



Impact of Light Tight Oils on Distillate Hydrotreater Operation

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1.0 Introduction

Light Tight Oil (LTO, also known as Shale Oil) formations are providing a new crude source to North America and soon to the world, with the recent construction of condensate splitters in the US Gulf Coast and the recent announcement that the U.S. government was lifting the crude export ban. Agreements between U.S and Mexico have been announced that will allow crude swaps, thereby sending LTO into refineries in Mexico. Other countries in the region are also examining the potentials of LTO imports. The economic advantages of processing LTO crudes are the low crude cost relative to world benchmark crudes and higher quality compared to other available crudes.

The production and processing of LTO crudes is relatively new (< 5 years), whereas Asia Pacific conventional crudes that have similar qualities (when compared to LTO crudes) have been in production and refined for many years. In addition, West African crudes and conventional U.S. crudes (such as West Texas Intermediate – WTI) have been displaced from U.S. refiners and replaced with LTO crudes. Therefore, a comparison of example LTO, Conventional U.S, Asian Pacific, and West African crude distillate qualities presents a possible mechanism to provide operating and product impact insight for hydrotreaters in LTO processing facilities. The following sections will provide some high level impacts of LTO processing on a facility, and then use a kinetic model to highlight the unit specific impacts that can occur.

2.0 Impact of Light Tight Oils on Refinery Operation

The following figure summarizes some of the high-level impacts of processing LTOs in a conventional refinery. The key challenges include, but are not limited to:

- Managing crude compatibility, asphaltene deposition, wax formation, and fouling in the crude and vacuum units
- Handling the higher content of naphtha in crude, as well as the lower content of vacuum resid
- Managing impact on reformer yields due to the poor N+2A content of naphtha
- Finding ways to handle poor cold flow properties in distillate train
- Identifying alternative operating and optimization opportunities to fully leverage LTO processing

Though outside the remit of this discussion, several resources are available to address the items listed above^{1, 2, 3, 4, 5, 6, 7, 8, 9, 10}. The focus of this paper is to understand the impact of LTOs in the distillate train, and highlight areas that refiners should evaluate and consider as part of LTO processing in their facilities.

