Debottlenecking an FCC gas concentration unit

Component trapping by physical carry-over of water can cause capacity bottlenecks that are not easily predicted

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Component trapping in fractionation towers refers to a phenomenon wherein a component having intermediate volatility, as compared to the light and heavy key components, accumulates in a tower. This occurs when the tower top temperature is too low for the component to vaporise and leave the column along with top vapours, and the bottom temperature is too high to allow the component to condense and leave the column along with bottom liquid. The component tends to accumulate in the tower because its rate of removal from the tower is lower than its rate of influx into the tower. The accumulation continues until the intermediate component concentrations in the overhead and bottom allow their removal at the rate they enter, or a flooding limitation is reached. This phenomenon of a trapped component periodically exiting through the top or bottom in larger quantities results in unsteady tower operation, upsets, difficulties in controlling column temperature profile and tray flooding. If the trapped component is water, then it may also cause accelerated corrosion.

This article describes the investigation of and the solution to water trapping in the gas concentration unit (GCU) in Essar Oil's Vadinar refinery. The FCC GCU typically has primary absorber, stripper, debutaniser and gasoline splitter towers for the separation of gas, LPG and gasoline. Water trapped in one or more of these towers can cause instability and reduction in capacity.

While the phenomenon of component trapping in fractionation towers and water trapping in the GCU of FCC units in refineries has been reported and discussed in earlier work,[1] this case study demonstrates that looking outside the affected towers can be a critical factor when evaluating possible solutions.

Overview of FCC gas concentration unit

In Essar Oil's refinery process, wet gas and raw gasoline from the FCC main fractionator overhead are routed to the GCU. In the GCU, C_2 and lighter components are rejected into the fuel gas system from the primary absorber. In the debutaniser column, C_3/C_4 (LPG) are separated from gasoline (see **Figure 1**).

Vapours from the reflux drum of the main fractionator flow through a two-stage centrifugal compressor to the high pressure (HP) separator. Prior to entering the HP separator, the reflux drum vapours are joined by the liquid from the bottom of the primary absorber and the vapours from the stripper over-

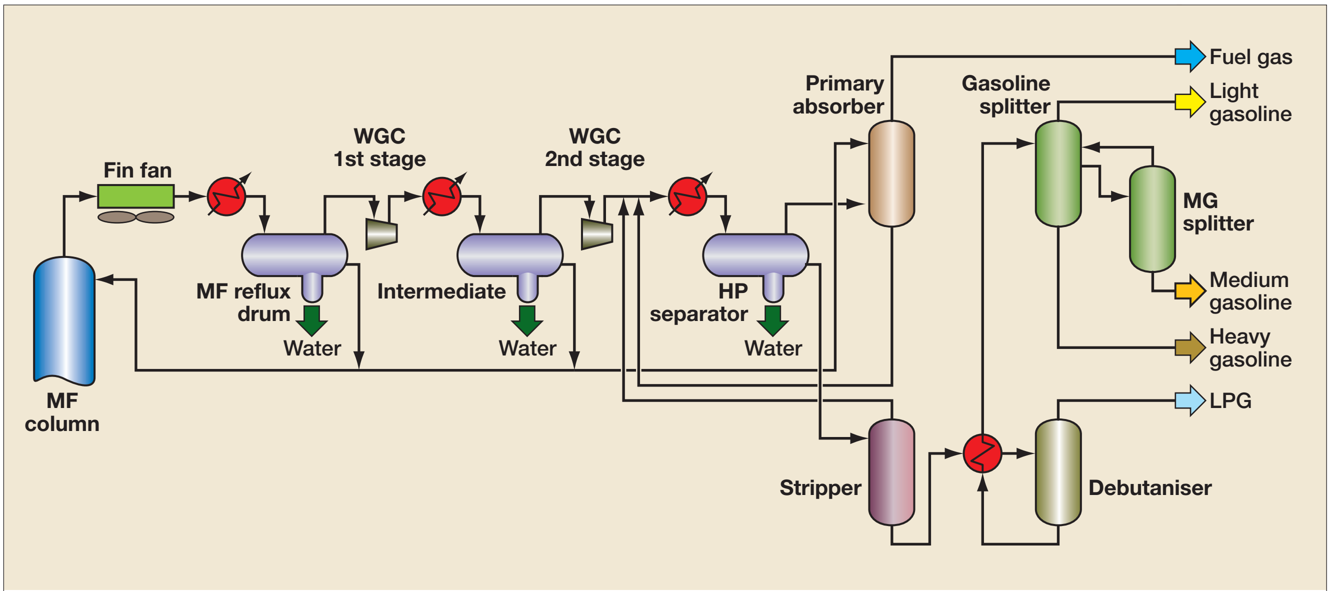

Figure 1 Overview of gas concentration unit

head and cooled in the trim cooler. The HP separator allows for liquid removal from the vapour streams. Hydrocarbon liquid is fed to the top of the stripper and the vapours are routed to the bottom of the primary absorber. A boot holds the interface level, creating the boundary between liquid phases such that the water can be removed from the separator. The primary absorber absorbs C_3 and heavier components from fuel gas, and the stripper strips the C_2 and lighter components from the liquid before it is fed to the debutaniser.

