

UNLOCKING CURRENT REFINERY CONSTRAINTS

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Unlocking current refinery constraints

When processing heavy feeds, technology based on residuum supercritical solvent extraction provides higher volumes of gas oil and DAO for conversion units. Potential constraints through existing vacuum and coker units can also be resolved

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The escalating demand for petroleum-refined products and high differentials between light and heavy crude oils have increased the usage of heavier crude oils.

Examples of heavy crude oils being used by refiners today include Athabasca bitumen, Lloydminster and Cold Lake heavy oils from Canada, Maya from Mexico, Arab Heavy from the Middle East, and other African and Venezuelan crude oils. When added to the conventional crude diet, these heavier crude oils with higher resid content will either increase fuel oil make or begin to burden existing vacuum and coking units. At the same time, the gas oil content in heavier crudes is usually lower compared to conventional crudes, resulting in lower feed to conversion units, such as the FCC or hydrocracker unit.

The increasing oil price is motivating refiners to look for solutions to extract more from the bottom of the barrel in a more cost-effective way. Refiners are increasingly using solvent deasphalting in the following applications:

— **Debottlenecking existing vacuum and coking units:** for refineries feeding vacuum residue to cokers, the addition of KBR's ROSE (residuum oil supercritical extraction) unit reduces the coker feed rate by up to 50%. The coke make is also reduced by 15–20%, thus debottlenecking the existing cokers

— **In place of vacuum distillation:** the higher yields from a ROSE unit when compared to vacuum distillation units help refiners improve overall refinery liquid yields by 2–5 vol%.

Figures 2 and 3 show the processing options for debottlenecking existing vacuum and coker units by using a ROSE unit in a revamp situation, or investing in a ROSE unit instead of a vacuum unit in a grassroots application.

SDA history

The oil refining industry has used solvent deasphalting (SDA) for over 50 years. Conventional SDA units separate

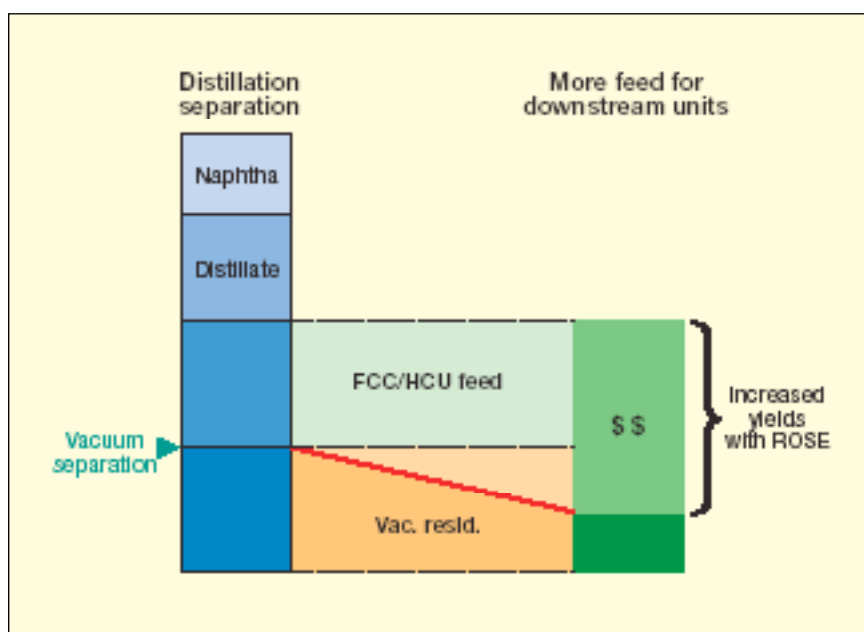


Figure 1 Increased yields from bottom of barrel

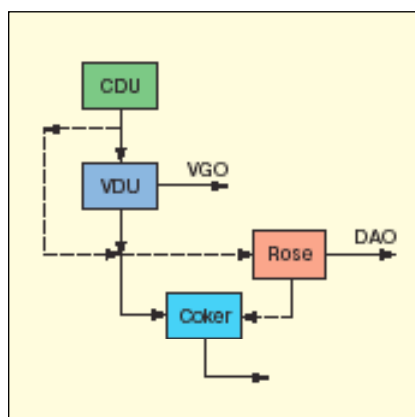


Figure 2 ROSE unit to debottleneck vacuum and coker

solvent from deasphalted oils (DAO) by boiling. The SDA process was initially used for recovering lube base oils from vacuum residues. The units were small, so energy efficiency was not a high priority. The Kerr McGee Corporation started research in the 1950s to extend the application of solvent extraction in the production of fuels and to improve