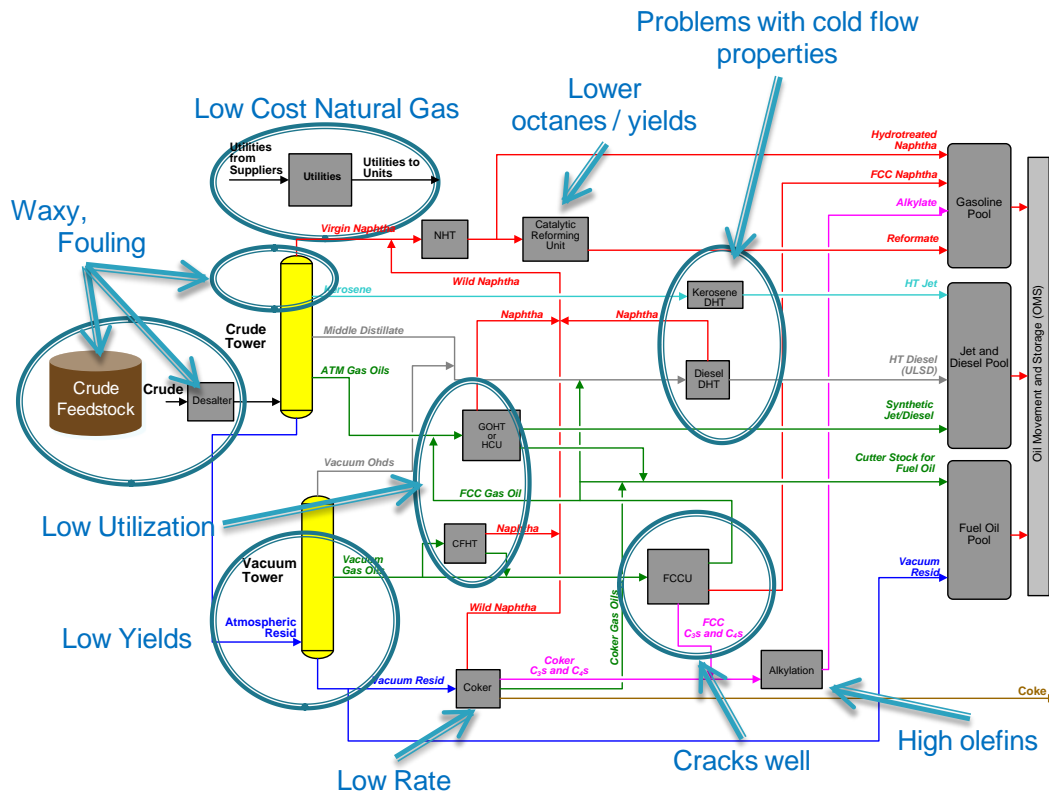


Figure 1: LTO Impacts on Refining

3.0 Distillate Evaluation Methodology

To begin the process of understanding the impact of LTO on conventional refining operations, benchmark crudes were selected that have similar properties of LTO crudes (high paraffin content, lower sulfur/nitrogen, poor cold flow properties, etc). In reviewing crude qualities on a global basis, some of the sweet waxy crudes from Asia Pacific have similar qualities as LTO crudes. Hence, for this study, the comparison crudes chosen were Bach Ho, Gippsland, Cossack, and Kutubu. In addition, West African light sweet crude (Qua Iboe) was included in the analysis, as West African light sweet crudes typically compete with LTO crudes in U.S. refineries.

Crude assays from an assay database that KBC licenses¹ were used as the basis to generate kerosene and diesel hydrotreater feeds. Each assay was individually processed in a Petro-SIM™ simulation model to generate a typical kerosene and diesel fraction. Each fraction was then processed in a generic kerosene or diesel hydrotreater (DHTR-SIM™) model to predict the performance changes in unit operation. The model not only predicts the operational and product quality changes, but also the reactor heat balance and catalyst deactivation impacts.

¹ KBC licenses the Chevron Crude Assay Database

The following table summarizes the general operating conditions of each hydrotreater.

Table 1: Hydrotreater Operating Conditions

| | Kerosene HDT | Diesel HDT |
|-----------------|--------------|-------------|
| LHSV | ~2.5 | ~1.0 |
| Reactor Inlet P | ~600 psig | ~1,200 psig |
| Cycle Length | ~ 4 years | ~ 2 years |

Though the design parameters, catalyst type, and operating targets for each refiner’s distillate hydrotreater units will vary, these generic units should provide valuable insight into the impacts of processing LTO crudes versus similar crudes.

Co-processing LTO with other feeds is an operational advantage for kerosene and diesel feeds. The unit capacity may not be entirely utilized by the LTO and a heavy/sour/aromatic feed might be included to utilize hydraulic and severity capacity. Kerosene and diesel boiling range fractions are generally compatible and operational issues due to blending of these dissimilar fractions are minimal. Compatibility for heavier boiling fractions (gas oils and resids) do exhibit different behavior, but are excluded from this discussion. Therefore, cases were included to understand the impact of processing blended distillate feeds, especially cracked stock streams.

Prior to beginning the evaluation process, some background is included on distillate hydrotreater configurations and catalyst systems.

3.1 Fixed Bed Hydrotreating Background

With refinery installed or revamped hydroprocessing units, the design basis was often dictated by processing of feedstock from heavy crudes, especially in the last decade. The aromatic nature of these heavy unconventional crudes, along with more hetero-atoms in cracked lighter products, typically requires saturation and conversion via hydrotreating. The hydrotreater operation is severe and requires high temperature and pressure operations, with shorter run lengths than similar downstream refinery processes ^{7,8,12,18}.

When examining LTO processing, the initial belief was that the existing unit can likely handle this feedstock. However, the paraffinic nature of LTO presents a different challenge, as the severity requirement is low yet must be high enough to remove the required sulfur. This feedstock provides an opportunity for refiners to modify catalyst selection, feed rate, hydrogen partial pressure (H₂pp), and operating temperature to maximize utilization of a given hydroprocessing asset.

