Expand crude diet flexibility through comprehensive oil management

One of the primary means for refiners to boost profitability is to improve crude diet flexibility. Many refiners are challenged with increasing their margins while the quality of the global crude oil supply declines. Refiners require the ability to process greater volumes of a variety of opportunity crudes, from light shale oils1 to heavy Canadian crude,2 without compromising refinery processes or equipment. Although opportunity crudes boost a refiner’s bottom line, they also introduce an array of challenges and risks.

Processing issues in the crude unit, such as fouling and corrosion, are frequently traced back to poor efficiency of contaminant removal in the desalter. The desalter often becomes the focus for correcting the problem. However, desalting inefficiency is only a symptom of systemic problems further upstream, which may occur during slop oil generation or in the tank farm. The problem cannot be efficiently and permanently corrected without a clear understanding of the root cause.3

The challenges posed by opportunity crudes also can be related to crude oil composition or incompatibilities with other crudes in the feedstock. Opportunity crudes often contain high concentrations of salts, solids, paraffins, asphaltenes, tramp amines, calcium naphthenates and other metallic contaminants. In the case of heavier crudes, the higher viscosity creates problems for transport and pumping.

When opportunity crudes are blended into a crude feedstock, incompatibilities arise that can lead to problems like asphaltenes destabilization and deposition. Even the desalter wash water can play a role. If this water is too alkaline or has too high of a pH, then it can stabilize emulsions and promote preferential partitioning of amines and naphthenate salts into the crude. These contaminants can lower the efficiency of the desalter, and when carried along in the desalted crude, they can cause processing problems in the crude unit, such as corrosion.

Since discounted crudes are associated with such a large and variable array of challenges, they cannot be processed without considerable uncertainty and risk of system upsets. Without a clear understanding of all of the processes, equipment, chemicals and crude feedstocks upstream of the desalting equipment, refiners must either limit the volume of discounted crude that they can reliably process, or suffer processing problems that threaten the reliability, efficiency and mechanical integrity of their equipment.

A comprehensive management approach. One company has taken a stewardship approach for crude oil processing that expands opportunities for running challenging crude slates and increasing crude diet flexibility. The developed program (FIG. 1) features a suite of tools, including engineering practices, monitoring and analysis of crude oil and water, as well as a variety of chemical treatments. It looks beyond the desalting operation to consider a comprehensive view of all equipment, processes and feedstocks that ultimately contribute to reliable desalter operations. A system review is conducted that includes tank farm operations, all crude feedstock

![FIG. 1. The crude management program takes a holistic view of the entire refinery operation, beginning with the transportation of crude into the facility, through the desalter, into the crude unit and then to wastewater treatment.](image-url)
and blending strategies, slop oil management practices, chemical inputs, desalter equipment and operating conditions, and wash water sources and quality.

Many refiners rely primarily on demulsifiers to treat emulsion problems when a new discounted crude enters the desalter (e.g., increasing the demulsifier dose). However, if the emulsion problem is due to the presence of solids or other contaminants, then other treatments or engineering practices would more efficiently resolve the problem. The management program directs the focus to the source of the problem and the correct location for treatment.

The approach begins with an initial system review, which includes a survey of tank farm management. This review examines how the refinery receives the crude—whether by truck, rail, pipeline or ship—to gain a perspective on all storage, handling and blending activities before the crude reaches processing units.

Since slop oil is frequently found to be the source of desalter upsets, slop oil management practices also are reviewed. Slop oil often contains a high percentage of solids, water, waxes and asphaltenes. If slop oil is identified as the source of processing issues downstream, then a program can be developed to properly treat it using a range of chemical, mechanical and engineering solutions. The treated slop oil can then be fed back into the process train without risk of upset to downstream units.

Other aspects of a comprehensive system survey include an assessment of the desalter operating capability, as well as a review of wash water quality and sources. An investigation also is conducted on how the effects of upstream oilfield operations, including chemical treatments, might impact downstream processing.

Once a system review is conducted, the source of processing issues can be identified and targeted. If desalter operations are the cause of processing issues, then the desalter will be the focus of treatment. However, if the source of the processing issue originates elsewhere, then solutions will target the appropriate source.

A major crude oil management tool used in many refineries to target the problem is crude pretreatment. Crude pretreatment is a strategy to apply a portion of the demulsifier to the crude storage tank. This significantly increases the amount of time the demulsifier is in contact with the oil, and allows it to penetrate to surfaces and interfaces. When pretreated crude oil is mixed with wash water and enters the desalter, it is chemically poised for fast and efficient emulsion resolution. A proper pretreatment program reduces the amount of demulsifier applied at the desalter in direct proportion to the amount added at the tanks. Rather than add to chemical costs, pretreatment programs often result in a decrease in overall chemical spend. Pretreatment also leads to a more stable and reliable crude feed, and typically allows desalters to be run with higher mixing pressures to maximize salt removal efficiency. This process results in fewer problems, such as corrosion, downstream in the crude unit.