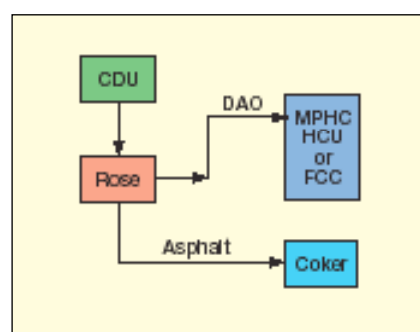


Figure 3 ROSE unit where there is no vacuum and coker

energy efficiency by separating solvent from the DAO in supercritical phase. The first supercritical solvent-extraction ROSE units were licensed in 1979. Subsequently, the success of the process has turned conventional SDA into an uneconomical practice in comparison. KBR acquired the technology from the Kerr McGee Corporation in 1995. To date, 48 ROSE licenses with a combined capacity of over 900 000 bpsd have been obtained by users all over the world.

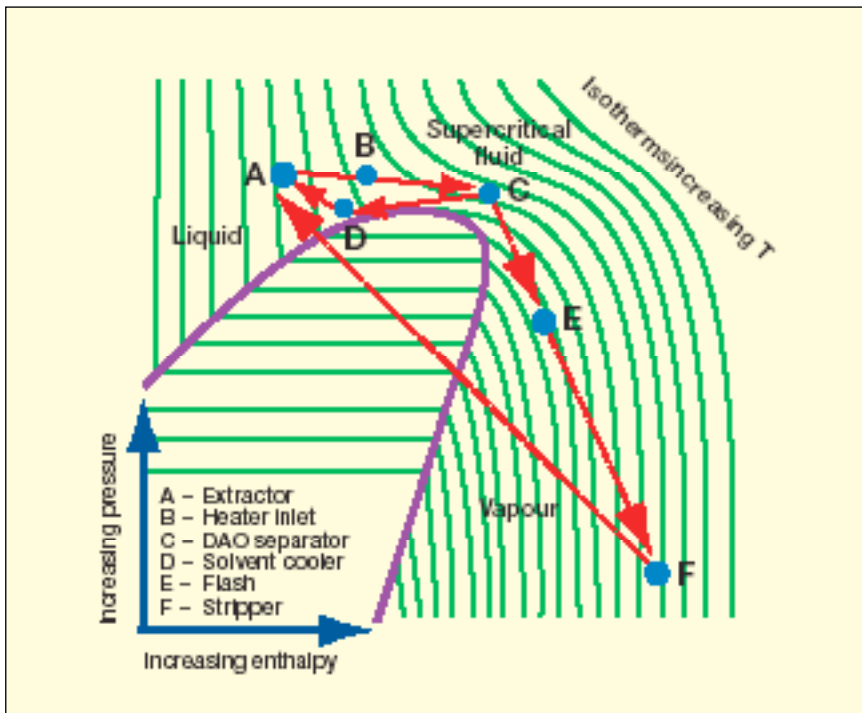


Figure 4 Supercritical solvent recovery mollier diagram

Comparisons

How is this process different to conventional SDA? It is a highly energy-efficient solvent deasphalting technology in which most of the solvent is recovered in supercritical mode. In Figure 4, point "C" represents supercritical phase separation conditions and point "F" represents conditions used by conventional SDA processes for separating solvent. The energy required for supercritical separation (C-A) is less than one-third of that required for conventional (F-A) SDA processes.

The ROSE process uses special internals and design parameters that permit the extraction of maximum quantities of high-quality DAO from atmospheric or vacuum residues and other heavy petroleum feedstocks. The high-efficiency internals reduce capital costs by allowing the use of smaller separator vessels. The asphaltene content of the DAO from the ROSE unit is normally less than 200 ppmw, compared to around 800 ppmw for other SDA processes. The DAO produced also has substantially reduced contaminants, such as nickel, vanadium, sulphur and Conradson carbon when compared to residues.

