provides more thorough coverage of the column surface area but it is carried out at only one elevation, while the grid scan covers the entire height of the tower. Both methods were used to monitor the vacuum tower wash bed, but the tomography scan was more suited to monitoring the general increase in the wash bed density. MPC had an experience where the bed started to coke, so the elevation chosen for the ThruVision scans was near the bottom of the structured packing layer, as shown in Figure 3.

Run cycle results

At the beginning of a cycle run, a baseline grid scan and tomography scan were carried out. Figure 3 shows the results from the baseline grid scan and Figure 4a shows the initial ThruVision scan results. Thereafter, the scans were repeated on a periodic basis, approximately every three months. The vacuum tower wash bed was operated very aggressively during the first cycle – minimum wash oil to maximise HVGO yield. This was purposely undertaken to set parameters for aggressive operation. The first section of the graph in Figure 5 shows the average wash bed densities calculated from the tomography scan data for Cycle 1. Figure 4b shows the ThruVision scan from the end of this cycle run. Over the two year period, there was a 40% increase in packing density due to coke build-up and/or excess liquid retention. After the two year period, there was an opportunity shutdown due to a problem that was unrelated to the coking. Subsequent shutdown and inspection showed the packing was severely fouled with coke (Figure 6) and so it was replaced.

The next cycle run was purposely operated with less aggressive operation, using higher wash oil rates to retard the rate of coking. This cycle run also lasted approximately two years, due to a forced shutdown from a hurricane striking the area of the refinery. As seen from the second

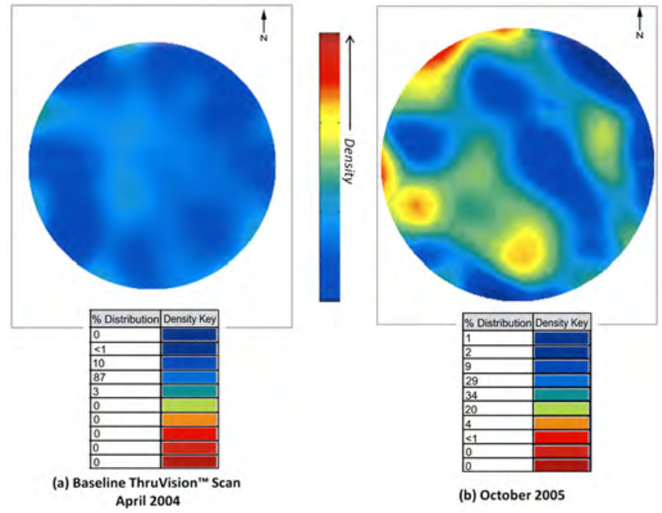

Figure 4. (a) Baseline scan results of crude vacuum tower wash bed; (b) scan result at the end of Cycle 1.

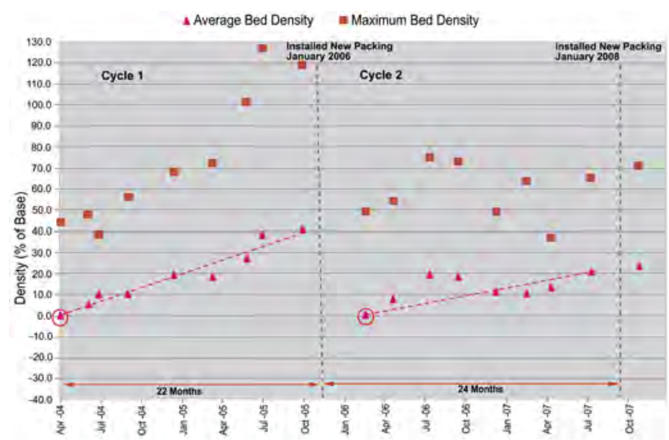

Figure 5. Cycle 1 wash bed densities when vacuum column operated aggressively vs Cycle 2 wash bed densities when vacuum column operated more conservatively.

Figure 6. Picture of wash bed packing following Cycle 1 operation.

