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Process Developments

Recover lube extraction gasoils from vacuum distillation units

Modeling methods explore revamping the vacuum unit to optimize lube oil production

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Since its introduction, vacuum distillation (VD) has become a key refinery operation and is used to continue upstream atmospheric distillation. Topped crude is processed at sub-atmospheric conditions to recover valuable gasoils at low temperatures and to avoid coking and overcracking. Typically, VD towers recover gasoils for downstream cracking units, while other towers produce lubricants. Also, VD is used to produce lube-grade gasoils for further processing by lubricant production facilities.

Vacuum tower expansion projects are part of the current trend to maximize capacity, and to minimize energy consumption and operating costs of refinery units. Simulation is a key activity for any major VD expansion efforts.

The presented case study explores applying simulation techniques to revamp an existing vacuum tower that produces cracking-ready gasoils. The goal is to increase the charge rate while recovering lube-grade gasoils. (This is based on an actual case.)

Existing tower configuration. In this case study, the pre-revamp vacuum tower was equipped with trays and provided five products: off-gas to vacuum system, light vacuum gasoil (LVGO), heavy vacuum gasoil (HVGO), slop wax and vacuum tower bottoms (VTB). All side products were taken from total draw chimney trays.

Typical specifications and simulation issues. Specifications for lube-grade gasoils in revamp projects usually include:

- Atmospheric tower bottoms (ATB) rate
- LVGO D2887 at 5% > 530°F
- LVGO D2887 at 95% = 970 – 980°F
- LVGO production rate (30% of ATB)
- HVGO D2887 at 5% = 680 – 720°F
- HVGO D2887 at 95% = 1,050 – 1,060°F
- HVGO EP 1,100°F
- HVGO production rate (maximize).

Due to the stringent list of specifications and tower hydraulic limitation, it is particularly difficult to converge the simulation and meet all specs.

Meeting the LVGO D2887 5% and 95% specification while achieving the desired product rate is always challenging due to these limitations:

- Crude type and ATB quality should contain the desired product quantity to produce the specified flowrate. Selecting the improper crude would result in either lower/ higher LVGO production rate or off-spec boiling points as shown in Fig. 1.
- Different D2887 conversion methods to TBP are available. The right conversion method should be carefully selected.
- Tower spacing limits fractionation and mass transfer options that could be utilized.
- High gasoils quality is critical for lube extraction. Entrainment and overflash rates are critical variables in VD.

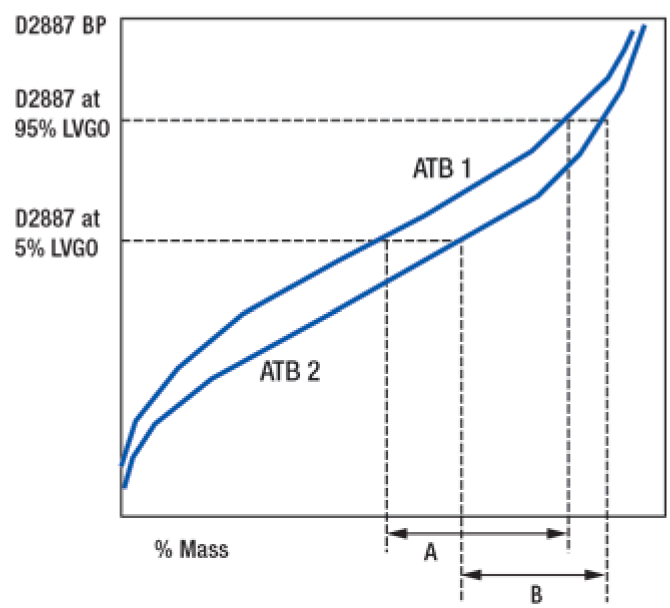

Fig. 1 Boiling curves for two ATB streams produced from two different types of crude. LVGO produced from ATB1 (mass % A) is of a higher quantity than that produced from ATB2 (mass % B).

Resolving the issues. In this case, the crude type used in an actual operation was identified and applied in the simulation. This approach ensured that the proper crude type was used as a simulation basis and provided the closest match to the desired product flowrates at the specified boiling range. Also, D2887 API 1994 direct conversion method gave the closest match to field results. This conversion method was selected in the oil characterization environment and simulation output settings of the model.