3.2 Fixed Bed Hydrotreating Configuration

Two typical hydrotreating configurations are utilized for hydrotreating distillate range material. The typical single stage separator configuration is shown below:



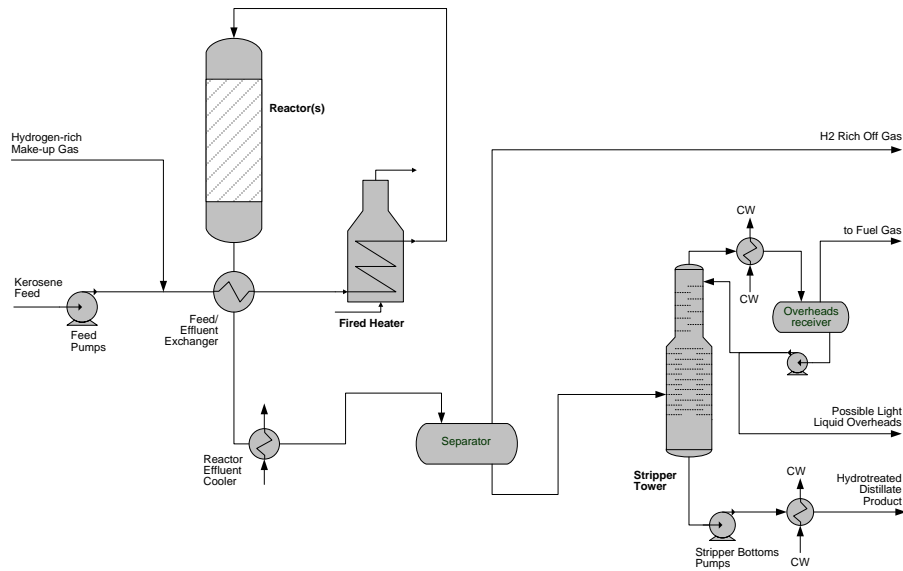


Figure 2: Single Separator Hydrotreater Configuration

The single reactor and single separator hydrotreater design above is typical for a kerosene and light diesel feedstock. The high pressure separator hydrogen-rich off gas can be used in a once through mode (naphtha hydrotreating units) basis or recycled with a compressor (kerosene and light diesel units). The recycle gas is typically treated to remove H₂S in this configuration in ultra low sulfur service, but some configurations do not amine treat the recycle gas.

More severe feedstocks require a more complicated reactor and recycle gas system. A multi-bed reactor with three separator hydrotreater configuration and recycle gas treating is shown below:

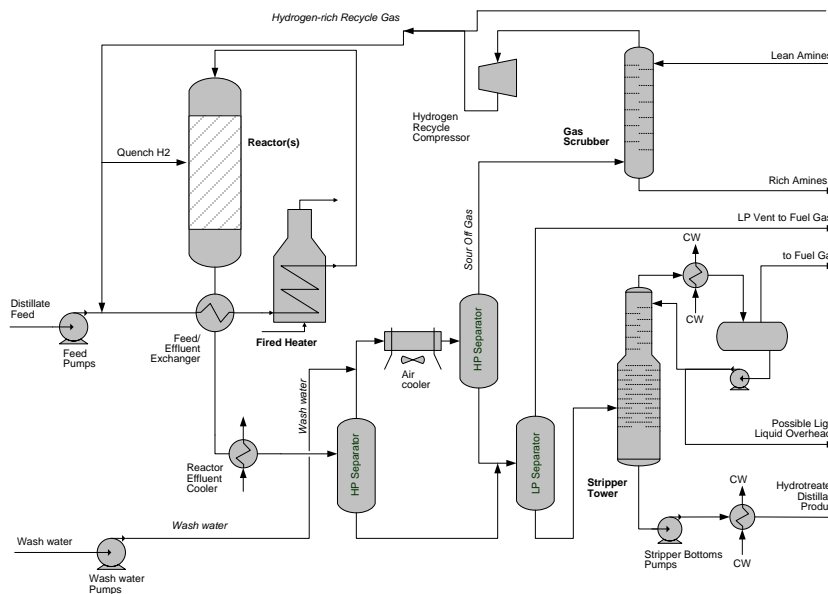


Figure 3: Four Separator Hydrotreater Configuration

The reactor shown above includes a hydrogen quench to control the reactor temperature rise, which is caused by significant hydrogen consumption, and an amine treater on the recycle gas to remove H₂S. This configuration also includes a water wash to remove the ammonia bisulfide from the REAC (Reactor Effluent Air Cooler).