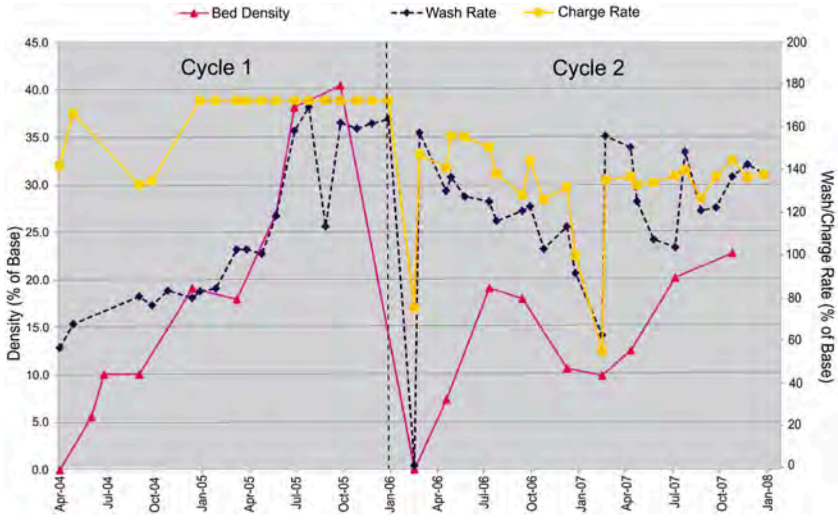

Figure 7. Wash bed packing density vs wash rate and charge rate.

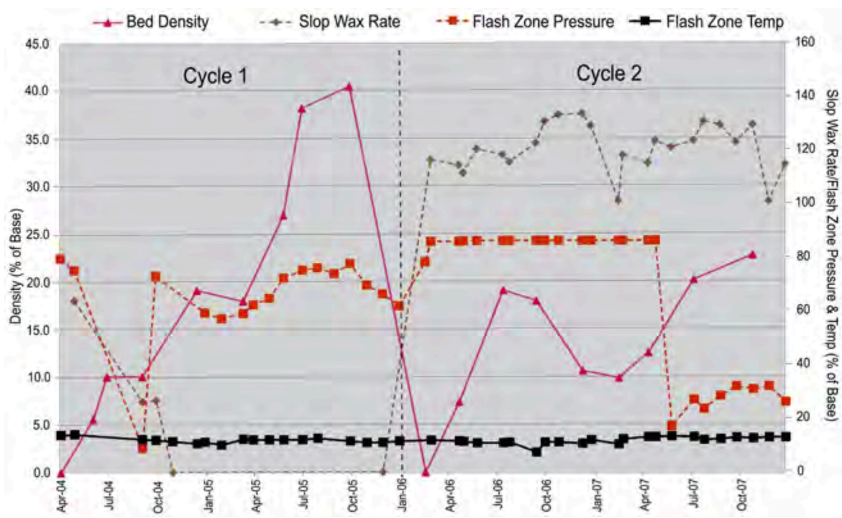

Figure 8. Wash bed packing density vs slop wax rate, flash zone pressure and flash zone temperature.

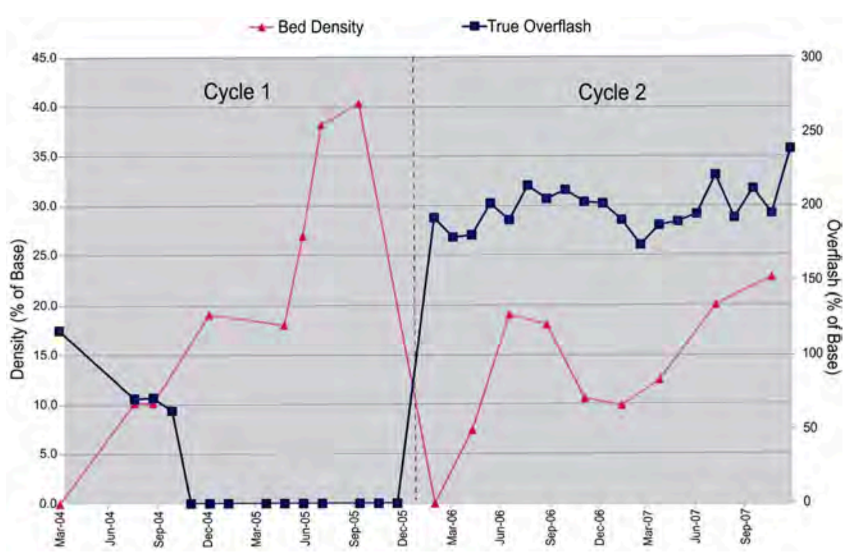

Figure 9. Wash bed packing density vs true overflash.