In the absorber-stripper configuration, it is envisaged that the dissolved water entering the column with the feed streams will get trapped. A water draw-off tray in the form of a chimney collector is typically installed near the top of these towers to facilitate water removal (see **Figure 2**).

Increased severity operation

Essar Oil proposed operating the FCC reactor in high severity mode to increase the yield of the lighter components. Process simulations were done by Essar Oil to predict the hydraulic loads in the GCU. Hydraulic ratings were performed by Koch-Glitsch with the simulated loads to check the adequacy of the GCU columns. The results indicated that the towers in the GCU had sufficient excess capacity to handle the future increased loads without any modifications to the existing internals.

When the severity in the FCC reactor was increased, problems were observed in operating the stripper and the debutaniser. The stripper had a higher and fluctuating pressure drop, and the debutaniser developed issues with boil-up. These symptoms forced the operators to lower the unit capacity.

During a troubleshooting review by Essar, it was observed that water was continuously being removed from the debutaniser reflux drum. The reflux drum was equipped with a control valve on the water drain, which normally did not open significantly at low severity reactor operation. At the higher loads and severity, the control valve opening was as high as 50-60% which

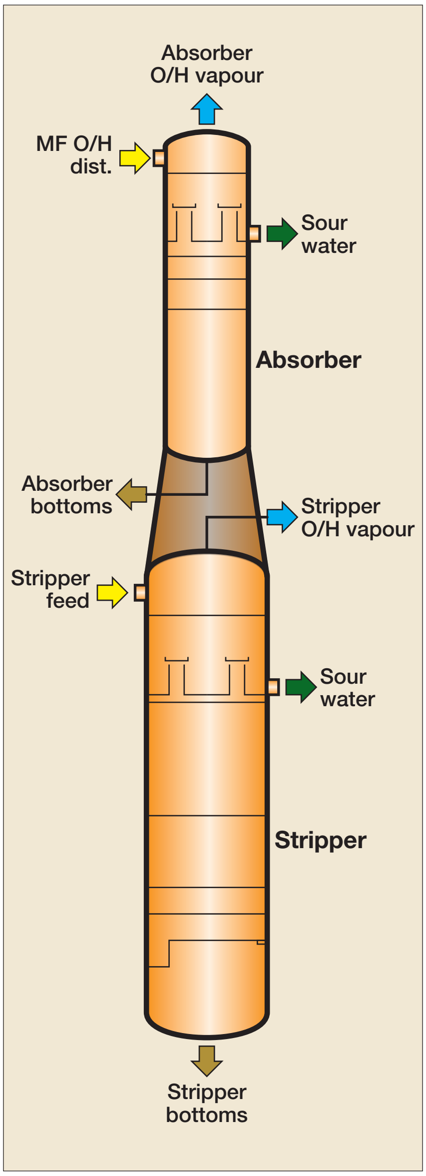

Figure 2 Water removal arrangement from absorber/stripper

corresponded to a water flow rate of around 450 l/h. This was much higher than the expected dissolved water in the feed to the GCU.

It was suspected that the water could be responsible for the issues with the towers. An attempt was made to increase the bottom temperature of the stripper to minimise water ingress into the debutaniser. Both the absorber and stripper were equipped with water draw-off trays; however, water was never available at the draw location of the absorber and stripper. When the bottom temperature of the stripper was increased, the operation became unsteady as pressure drop increased and fluctuated between 0.23 kg/cm^2 and 0.35 kg/cm^2. The stripper could not be stabilised with the higher bottom temperature, and capacity had to be reduced to ensure steady operation. Increasing the stripper reboiler duty also resulted in increased recirculation of the stripper overheads through the HP separator and into the absorber.

Cyclical slugging is the typical symptom of unsteady state water accumulation. Water builds in the column until the column floods or a slug leaves from the top or bottom of the column. It was clear that the amount of water entering the system could not be handled by the existing tower configuration. The focus then shifted to the HP separator of the GCU where there is a provision for separating free water in the boot of the vessel.

Performance improvement study of HP separator

Koch-Glitsch was asked to analyse the options to improve water separation in the HP separator. In Essar's configuration, the HP separator is a horizontal drum with a water boot and no internals. It separates three phases: hydrocarbon vapours, hydrocarbon liquid and water.

Because superior collection of dispersed water was needed, Koch-Glitsch evaluated the use of Ky-Flex liquid-liquid settling media to improve the separation (see **Figure 3**).