When processing LTO feeds in these more complicated reactor systems, the operating conditions will change. The LTO feeds have low aromatic, sulfur, and nitrogen and the hydrogen consumption is typically low. Therefore, the resulting heat release and temperature rise are lower, thereby reducing the need for hydrogen quench. The low heat release reduces the feed/effluent heat recovery and increases duty requirements on the feed heater, as well as impacting reactor quench control. Hence, these systems will require review as part of processing LTO feeds within these units to avoid operating outside of design conditions or reliable equipment capabilities.

3.3 Catalyst Systems

The kerosene catalyst systems focus on stabilizing product color, meeting sulfur specification (if one exists), and removal of potential contaminants, such as arsenic and silicon in the top portion of the catalyst load. The low hydrogen consumption and deactivation rate allows for long cycle length and a low activity catalyst is successful in this application. The kerosene catalyst system might include a consideration for a dewaxing component to improve cold flow properties.

The diesel catalyst system can also have a relatively low hydrotreating activity but needs sufficient activity to meet sulfur and cetane improvement to meet ULSD (Ultra Low Sulfur Diesel) specification. These units also need to consider the removal of potential contaminants in the top catalyst load plus cold flow property improvement in products. The hydrotreating bed can have a first bed that manages pressure drop due to feed contaminants and saturates the olefins contained in cracked stocks, and the remainder of the first bed and other reactor beds being hydrotreating catalyst. The operational options might be to split the catalyst load, with a higher activity catalyst and dewaxing catalyst occupying the same reactor. Other options would be to use two separate reactors, thereby allowing more operational flexibility.

The catalyst system chosen for each feedstock in this study was appropriate for the paraffinic feed quality. Hence, the results provided here give the general impact of alternate feedstocks, but each catalyst system and reactor configuration will impact a refiner's specific results.

4.0 Kerosene Hydrotreater Operations

Kerosene has two potential product dispositions: jet product or diesel blending. The jet option has the more stringent specifications to meet than diesel, making jet a more restrictive specification to meet without hydrotreating. LTO jet streams are nearly at jet quality and can be met with blending or clay treating. The diesel option requires hydrotreating. Some facilities see the kerosene stream as a fungible product and hydrotreat to meet the ULSD specification and clay treat when producing Jet. The fungible advantage is most readily captured in northern tier refineries in the production of arctic diesel.

4.1 Feedstock Qualities

The following table summarizes the typical properties of the kerosene range material (350-500°F) for the crudes reviewed in this analysis. These cuts were generated by taking the respective crude assays and processing them in a KBC DISTOP™ simulation to produce as-cut kerosene streams. Though this stream is typically drawn to a freeze point specification, this fixed cut range was selected to demonstrate the impact of crude type on cold properties.

Table 2: Kerosene Properties

| Property | WTI | Bakken | Eagle Ford | Bach Ho | Cossack | Gippsland | Kutubu | Qua Iboe |
|------------------|------|--------|------------|---------|---------|-----------|--------|----------|
| API | 43.2 | 41.2 | 44.6 | 46.8 | 42.2 | 43.7 | 40.0 | 38.7 |
| Sulfur, ppmw | 1271 | 75 | 42 | 52 | 70 | 587 | 68 | 516 |
| Paraffins, vol% | 42 | 35 | 45 | 54 | 43 | 47 | 36 | 30 |
| Aromatics, vol% | 14 | 16 | 13 | 12 | 17 | 20 | 21 | 17 |
| Freeze Point, °F | -52 | -47 | -49 | -28 | -52 | -38 | -31 | -55 |

As shown above, the key differences in properties are sulfur and freeze point. The LTO Kerosene streams have similar sulfur to their Asia Pacific crude counterparts. In fact, most LTO Kerosene streams require very little hydrotreating to achieve sulfur levels for blending into the diesel pool.