These benefits (ie, lower energy usage, use of smaller separators and cleaner DAO) have been particularly useful in the conversion of conventional and third-party SDA units to ROSE. Some licensees have doubled throughput, reduced energy consumption by as much as 30%, improved DAO yield by 2-5% and at the same time have seen an order of magnitude reduction in asphaltene carryover in DAO.

In summary, the process offers the following operational and economic

advantages over conventional SDA:

- Higher yield and improved DAO quality
- Flexibility in varying DAO yield and quality by adjusting operating conditions and, if necessary, changing solvent
- Supercritical solvent recovery significantly reduces operating costs by almost eliminating evaporation and condensation of solvent.

Unlocking current refinery constraints

With the higher utilisation of heavy crude oils, refiners often encounter higher resid loads with higher levels of contaminants (such as sulphur, nitrogen, metals, CCR), increased aromatics content and, more often than not, higher acid content in their feeds. On the other hand, the gas oil content of the new feeds will be lower, creating a potential loss of feed in downstream VGO processing units, such as the FCC or hydrocracking units. All these

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elements present challenges that refiners need to solve.

Refiners with no coker or vacuum units

Vacuum distillation units (VDUs) are considered to be one of the conventional building blocks in refinery operations. However, with time, the higher utilisation of heavy and high-acid crude oils has started to push the limit of the vacuum distillation process. High operating temperatures in vacuum units have a tendency to crack some of the heavy crude oils. To avoid coking of internals due to cracking, vacuum units have to operate at lower temperatures, thereby limiting the lift of vacuum gas oils. This is an ineffective use of vacuum units when it comes to the distillation of heavy oils, which are prone to cracking, and this limitation will hold back more heavy material in the residue stream.

Another aspect also associated with some heavy crudes is the high acid content. The acids in crude require the use of 317L stainless steel or equivalent material in all areas where temperatures exceed 450°F. Thus, the vacuum tower up to the top neck has to be lined with 317L. This increases both the cost of the vacuum unit and the overall project schedule.

These two problems can be easily solved using a ROSE unit in place of a vacuum unit.³ The reasons for the favourable economics in using a ROSE unit in place of a vacuum unit are as follows:

- **Higher yields:** the lower operating temperatures in ROSE units eliminate the potential for cracking of the heavy oil, providing the ability to extract much higher volumes of DAO than the VGO removed by the vacuum unit. Examples of higher yields from some crude oils are as follows:

	Vacuum VGO, vol%	ROSE DAO, vol%
Arab Heavy	26.5	38.5
Maya	26.5	34.0
Athabasca Bitumen	16.0	32.0
Marlim	36.0	52.5

- **The high hydrogen content of DAO gives higher liquid yields:** ROSE separates DAO by dissolving primarily paraffins in solvent. Thus, the DAO produced is more paraffinic than the VGO, which includes aromatics boiling below the VGO cut-off temperatures. Therefore, the DAO has a higher hydrogen content and gives a substantial yield advantage over VGO in downstream catalytic cracking units. For example, the Watson "K" factor of VGO for 71 vol% yield on ATB is 11.67. The Watson K for DAO at a yield of 90 vol% is 11.74. So not only was more DAO extracted, it also had higher hydrogen content

— **Reduced residue stream:** in many cases, the amount of ROSE asphaltenes produced is about half of the vacuum bottoms. This reduces the size of a new coker when coking is used to crack residue; if the residues are blended into fuel oil, the fuel oil make drops to less than half when compared to vacuum distillation, saving substantial quantities of valuable cutter stock.

Debottlenecking existing vacuum and coker units

Vacuum units generally become the first bottleneck when refiners increase the intake of more heavy and/or high acid crudes. The use of heavy oils increases the feed to the vacuum unit, overloading its hydraulic capacity. Refiners can choose to revamp the constrained vacuum units and associated cokers. However, when faced with high acid crudes, revamping could become expensive if existing vacuum columns and associated transfer lines do not have the high metallurgy capable of handling the high-acid crudes. The capacity and the metallurgy constraints can be removed by adding a ROSE unit in parallel with the vacuum unit, as previously shown in Figure 2. The unit can process all atmospheric bottoms above the capacity of the vacuum units. It can also process all atmospheric bottoms from the high-acid crude train.