Ky-Flex media works by enhancing gravity separation. It minimises turbulence effects by dividing the stream into a number of separate chambers, which provides four primary benefits:

(1) Decreases the equivalent hydraulic diameter, thereby greatly reducing the Reynolds number of the flowing fluid and producing a deep laminar flow environment that is optimal for gravity settling

(2) Isolates the fluid in separate channels, thereby limiting how far droplets can 'wander' and reducing the negative impact of eddy currents

(3) Decreases the distance a droplet needs to rise or fall before reaching an interface, thereby greatly lowering the settling time requirement

(4) Provides multiple interfaces inside the equipment where drop-

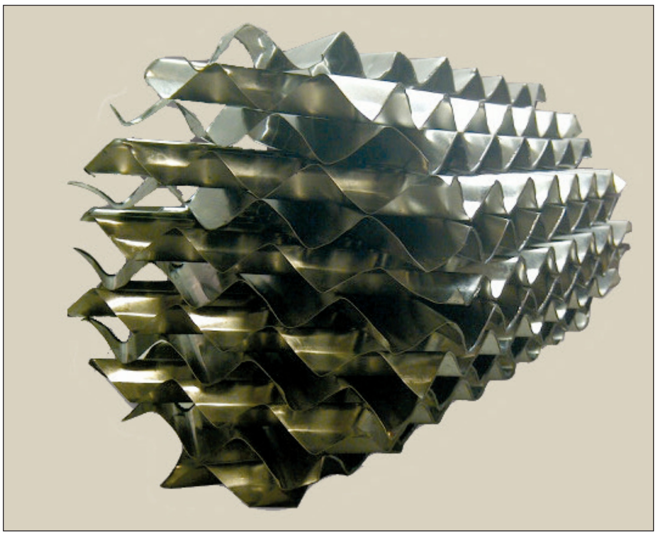

Figure 3 Ky-Flex liquid-liquid settling media

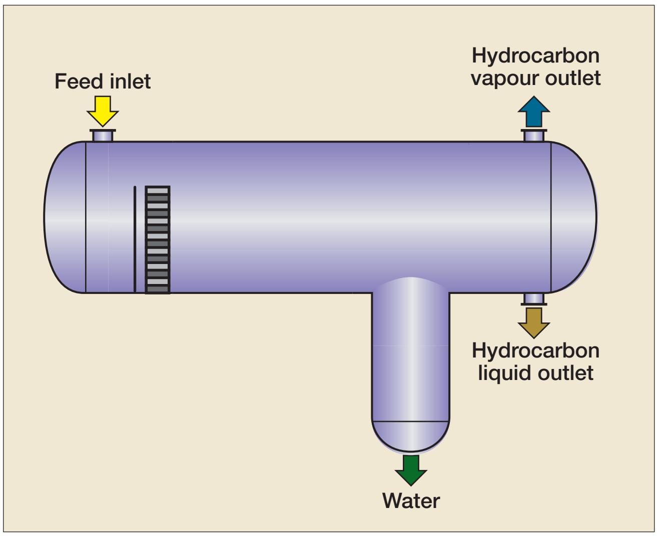

Figure 5 HP separator after installation of turbulence isolation baffle and Ky-Flex liquid-liquid settling media

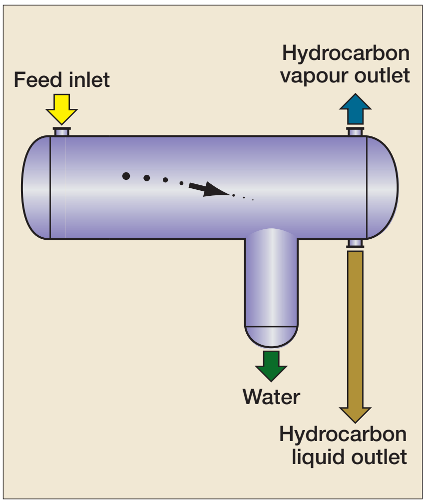

Figure 4 Velocity vector of droplet

Figure 6 Fouled debutaniser reboiler tubes

lets can coalesce, thereby positively improving the settling process.

A high Reynolds number causes higher turbulence, eddy currents and interferes adversely with the settling of droplets. The estimated Reynolds number was 185 000 in the HP separator, well within the turbulent regime. **Figure 4** indicates the velocity vector of the droplets in turbulent regime. The application of Ky-Flex liquid-liquid settling media would reduce the Reynolds number to less than 1000, well within the laminar regime, and allow a greatly enhanced and predictable separation.

To maximise the performance of the Ky-Flex media, Koch-Glitsch recommended installing a turbulence isolation plate upstream to provide a proper liquid distribution to the media. The purpose of this baffle is to provide a quiescent zone prior to the liquid's entry into the liquid-liquid separation region. The quiescent flow regime provides an environment in which liquid-liquid separation is optimised.