Regarding freeze point, the LTO cold properties are on par with conventional US crudes as well as West African crude sources. However, the Asia Pacific crudes have extremely poor freeze point values. To meet specification for Jet production, the back-end cutpoint would have to be adjusted down by as much as 50°F, which will significantly decrease jet production but will result in additional material in the diesel pool and for hydrotreating in the diesel units. Therefore, refiners processing Asia Pacific crudes that are considering LTO imports may be able to substantially increase Jet production, at the expense of diesel.

4.2 Reactor Operating Results

Using the generic reactor discussed above, each of the LTO and paraffinic kerosene feeds were processed through the unit. As most kerosene hydrotreaters operate in either a sulfur mode to meet Ultra Low Sulfur Kerosene (ULSK) qualities or in low severity mode to meet Jet specifications, we chose to operate the reactor at the more severe ULSK conditions of <10 ppm sulfur. Given the low sulfur content of the feeds in question, the reactor was run to a typical Middle of Run (MOR) WABT and at constant LHSV. Obviously, each crude has a different yield of kerosene, especially when cutpoint impacts to achieve freeze point are addressed, but the constant LHSV approach helped normalize the results for demonstration purposes. The following table summarizes the key operating conditions and performance results.

Table 3: Kerosene Hydrotreater KPIs

| Property | UOM | WTI | Bakken | Eagle Ford | Bach Ho | Cossack | Gippsland | Kutubu | Qua Iboe |
|-------------------|------|------|--------|------------|---------|---------|-----------|--------|----------|
| Sulfur | ppmw | 10 | <1 | <1 | <1 | <1 | 3 | <1 | 4 |
| LHSV | hr-1 | BASE | BASE | BASE | BASE | BASE | BASE | BASE | BASE |
| WABT ¹ | °F | BASE | BASE | BASE | BASE | BASE | BASE | BASE | BASE |





| | | | | | | | | | |
|--------------------------------------|------------|------|---|----|-----|----|----|---|---|
| Chemical H2 Consumption ¹ | scf/bbl FF | BASE | 1 | -8 | -12 | -2 | -5 | 4 | 8 |
|--------------------------------------|------------|------|---|----|-----|----|----|---|---|

Note 1 – Variable value is delta of New Case minus Base Case

As expected, the LTO and Asia Pacific crudes produced minimal product sulfur when compared to a conventional U.S. crude and West African crude. Therefore, most kerosene hydrotreaters should be able to process LTO crudes if they are capable of processing the other peer crude kerosene streams. Hydrogen consumption does not vary substantially, as most ULSK units are focused on meeting the sulfur target for ULSD blending. Minimal conversion, gravity shift, boiling point shift, and cold property shift occur across conventional hydrotreating units in ULSK mode.

For refineries considering LTO processing, the key challenge will be managing the cutpoint implications on jet/kerosene yield rather than hydrotreater performance, as well as managing any trace contaminants that are contained in the crude that appear in the kerosene range. Optimization opportunities may exist if the LTO crude provides hydraulic capacity in the unit or allow the refiner to run the unit in block operation to create capacity for treating other streams (naphtha, distillate, etc).

5.0 Diesel Hydrotreater Operations

One of the key advantages of processing LTO crudes is that the severity requirements are significantly lower than medium or heavy crudes. Therefore, for any given refiner, including LTO in the process mix can allow for alternate operating scenarios, such as additional throughput, including some or more cracked stocks, or extending catalyst cycle length. However, these paraffinic crudes have poorer cold flow properties compared to conventional crudes, and must be manage through product blending, additives, or catalyst systems.

5.1 Feedstock Quality

The following table summarizes the key feed properties for our marker crude, LTO crudes, and global paraffinic crudes. These cuts were generated by taking the respective crude assays and processing them in a KBC DISTOP™ simulation to produce as-cut diesel streams. The cutpoint ranged between 500 and 650°F. Though multiple assays exist for each crude type, the following information provides a general indication of the distillate qualities for each respective crude.