Another example of a tool for treating processing issues is wash water acidification. Analysis of a new crude oil might highlight potential problems, such as high concentrations of calcium naphthenate or amines that could cause corrosion issues in the crude unit overhead. A solution could then be initiated, such as contaminant removal to acidify the wash water to the proper level to promote partitioning of the contaminants into the brine, thereby removing them from the desalted crude to be charged to the tower.

Other capabilities in the management program include a field asphaltenes stability index test to manage asphaltenes stability, and solids release technology to enhance solids removal, improve emulsion resolution and reduce the impact of solids in downstream processes.

The program continuously optimizes the refinery’s processes as new crude slates are introduced. When a particular discounted crude is no longer part of the crude blend, the management program provides the tools to change the treatment for uninterrupted and upset-free processing. When new crudes come to market, the program is ready to help the refiner reliably introduce them into the process and protect profitability.

From obstacles to opportunities. The crude management approach has helped expand crude diet flexibility in a number of refineries across North America. Specifically, the program has enabled refiners to incorporate growing volumes of Canadian heavy oils and shale oils into their crude blends while minimizing processing problems.

Heavy oil processing. Conventional heavy oil, bitumen and upgraded bitumen comprise the majority of production from the Western Canada Sedimentary Basin underlying Alberta and Saskatchewan. The high viscosity, high solids content, and asphaltenes in these opportunity crudes present many processing challenges. These challenges include stabilized emulsions, sludge deposition, solids contamination, fouling of the heat exchanger train and furnace, and oily brines leaving the desalter and causing upsets in the wastewater treatment plant.

In one example, a refiner in the midcontinental US experienced desalter upsets due to inconsistencies in the quality of crude coming from the tank farm. These upsets resulted in periods of high slop oil generation. Adding the slop oil back into the feedstock for reprocessing subsequently resulted in a reduction in fresh crude rate. In an attempt to re-establish desalter performance, the refiner sequentially increased primary demulsifier dosage 10 times, a reactive approach that increased treatment costs.

The management program helped identify the source of the problem and recommended a targeted solution. A system-wide survey was conducted that encompassed the crude unit, tank farm and slop oil management system. The survey identified accumulated waxy sludge and solids in a crude storage tank as major contributors to desalter upsets. Infrared scans confirmed approximately 17 ft of sludge in one of the crude tanks. On an intermittent basis, tank sludge was being released into the crude charge, causing desalter upsets and generally poor desalter performance. Periods of high brine oil and grease were also observed to increase the rate of slop generation. Water carryover in the desalted crude was leading to pressure increases in the atmospheric tower.

A crude pretreatment program was implemented that included a heavy oil demulsifier formulated for tank farm conditions. The crude pretreatment helped deliver a more consistent feed to the desalter and minimized sludge accumulation in the tanks. Oil demulsifier contact time was maximized, which delivered faster emulsion resolution at the desalter and improved cost efficiency. Additionally, the injection of the heavy oil demulsifier into the crude storage tank enabled better resolution of tank emulsions with a
cleaner water draw.

Four yr after implementing the heavy oil demulsifier pretreatment program, only 16 in. of accumulated sludge remained in the treated crude tank, a 90% reduction from initial levels. During this same time period, a non-pretreated tank containing the same crudes had built up a 12-ft sludge layer (FIG. 2). The significant sludge reduction in the pretreated tank stabilized the desalter operation. At present, the refiner operates with a 3-in. emulsion interface in the desalter, a 95% reduction from pre-program conditions. The refinery’s total slop generation rate was reduced by more than 65%, which allowed for an additional 1 Mbpd of fresh crude rate.

The heavy oil pretreatment demulsifier program delivered improved performance for equivalent costs compared to the base case. Operating expenses with the program were cost neutral, while the value of reduced sludge accumulation in tankage and the higher fresh crude rate translated to savings of $1 MM/tank and $625,000/yr in incremental profit, respectively.

In another application, a US Gulf Coast refiner needed a treatment option that would allow processing of higher volumes of discounted crudes containing microfine solids. These solids commonly lead to emulsion growth in the desalter, poor brine quality, reduced solids removal efficiencies and fouling of downstream equipment. The refiner had set key performance indicators (KPIs) of less than 1,000 ppm oil and grease in brine, and greater than 50% solids removal across the desalter.

Using the management program, a system-wide survey of the facility was conducted, including the crude unit and tank farm, to identify solutions for improved solids removal. A treatment protocol was designed that included the implementation of a solids release agent program. This prescribed treatment transferred de-oiled solids from the crude oil and interface emulsion layer into the desalter brine. Using the solids release agent, the refiner was able to increase the volume of high-solids crude to nearly 50% of the total charge, while decreasing desalter brine oil and gas by more than 70%. At the same time, solids removal across the desalter (desalted crude vs. raw crude) improved from 50% to more than 70%. The interface emulsion layer in the desalter was reduced by 35% as a result of the improved solids control (FIG. 3). Also, the solids release agent removed oil from the surfaces of the solids, reducing brine oil and grease.