section of Figure 5, over the two year cycle run the average packing density increased by just over 20%. The shutdown provided an opportunity to open the vacuum tower and inspect the packing; only surface deposits of coke were observed. The packing was again replaced to start the next cycle run with fresh, clean packing.

Cycles 1 and 2 established boundaries for operating parameters between very aggressive operation and conservative operation. Several operating parameters were compared to the average packing density from the scans in order to correlate the best operating parameter with the rate of coking. Figures 7, 8 and 9 show this operating data vs the average bed density. There appeared to be no correlation between charge rate, flash zone temperature or flash zone pressure with the change in average bed density (reflecting the rate of coking), only a weak correlation between wash oil or slop wax rate with the change in average bed density.

By far the best correlation came between the true overflash rates vs the change in average bed density (Figure 9). Therefore, for the next cycle run the true overflash rate was going to be manipulated in order to try and regulate the coking rate.

The third cycle run lasted almost six years. This cycle run can be divided into three segments due to the operating demand placed on the refinery. The operating conditions for the first segment were based on the need for the vacuum tower wash bed to operate for five years without coking prematurely. The wash bed was operated with slightly less overflash than during Cycle 2 in order to gain a higher HVGO yield, yet still have some confidence that the wash bed would not coke prematurely.

In late 2010, management decided to lengthen the cycle time beyond the original five years. Therefore, the overflash rate was dramatically increased in order to retard the coking rate at the expense of some HVGO yield. Then in mid-2012, management advanced the planned end of the cycle run. At that time, operations reduced the overflash rate to increase HVGO yield. Knowing the wash bed packing was going to be replaced allowed operations to tolerate an increased coking rate. However, to provide leeway, the decision was made to be less aggressive than Cycle 1. Figure 10 shows the overflash rate vs the packing density over the 69 month cycle run.

The slope of the overall increase in the average packing density over the time period for each operating stratagem is in Figure 10. At the beginning of the cycle, the rate of coke build-up was represented by a slope of 0.84, the most aggressive operating period. When the decision was made to lengthen the run time, operations became more conservative, operating with a higher overflash rate and the slope reduced to 0.2. Later in the cycle, when the cycle end date was advanced, operation became a bit more aggressive, reducing the overflash rate and achieving a coke build-up rate of 0.54, in between the aggressive and conservative modes of operation. By the end of the cycle, the average wash bed density was of the same order of magnitude as the aggressive short run of Cycle 1. Subsequent inspection of the wash bed packing during the turnaround showed that it was not completely fouled or coked. This highlighted that a little more runtime was left. However, the coking rate had been successfully managed, while the HVGO yield had been maximised through changing operating demands over the course of the cycle.

ThruVision scans were used to monitor and determine the average wash bed packing density through the cycle run. While the primary purpose for conducting a tomography scan is to study liquid distribution through a bed, the primary use for this application was to track the bed density to monitor the build-up of coke or the retention of liquid in the packing due to coke fouling. Figure 11 shows the baseline density profile and the cycle ending density profile. Note how the density range shifted over the cycle. The authors of this article suspect that the bed densities through the core of the column were understated due to the high overall density not allowing the scan source to penetrate all the way through the middle of the bed.

