Optimising preflash for light tight oil processing

For a crude unit handling light tight oil feedstock, a semi-preflash column can deliver significant advantages in energy saving, capacity gain and revamp.

Soun Ho Lee GTC Technology

The basic function of a crude distillation unit is to provide the initial separation of crude oil feed into the desired fractions to feed downstream units. Now, newly introduced light tight oil feed processing may limit existing crude distillation unit capacity. The addition of a feed preflashing option may improve capacity and/or energy efficiency for light tight oil processing.

Two preflash options which are commonly implemented for crude distillation units are a preflash drum and a preflash column. Each has strengths and weaknesses.

This article discusses an improved semi-preflash column design that optimises the traditional preflash drum and preflash column options. A case study includes revamp economics for the arrangement.

Light tight oil
Light tight oil describes petroleum fractions produced from low permeability formations such as shale or tight sandstone. Improved hydraulic fracturing technology with directional drilling has increased light tight oil production in North America, where processing light tight oil can be a game-changer for refiners. Light tight oil slates produced in North America have typically light and sweet natures. However, its characteristics vary significantly.

Adapting light tight oil as a new feedstock may require a significant retrofit in a refinery layout which was originally configured with traditional crude oil feedstock. Capacity imbalance in downstream conversion units and insufficient overhead train processing capacity are already well recognised issues with refiners. This imbalance issue is more exaggerated in refineries which are designed with heavy crude slates and a high conversion ratio. These mismatches between new light tight oil feedstock and current refinery configurations are initiated in the crude distillation unit which provides initial separation of feedstock for entire downstream refinery processing units.

There has been extensive research to try and identify ‘magic juice’, blending ratios of light tight oil and traditional heavy crude oil slates to fit existing refinery layouts. Meanwhile, it has been discovered that blending between light tight oil and traditional heavy crude oil can cause asphaltene destabilisation due to the paraffinic nature of light tight oil. This destabilisation can cause unexpected fouling issues.

This article focuses on debottlenecking and enhancing crude distillation unit capacity and energy consumption using various preflash options. Other retrofit strategies for light tight oil processing are not discussed.

Crude distillation unit preflashing
Implementing crude feed preflashing has been one of the common options to debottleneck crude distillation units. Switching feedstock to a lighter crude slate can cause undesired feed vaporisation at the feed furnace pass control valve and limit capacities in the crude atmospheric column and overhead condensing circuits. Adding a preflash drum or column can reduce the charge rate to the feed furnace. In addition, transfer line vibration due to capacity limitation can be resolved through adapting feed preflashing.

Two preflash options that are commonly implemented in a crude distillation unit are the...
preflash drum and preflash column. Another preflash option, GT-IPS is a semi-preflash column design that may be optimised between traditional preflash drum and preflash column options.

**Preflash drum option**
The preflash drum is the simplest option for crude preflashing. Complex modification of equipment and instrumentation is not required for this option compared to the preflash column, making it the most economical option with regards to capital expenditure (Capex).

One weakness of the preflash drum is that this option does not have the capability to control preflashed vapour quality in foaming prone service. Therefore, the preflash drum is prone to have challenges with entrainment. Entrainment can be accelerated in a foaming environment. Improper location of preflashed vapour feeding and/or undesirably entrained heavy oil boiling range materials can contaminate rundown product qualities.

Introducing preflashed vapour to a flash zone is the safest configuration to prevent product contamination. However, lower temperature of preflash vapour containing entrainment can quench the main feed vapour and can reduce feed lifting.

Although recent technology such as Vortex Tube Cluster (VTC) helps to discourage the chances of foaming, a preflash drum should be sized large enough to prevent foaming.

**Preflash column option**
The preflash column option produces preflashed products. Although it requires higher Capex than a preflash drum, this option is especially effective when the column top section and overhead condenser capacities are limited.

A rectifier is a common configuration for a preflash column. Crude feed is introduced at the preflash column bottom and preflashed vapour is rectified by reflux liquid. Overhead vapour can be condensed through a crude atmospheric column overhead condenser if the condenser has ample capacity. An exclusive preflash column overhead condenser needs to be installed if a crude atmospheric column overhead condenser is limited. Some deluxe preflash columns have a bottom stripping section to control the front end of the crude atmospheric column top product.

High Capex is a major drawback of a preflash column. Moreover, a large plot space is generally needed to add the equipment.

**GT-IPS semi-preflash column option**
GT-IPS (Improved Preflash System) has a ‘semi-preflash column’ arrangement compared to the traditional preflash column. Like the preflash drum option, the semi-preflash column does not produce any independent product. This column functions as a preflash column but the additional overhead condenser and receiver are not equipped for the preflash column.