Two theoretical stages were used for each P/A section. One theoretical stage was used for the wash-oil section. The flash zone was simulated at 0.50 psia and 688°F. The overhead was set at 0.18 psia, as per the pressure drop obtained from test run data. Using the listed processing parameters, all specifications were met except for the LVGO 95% spec, which was off by 10 – 20°F. Issues that caused this spec deviation include:

- Due to the significant overlap of ~300°F between the LVGO and HVGO boiling ranges, over-fractionation between the two products was not desired.
- Because of item one, changes to the wash oil/ slop wax rate impacted both the LVGO and HVGO product specifications.
- Also, the wash-oil rate was restricted to a minimum value to avoid dryout and coking in the wash section packing.
- LVGO product rate was a specification and could not be manipulated.
- Flash zone temperature was to be maintained at maximum value to maximize gasoils recovery.

To meet the LVGO 95% specification, an external LVGO slip-stream from LVGO P/A draw line to HVGO P/A return line was introduced as shown in Fig. 2. The slip-stream allowed washing of the HVGO with lighter LVGO and provided a tool to control fractionation and achieve the desired HVGO 5% and LVGO 95% specifications.

Entrainment precautions. Several precautions were taken while setting simulation parameters to avoid liquid entrainment at the feed and the spray nozzles. Proper tower internal devices that provided adequate vapor distribution and minimum liquid entrainment accompanied these techniques.[1,2]

Impact of liquid entrainment at the feed was predicted by applying the technique provided by S. W. Golden et al.[3] This technique forced the simulation to predict the required wash-oil rate to compact entrainment and avoid coking. In addition, the flash zone pressure and temperature were raised to 0.65 psia and 700°F, which increased the vapor density and lowered the C-factor from 0.52 fps to about 0.40 fps. Result: Entrainment at the feed and spray distributors was minimized.[1,2]

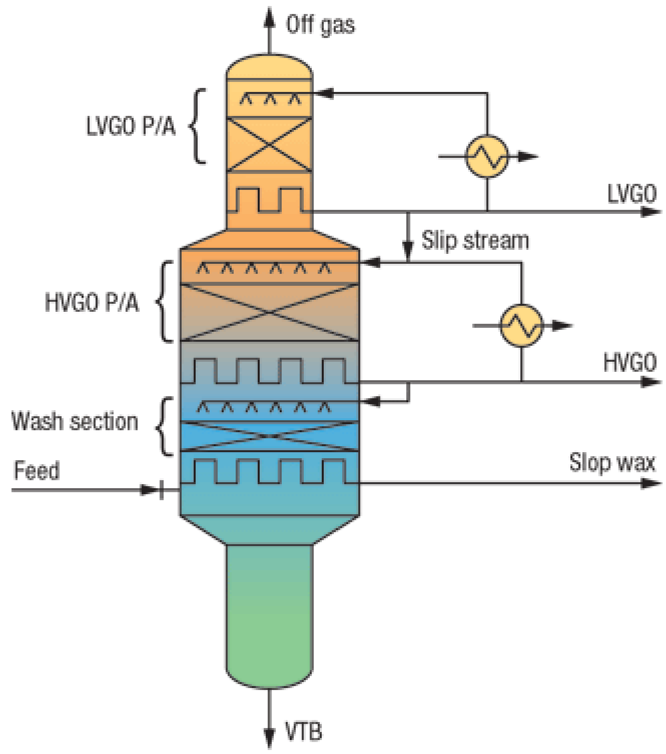

Fig. 2 After-revamp vacuum tower. New packing, spray distributors, chimneys and slip-stream are shown.

As the tower internals vendors submitted their recommendations to replace the trays with packing, the simulation was updated with the new pressure drop of 0.11 psi, which raised the overhead pressure to 0.54 psia. This further lowered the C-factor and entrainment across the tower. Also, the entrainment level from spray distributors was estimated.[4] Since vendors provided spray distributor details in the late stages of detailed engineering, entrainment was accounted for by applying an over design factor. Alternately, the entrainment level would have been incorporated directly in the simulation. **HP**

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