Table 1 compares yields and qualities of DAO separated from atmospheric (ATB) and vacuum bottoms (VTB) from Arab Heavy and Maya crude oils. Column 1 shows that 49.7 Mbpsd of vacuum resid is produced as coker feed when processing 200 Mbpsd of Arab Heavy crude oil. The ROSE unit can separate 23.3 Mbpsd of DAO as feed for hydroprocessing and FCC units, thus reducing total coker feed to 26.5 Mbpsd, almost a 47% reduction. The DAO, when mixed with VGO, has sufficiently low metals to allow processing in fixed-bed hydroprocessing units. While calculating yields, the CCR in asphalt has been limited to 38 wt% to allow cracking in most modern delayed cokers.

The cokers are the next bottlenecks. As described, the coker can be debottlenecked by installing a ROSE unit upstream from the coker. As previously described, in addition to the hydraulic debottlenecking, the coke make drops by about 20%, thus debottlenecking the coke drums.³

An overall mass balance will indicate that the total liquid yields per barrel of feed will be increased by approximately 3–5 vol%. In essence, this solution will have the net result of converting low-value coke product into high-value refinery liquid yield. Moreover, the addition of a ROSE unit may reduce downtime, as opposed to revamping

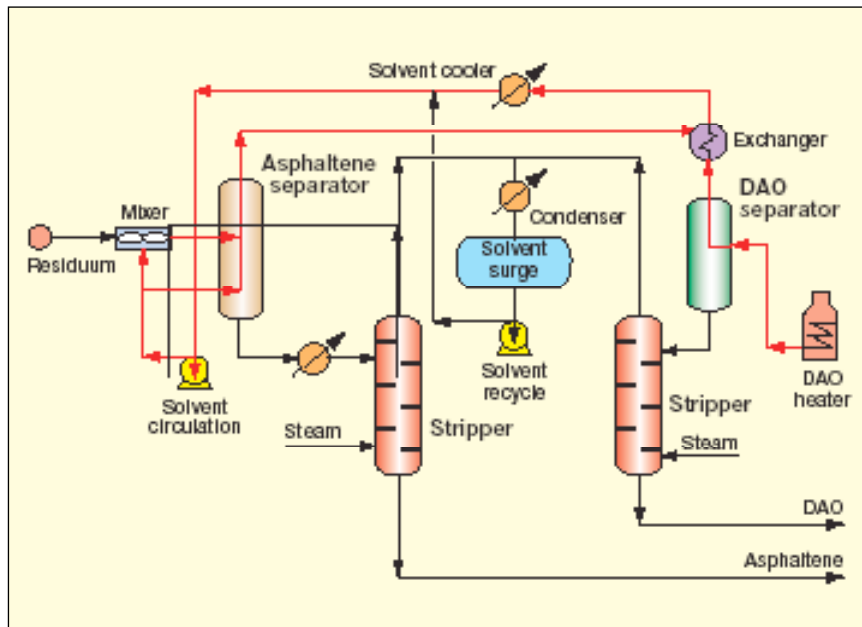


Figure 5 ROSE process flow diagram

ROSE generates more feed for downstream units

	Arab Heavy VTB	Arab Heavy ATB	Maya VTB	Maya ATB
Feed				
Rate, kbpsd	49.7	103.3	63.6	116.9
API	3.2	11.5	-0.2	7.6
CCR, %	23.8	12.4	31.2	18.3
Metals, ppmw	251	129	816	477
DAO Prod.				
Rate, kbpsd	23.3	76.8	14.5	67.7
API	13.4	18.1	17.9	18.0
CCR, %	6.0	2.2	4.4	1.5
Metals, ppmw	9	3	8	6
Pitch Prod.				
Rate, kbpsd	26.5	26.5	49.1	49.1
API	-4.7	-4.7	-4.7	-4.7
CCR, %	38	38	38	38

Basis: refinery feed rate: 200 000 bpsd

Table 1

both the vacuum unit and the coker. The technology thus offers the following economic and operational benefits to refiners over other upgrading technologies:

- Easy integration with downstream units through yield and quality control of DAO
- Significantly lower capital and operating costs
- Ease in processing of high-acid crude oils
- Faster project execution through modular construction
- High reliability (>95% onstream factor) and long cycles (up to nine years) between major turnarounds.

Figure 5 shows the simplicity of the process and the reason for the associated low installation cost.

ROSE is a mark of KBR.

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