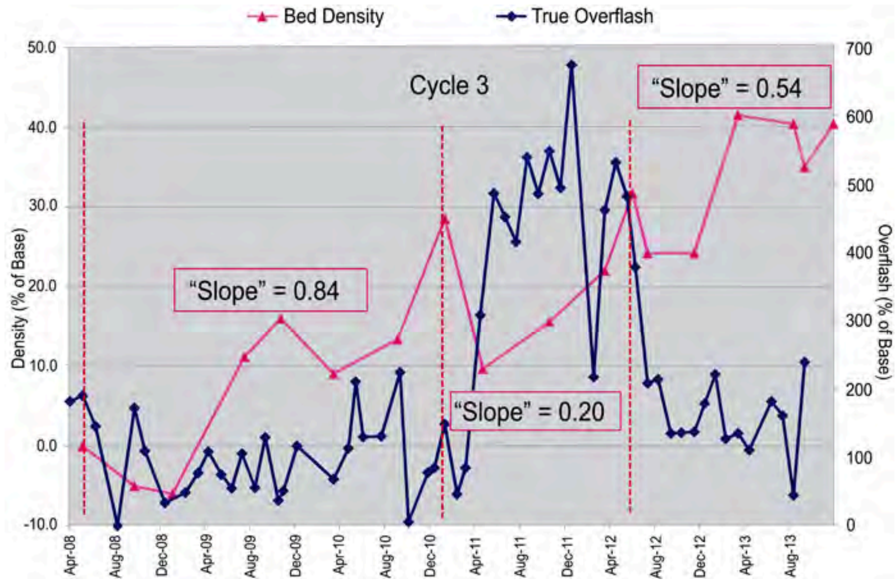

Figure 10. Trend of wash bed packing density vs true overflash over the 69 month run of Cycle 3.

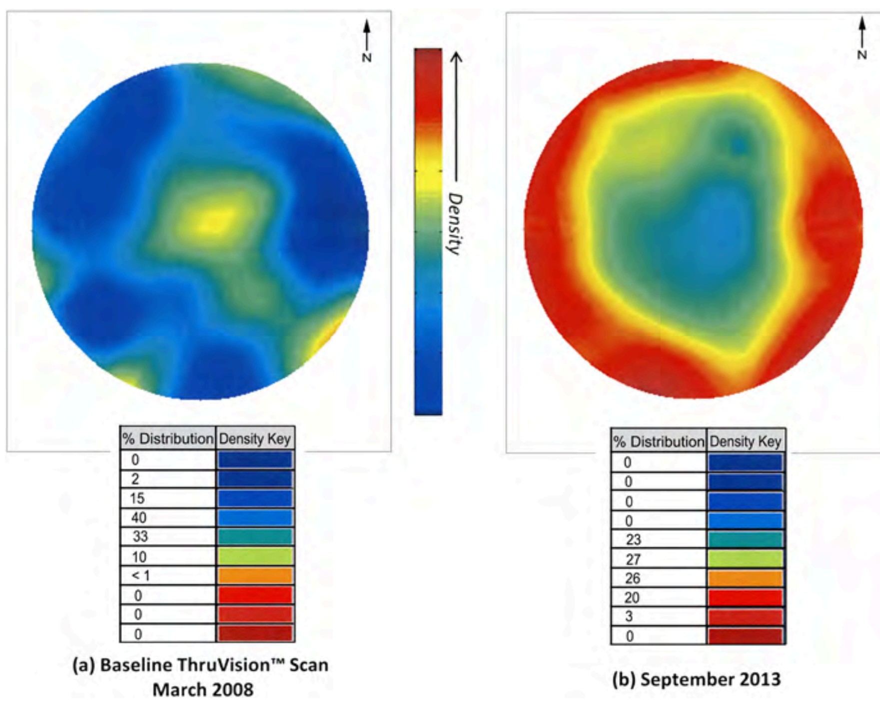

Figure 11. (a) Baseline scan results of crude vacuum tower wash bed at the beginning of Cycle 3; (b) scan result at the end of Cycle 3.

Conclusion

Several conclusions can be made from this study. The tomography scans yielded extensive cross-sectional coverage to monitor fouling/coking in packed beds in the studied application, and the results of the scans can be used to monitor wash bed coking and to make decisions on operating conditions to target a run (cycle) length in the studied application. This case study also shows that coking in the wash bed is directly correlated with the true overflash rate, and this operating stratagem can be used to maximise profit by treating the wash bed packing as a consumable item.

Note

In Figures 4 and 11, note the increase in packing density both from a change in colour palette and density range distribution.

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