Maintaining a desired preflash vapour quality is one of the most critical issues. To wash out the entrained components, some liquid is drawn from the crude atmospheric column and routed to the semi-preflash column as reflux.

One of the benefits of the GT-IPS concept is its flexibility. The preflash column reflux source and the preflashed vapour routing can be varied depending on process conditions, including crude slate and target performance, and refinery layout.

To compare the three preflash options in more detail, the revamping of a crude distillation unit for light tight oil processing is included as a case study.

**Case study: unit description and study basis**
Eagle Ford, a common light tight oil in the US, was selected as the feedstock. Eagle Ford tight oil has light and sweet characteristics with approximately 0.1 wt% sulphur content and is in a highly variable slate. Published gravity varies between 40° and 62° API.

The case study’s crude distillation unit receives 100% 60.7° API Eagle Ford; 50 000 b/d of light tight oils are charged and heated through pre-heat trains and furnaces, and then introduced into the crude atmospheric column. This column separates the charged oils to intermediate products: unstabilised naphtha, kerosene, diesel and reduced crude (R/C).

The crude atmospheric column equips three pumparound circuits: top pumparound, kerosene and diesel pumparound circuits. A top reflux stream which is recycled from the unstabilised naphtha (overhead distillate) is combined with the top pumparound stream before return-
ing to the crude atmospheric column. The amount of the top reflux stream can be adjusted relative to the unstabilised naphtha boiling range of the processed crudes. The wash section is equipped with structured packing while the rest of the sections consist of trays. Two side strippers which belong to the crude atmospheric column are operated with stripping steam. Figure 1 illustrates the base case configuration of the crude distillation unit.

To evaluate the optimum preflash option, three case studies are conducted and compared to the base case. Light tight oil charge rate, quality, and product yields are maintained among the four cases.

Since preflash equipment pressure is floated by crude atmospheric column operating pressure, in each case the preflash system pressure is set through a pressure drop prediction between the preflash and hydraulic end point in the crude atmospheric column.5 In addition, no extra capacities are available in the crude atmospheric column overhead condenser and feed furnace. The base case’s crude atmospheric column overhead condenser and absorbed feed furnace duties are defined as maximum. Since preflash options let down preheat train pressure, an additional booster pump is required to transport the remaining feed to the feed furnace and crude atmospheric column. Additional feed booster pump discharge pressure is set to prevent vaporisation through the entire preheat train and the feed furnace pass control valve. Table 1 depicts the process conditions of the crude distillation unit.

**Table 1**

<table>
<thead>
<tr>
<th>Case</th>
<th>Base Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>100% Eagle Ford</td>
</tr>
<tr>
<td>Crude slate</td>
<td>100% Eagle Ford</td>
</tr>
<tr>
<td>Crude charge, BPD</td>
<td>50 000</td>
</tr>
<tr>
<td>°API</td>
<td>60.7</td>
</tr>
<tr>
<td>-300°F nominal cut fraction, LV%</td>
<td>58.2</td>
</tr>
<tr>
<td>300-450°F nominal cut fraction, LV%</td>
<td>14.7</td>
</tr>
<tr>
<td>450-650°F nominal cut fraction, LV%</td>
<td>13.4</td>
</tr>
<tr>
<td>+ &gt;650°F nominal cut fraction, LV%</td>
<td>13.7</td>
</tr>
</tbody>
</table>

**Operating parameter**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Base Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace coil outlet temperature, °F</td>
<td>674</td>
</tr>
<tr>
<td>Crude atmospheric column top pressure, psi, g</td>
<td>24</td>
</tr>
<tr>
<td>Unit bottom stripping steam rate, Lb/BBL</td>
<td>7.9</td>
</tr>
<tr>
<td>Unit kerosene stripping steam rate, Lb/BBL</td>
<td>12.0</td>
</tr>
<tr>
<td>Unit diesel stripping steam rate, Lb/BBL</td>
<td>6.2</td>
</tr>
</tbody>
</table>

**Fractionation performance**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Base Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha D86 (95 LV%), °F</td>
<td>291</td>
</tr>
<tr>
<td>Kerosene flash point, °F</td>
<td>100.8</td>
</tr>
<tr>
<td>Kerosene freezing point, °F</td>
<td>-58.0</td>
</tr>
<tr>
<td>Diesel D86 (90 LV%), °F</td>
<td>649</td>
</tr>
<tr>
<td>Reduced crude D86 (5 LV%), °F</td>
<td>617</td>
</tr>
</tbody>
</table>

![Figure 1](#) Crude distillation unit: base configuration
Case study A: preflash drum

Case study A illustrates how preflash drum implementation is conducted. A modified configuration is illustrated in Figure 2.