Ultimately, the management approach and customized solids release agent program helped the refiner increase the volume of high-solids crudes in its crude diet while achieving desalter KPIs. The greater flexibility in the crude mix translated to an incremental $135,000/d profit for the refinery.

**Shale oil processing.** With growing production rates in the US, shale oil has rapidly become a major part of many refinery feed slates. At first glance, shale oil seems relatively easy to process because it tends to be light and has low viscosity. However, shale oils also tend to contain high concentrations of paraffin and, consequently, can generate wax deposits that foul transportation pipelines, storage tanks and process units. Some shale oil components may lead to corrosion issues, and blending shale oils with heavy asphaltene crudes can negatively impact the stability of the blended crude feed. These
problems, and their resulting negative effects on refinery operations, have been successfully addressed with the crude management program.

A pipeline shale crude feed with a high wax content created multiple operating problems for a US mid-continent refiner’s desalter (FIG. 4) and fluid catalytic cracking (FCC) unit. Crude tanks filled with up to 5 ft of sludge that was high in solids, waxy hydrocarbons and water. In the desalter, interface emulsions would grow as the tank periodically released large amounts of sludge, causing the grids to short out and high levels of solids to be carried over in the desalted crude. The refiner had been conducting weekly demulsifier slug treatments to resolve the interface emulsion and return the grids to normal operation. In addition, the FCC catalyst suffered major iron loadings, causing the refiner to dump catalyst at a cost of more than $500,000/event.

A technical assessment was performed using the crude management approach. Gas chromatography data confirmed the presence of high-melting-point waxes in the crude, and visual inspection showed wax accumulation on sample containers. A tank pretreatment program was initiated to help break wax-stabilized emulsions and relieve the desalter of upsets. A strategy also was developed to optimize the desalter level and maximize oil residence time without producing oil in the brine. This provided more time to resolve wax-stabilized emulsions. A new demulsifier, selected through testing of the paraffinic crude slate, was identified and deployed to provide better emulsion resolution. In addition, the continuous mudwash rate was increased to maximize solids release to the brine.

The comprehensive solution resulted in control of the emulsion layer in the desalter, allowing the refiner to discontinue the demulsifier slug treatments. An eightfold increase was seen in the volume of solids released to the brine. Solids were decreased in the desalted crude, and periodic high solids carryover events were eliminated. As a result, the iron content in the desalted crude dropped by 50%, and iron loadings to the FCC catalyst were brought under control. The refiner was able to avoid the $500,000/event cost of dumping catalyst.

In another example, a refiner in Canada faced asphaltene instability problems, caused by the presence of light, paraffinic Bakken shale oil in the crude slate. This led to processing challenges that included interface emulsion growth in the desalter, difficulty maintaining desalter level control, water carryover in the desalted crude and brine with a high oil content. The wastewater treatment plant was compromised by the oily undercarry, forcing the refiner to reduce the amount of heavy crude in the feed mix by 10 Mbdp.

A technical assessment confirmed that the Bakken shale oil caused severe asphaltene instability in the crude blend. A program was implemented to monitor asphaltene stability in the field using the proprietary asphaltene stability index test protocol. This test helped guide crude blending practices and avoid desalter upsets. Demulsifier dosage was increased to minimize the impact of asphaltenes on desalter performance.

Upon implementation of the solution, the refiner was able to achieve stable desalter operations by optimizing the amount of heavy crude and Bakken in the blend. Lost opportunities were avoided on crude slate optimization, which translated to a $5/bbl incremental savings. If processing challenges had continued without the solution in place, the lost opportunity discount would have amounted to as much as $18 MM/yr.

**Recommendations.** Management of crude feed slates is gaining greater acceptance among refiners, particularly as more of them experience the positive impact that the management program has on their long-term operability and performance. The approach includes a comprehensive system review, a focus on the true source of processing problems, and a wide range of chemical treatment technologies and engineering solutions.

Management of crude feed slates allows refiners to run higher volumes of a variety of discounted crudes while protecting their assets. This advantage results in improved profitability, even while increasing crude diet flexibility in response to changing global crude supplies. **NOTE**

**LITERATURE CITED**


**NOTE**

Baker Hughes’ proprietary Crude Oil Management Program is designed to help refiners manage challenging crude slates and increase crude diet flexibility.

**MAINTENANCE AND RELIABILITY**

**FIG. 4.** A tank pretreatment program was initiated at a US mid-continent refinery to help break wax-stabilized emissions and relieve the desalter of upsets.