Table 4: Diesel Properties

| Property | WTI | Bakken | Eagle Ford | Bach Ho | Cossack | Gippsland | Kutubu | Qua Iboe |
|---------------------|------|--------|------------|---------|---------|-----------|--------|----------|
| API | 35.3 | 34.7 | 38.5 | 40.5 | 34.8 | 36.0 | 32.3 | 33.0 |
| Sulfur, wt% | 0.25 | 0.08 | 0.03 | 0.03 | 0.04 | 0.12 | 0.05 | 0.12 |
| Nitrogen, wt% | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 |
| Paraffins, vol% | 35 | 29 | 42 | 46 | 40 | 49 | 31 | 27 |
| Aromatics, vol% | 20 | 24 | 17 | 16 | 23 | 24 | 28 | 23 |
| Cloud Point, °F | 10 | 4 | 17 | 39 | 15 | 37 | 26 | 15 |
| Pour Point, °F | 8 | 0 | 14 | 7 | 13 | 32 | 22 | 10 |
| Cetane Index, D4737 | 61 | 59 | 68 | 76 | 59 | 63 | 54 | 55 |

As shown by the table above, LTO crudes such as Eagle Ford and Bakken, have significantly lower sulfur and nitrogen than their U.S. conventional crude counterpart. When comparing LTO crudes to other Asian light sweet crudes, the properties are quite similar (low sulfur, high paraffins, low aromatics). Therefore, refineries that are currently processing these (or other) light sweet crudes can consider processing LTO crudes. Finally, many U.S. refiners have been displacing West African crudes for domestically produced LTOs. As shown, though the selected West African crude has similar sulfur and nitrogen levels as LTOs, it has lower paraffins and the same or higher aromatics. Hence, the LTO crudes should be easier to process within the distillate hydrotreater than the West African counterpart.

5.2 Reactor Operating Results

Each crude's diesel was processed by itself through the generic hydrotreater mentioned previously. Each case was run at constant throughput (i.e. LHSV) and to either an 8 ppm sulfur target or to minimum WABT to understand the impact of crude type on hydrotreater operation. Though most refiners will process a blend of several crudes at any one time and a complete 100% swap on crudes is not typical, the analysis does provide insight to the impact of diesel quality on hydrotreater performance. The following summarizes key performance indicators of the unit, with WTI crude as the base operation.

Table 5: Diesel Hydrotreater KPIs – Virgin Diesel Feeds

| Property | UOM | WTI | Bakken | Eagle Ford | Bach Ho | Cossack | Gippsland | Kutubu | Qua Iboe |
|--|------------|--------|--------|--------------|--------------|--------------|--------------|--------|----------|
| Sulfur | ppmw | 8 | 8 | <1 | <1 | 3 | <1 | 8 | 8 |
| LHSV | hr-1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| WABT ¹ | °F | BASE 1 | -23 | Minimum WABT | Minimum WABT | Minimum WABT | Minimum WABT | -10 | 3 |
| Total Delta T ¹ | °F | BASE 1 | -7 | -33 | -49 | -8 | -19 | 20 | 24 |
| Chemical H2 Consumption ¹ | scf/bbl FF | BASE 1 | -56 | -164 | -227 | -62 | -105 | 69 | 101 |
| Delta API (Bottoms – Feed) ¹ | | BASE 1 | -0.4 | -1.9 | -2.9 | -0.4 | -1.1 | 1.2 | 1.5 |
| Delta Cetane (Bottoms – Feed) ¹ | | BASE 1 | -0.4 | -3.7 | -6.6 | -0.3 | -2.0 | 2.8 | 3.2 |
| Cycle Length ¹ | Years | BASE 1 | 2.6 | 2.7 | 2.6 | 3.0 | 2.8 | 1.0 | 0.0 |

Note 1 – Variable value is delta of New Case minus Base Case

A few interesting findings come out of this analysis:

- As expected, processing LTO diesel significantly reduces the operating severity (i.e. WABT) and associated hydrogen consumption
 - The lower WABT also increases total cycle length, thereby providing for optimization opportunities on alternate operating scenarios
 - For those crudes that result in minimum reactor WABT operation, additional catalytic capacity exists for alternate operating considerations
- With a reduction in hydrogen consumption, the reactor delta temperature decreases as well
 - This reduction will impact the heat recovery train in the unit and may require additional heater firing to achieve reaction temperatures