Turnaround and installation

In the subsequent turnaround, the Ky-Flex media and turbulence isolation plate were installed in the HP separator (see **Figure 5**).

The debutaniser reboiler was inspected during shutdown. Layers of deposits were observed on top of the tubes across the exchanger (see **Figure 6**). Analysis of these deposits indicated a predominant presence of iron content in the sample, which indicated fouling due to polymeri-

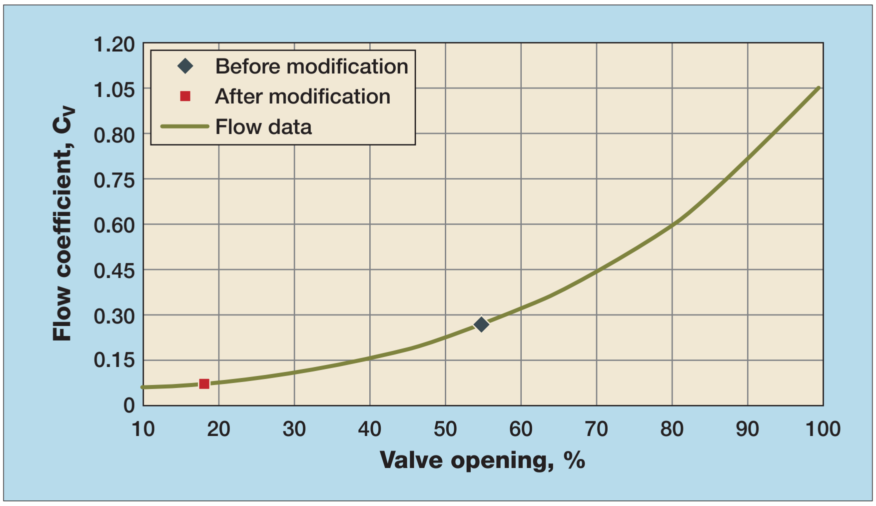

Figure 7 Debutaniser overhead receiver boot control valve opening

Comparison of pre- and post-revamp results

Parameter	Pre-revamp	Post-revamp	Results/comments
Feed from FCC main column receiver to HP separator, t/h	147	182	Feed rate increased by 124%
Pressure drop across stripper, kg/cm^2	0.26	0.25	
Temperature at stripper bottom, °C	125	116	Reduction in stripper bottom temperature reduced reboiler duty
Water from debutaniser overhead receiver to debutaniser feed, %	0.132	0.05	
Temperature at debutaniser bottom, °C	164	170	Fouled reboiler tubes limited temperature
Debutaniser reboiler duty, GCal	9.2	13.6	Reboiler duty debottlenecked

Table 1

sation of diolefins in the presence of water at high temperature on the reboiler process side (shell side). The duty of the debutaniser reboiler was limited due to this fouling which affected the operation of the debutaniser. The deposits on the reboiler were cleaned in the shutdown.

Results

Post-installation of the Ky-Flex media in the HP separator, the water carry-over was reduced significantly to the debutaniser overhead receiver. As a result, the control valve in the debutaniser overhead receiver boot opened less frequently with minimal and intermittent water withdrawal (see **Figure 7**). The corresponding water flow rate was reduced from approximately 450 l/h to 108 l/h. The bottom temperature of the stripper could be reduced with a resulting reduction in reboiler duty (see **Table 1**).

The operation became stable and the capacity of the gas concentration unit could be increased. The results of the pre-revamp and post-revamp operation are shown in **Table 1**.

Conclusion

Component trapping by physical carry-over of water can cause capacity bottlenecks that are not easily predicted by performing process simulations and hydraulic rating of internals. Koch-Glitsch worked closely with Essar Oil and utilised their experience to troubleshoot and thoroughly review the equipment in the unit, especially those performing physical separations, to identify potential problems. Based on the symptoms and unsteady operation of the stripper and debutaniser under increased loading, it was suspected that water accumulation within the system was the cause.

Koch-Glitsch focused on the most convenient way of removing water prior to the affected columns, leading to the recommendation to revamp the HP separator immediately upstream. Once the problem was fully understood, and the focus was put on the HP separator, the Koch-Glitsch process engineering group evaluated the performance shortfalls of the existing arrangement and prepared a solution to remedy the problem. By incorporating experience and proprietary separations software, Koch-Glitsch provided a solution that would meet Essar's capacity goal. By understanding and targeting the source of the problem, the solution was implemented in the HP separator vessel which debottlenecked and improved the performance of the GCU.

Reference

1 Kister H Z, Component trapping in distillation towers: causes, symptoms and cures, *CEP*, Aug 2004.

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