Considering that potential rundown product contamination can occur by entrainment, preflashed vapour is introduced to the crude atmospheric column flash zone. The preflash drum operating pressure is determined per the crude atmospheric column flash zone pressure and the pressure drop through the preflash vapour line circuit.

Preflashing requires a higher furnace coil outlet temperature to maintain the current total distillate yields. Higher internal reflux ratios for fractionation sections are also required to achieve target distillate product yields and qualities. The preflash drum operating temperature is selected based on reusing atmospheric column overhead condenser duty. A higher preflash temperature can increase the amount of preflashing but it requires a higher furnace coil outlet temperature and a simulated overhead condenser duty that exceeds the current value. Therefore, the position of the preflash drum in this case study is determined by overhead condenser duty limitation.

Case study B: preflash column

Case study B gives an overview of implementing a preflash column. The preflash column is configured as a rectifier in this case study, and is equipped with an independent overhead receiver and overhead condenser. The preflash column is positioned between the preheat train and furnace to
maximise the amount of preflashing.

The preflash column overhead vapour streams are split into two streams. The amount of preflushed vapour stream charged to the crude atmospheric column overhead condenser is quantified by the crude atmospheric column overhead condenser limitation. The remaining preflushed vapour stream is condensed through an additional preflash column overhead condenser. The reflux rate for the preflash column is driven from the new preflash condenser and overhead receiver. Produced preflash overhead liquid distillate is combined with crude atmospheric overhead distillate and transported to a naphtha stabiliser for further separation. A modified configuration for this case is illustrated in Figure 3.

**Case study C: GT-IPS semi-preflash column option**

Case study C describes implementation of the GT-IPS semi-preflash column. A modified configuration for this case is illustrated in Figure 4.

Prior to being sent to the crude atmospheric column, produced preflushed vapour is rectified by the reflux stream recycled from the crude atmospheric column. The reflux source for the semi-preflash column is the crude atmospheric column overhead distillate in this particular case study. This reflux routing configuration is determined based on the amount of preflushed vapour and quality. Case study results show that the rectified preflushed vapour is suitable for mixing with the unstabilised naphtha stream. Nevertheless, preflushed vapour is introduced underneath the naphtha/kerosene fractionation section, taking floating semi-preflash column pressure into consideration.

The semi-preflash column operating pressure is determined by the crude atmospheric column operating pressure and the preflash vapour line pressure drop. The column operating temperature is selected based on reusing atmospheric column overhead condenser duty. A higher preflash temperature can increase the amount of preflushing but it requires a higher furnace coil outlet temperature and simulated overhead condenser duty that exceeds the current value.

Like the case study A preflash drum, the semi-preflash column is also located in the middle of the preheat train. However, a higher preflash percentage through the semi-preflash column allows the semi-preflash column to be located in a higher temperature zone of the preheat train, compared to case study A.

**Case study results**

The three case study results are summarised and compared with base case conditions in Table 2. Since feed preflushing results in a lower preflash drum or column bottom temperature, the temperature drop through each preflash option is quantified. The crude atmospheric column pumparound balance for each case is adjusted to maintain base case product yields and product qualities. These temperature drop values through preflushing and shifted pumparound balances are reflected in preheat train temperature profiles and furnace inlet temperature prediction. Identification of the cracking
tendency of the chosen light tight oil slate can help optimise furnace coil outlet temperature further.

The capacities of crude atmospheric column distillation equipment are calculated with simulated traffic. Calculated capacities are based on the packed wash section and fixed valve trays for the rest of the section. The calculated capacity for each section is plotted in Figure 5.

Case study: retrofit economic evaluations

The case study A preflash drum does not provide significant furnace duty savings. Moreover, the calculated capacities of this preflash drum case are similar to those in the base case. Higher internal reflux ratios for fractionation sections erode gain in distillation capacity. A lower preflash drum temperature requires the higher discharge pressure of a new booster pump installation compared to the other two cases: the preflash column and the semi-preflash column options.

Table 2 shows that the case B preflash column option achieves the highest preflashing percentage among three cases. Meanwhile, the highest temperature drop is observed in the case B preflash option, resulting in the lowest furnace inlet temperature. Nevertheless, the lowest net amount of furnace charge provides the minimum absorbed furnace duty. The preflash column also provides the highest distillation equipment capacity gain.

In case C, the GT-IPS semi-preflash column option shows lower furnace duty saving and distillation equipment capacity gain compared to the preflash column option. However, furnace duty saving and crude atmospheric column capacity gain are still substantial compared to the base case and the case A preflash drum.

The case study A preflash drum does not provide significant furnace duty savings. Moreover, the calculated capacities of this preflash drum case are similar to those in the base case. Higher internal reflux ratios for fractionation sections erode gain in distillation capacity. A lower preflash drum temperature requires the higher discharge pressure of a new booster pump installation compared to the other two cases: the preflash column and the semi-preflash column options.

Table 2 shows that the case B preflash column option achieves the highest preflashing percentage among three cases. Meanwhile, the highest temperature drop is observed in the case B preflash option, resulting in the lowest furnace inlet temperature. Nevertheless, the lowest net amount of furnace charge provides the minimum absorbed furnace duty. The preflash column also provides the highest distillation equipment capacity gain.

In case C, the GT-IPS semi-preflash column option shows lower furnace duty saving and distillation equipment capacity gain compared to the preflash column option. However, furnace duty saving and crude atmospheric column capacity gain are still substantial compared to the base case and the case A preflash drum.

The case study A preflash drum does not provide significant furnace duty savings. Moreover, the calculated capacities of this preflash drum case are similar to those in the base case. Higher internal reflux ratios for fractionation sections erode gain in distillation capacity. A lower preflash drum temperature requires the higher discharge pressure of a new booster pump installation compared to the other two cases: the preflash column and the semi-preflash column options.

Table 2 shows that the case B preflash column option achieves the highest preflashing percentage among three cases. Meanwhile, the highest temperature drop is observed in the case B preflash option, resulting in the lowest furnace inlet temperature. Nevertheless, the lowest net amount of furnace charge provides the minimum absorbed furnace duty. The preflash column also provides the highest distillation equipment capacity gain.

In case C, the GT-IPS semi-preflash column option shows lower furnace duty saving and distillation equipment capacity gain compared to the preflash column option. However, furnace duty saving and crude atmospheric column capacity gain are still substantial compared to the base case and the case A preflash drum.

Table 2
The case B preflash column option provides the best performance improvement but it requires an additional overhead condenser and receiver for the preflash column and complex piping modification which influence retrofit cost. The highest Capex is identified for the case B preflash column option. The larger plot requirement for the modification is another drawback in case B. If space is limited in the existing unit, this case is not viable for implementation.

In case C, GT-IPS does not necessitate substantial addition of equipment as is required in the case B preflash column. Also, new booster pump differential pressure and capacity requirements in case C are lower than those in case A.

Calculations of pay-back period are conducted to gauge retrofit economics. Gains in crude atmospheric column capacity and/or furnace/transfer line capacity significantly improve retrofit profitability. However, profits through these factors vary noticeably per refinery layout and equipment limitations. Therefore, these factors are not considered in the pay-back period calculations and only furnace heating medium saving is used for economic evaluations.

Profitability indexes are expressed with regard to pay-back period. These indexes are shown in Figure 6. The modification costs are estimated based on the US Gulf region. Most US refiners utilise both refinery fuel gas and natural gas as furnace heating mediums. However, the mixing ratio between two different utilities depends upon the particular refinery. Therefore, a single equivalent fuel oil (EFO) basis is selected. Three different fuel oil prices are selected through the last four-year fuel gas and natural gas trend. Typical furnace efficiency and EFO lower heating values are used for heating medium consumption predictions.

Figure 6 shows that case C’s GT-IPS is identified to provide better retrofit economics compared to the other two cases. Adding extra profit through capacity gain can further improve retrofit profitability.

**Conclusion**

The technical results and economic evaluations from three case studies show that the GT-IPS semi-preflash column can deliver significant energy savings and capacity gains compared to the preflash drum option. Meanwhile, the lower investment cost for GT-IPS provides better retrofit economics compared to the preflash column case. These benefits show that GT-IPS is a viable option for efficient light tight oil processing. Actual preflashing options and designs can be customised after reviewing the specific circumstances of a crude distillation unit configuration and refinery layout. Retrofit economics can be precisely gauged after reflecting actual profit gains.

This article is an updated version of a presentation given at AIChE 2015 Spring Meeting Kister Distillation Symposium, 27-30 April 2015, Austin, Texas.

GT-IPS is a mark of GTC Technology US, LLC.

**References**

Soun Ho Lee is Manager of Refining Application with GTC Technology in Euless, Texas, specialising in process design, simulation modelling, energy saving design and troubleshooting for refining and aromatic applications.

Email: sounho@gtctech.com