- Many of the Asian crudes show similar performance to Bakken and Eagle Ford
 - Bach Ho performance is significantly different, given its low sulfur, low aromatics, and high API gravity.
 - For refineries processing West African crudes, the performance shift can be even more significant, as these crudes are higher in aromatics and tend to have higher levels of very difficult sulfur in the diesel feed.
 - For diesel units or refineries with hydrogen limitations and constraints, the LTOs can provide a capacity advantage

As shown above, processing LTO is quite similar to processing other global paraffinic crudes that refiners have vast experience treating. These crudes can also provide additional advantages, as they relieve other constraints within the unit, especially those driven by severity and cycle length. Therefore, by including some of these feeds within the crude mix, the refiner may be able to operate the unit and possibly the wider refinery in a more advantageous manner.

5.3 Cracked Stocks

Most distillate hydrotreaters have to process not only virgin diesel material from the crude unit, but also cracked stocks, such as LCO (FCC Light Cycle Oil) or LCGO (Light Coker Gasoil). A set of cases was run using a typical LCO from a high severity FCC that is processing unhydrotreated feed. This feedstock was chosen as it is the most severe feedstock within most refineries.

For the second set of cases, LCGO was chosen as a feed. Given the global trend to reduce fuel oil production by processing vacuum resid in Delayed Cokers, most refiners are processing LCGO in their distillate units or soon will be doing so. The challenge for LCGO processing is the high olefin content as well as other contaminants that come with the process (i.e. Silica).

To examine the impact of these alternatives, the following cases were run. For LCO, the same generic model was used and 10% LCO was added to the feed mixture for the base WTI crude. Total throughput was adjusted to return the operation to base line cycle length while retaining LCO percentage at 10%. Then, crude types were changed and the unit throughput and LCO percentage adjusted to return the unit to baseline cycle length, with the priority being to first return the unit to base throughput (LHSV) and then increase LCO percentage. For the cases, LCO qualities were held constant, though in reality, the FCC LCO would shift with change in crude type.

For the LCGO cases, a similar approach was used. The base WTI crude and 10% of a generic LCGO was processed in the unit. Throughput was adjusted to return the unit to baseline cycle length while retaining the LCGO percentage at 10%. Crude types were changed and throughput and LCGO percentage adjusted to meet baseline cycle length, with the priority being to first return the unit to base throughput (LHSV) and then increase LCGO percentage. As with LCO, LCGO qualities were held constant, though they would shift in a real plant with crude changes.

The following table summarizes the KPIs for each of the cases. Please note that the LCO and LCGO each have different base cases.



Table 6: Diesel Hydrotreater KPIs – Virgin and Cracked Diesel Feeds

| Property | UOM | WTI + LCO | Eagle Ford + LCO | Cossack +LCO | | WTI + LCGO | Bakken + LCGO | Gipssland + LCGO |
|--------------------------------------|------------|-----------|------------------|--------------|--|------------|---------------|------------------|
| Sulfur | ppmw | 8 | 8 | 8 | | 8 | 8 | 8 |
| LHSV | hr-1 | 0.84 | 1.0 | 0.92 | | 0.89 | 0.92 | 1.0 |
| % Cracked Stock | vol% | 10 | 18 | 10 | | 10 | 10 | 14 |
| Total Delta T ¹ | °F | BASE 2 | -14 | 0 | | BASE 3 | 4 | -9 |
| Chemical H2 Consumption ¹ | scf/bbl FF | BASE 2 | -91 | -19 | | BASE 3 | 7 | -57 |
| Cycle Length ¹ | Years | BASE 2 | BASE 2 | BASE 2 | | BASE 3 | BASE 3 | BASE 3 |

Note 1 – Variable value is delta of New Case minus Base Case

Some conclusions on the cracked stock studies:

- Processing LCO or LCGO with virgin stocks may require a reduction in feed rate (or other mechanisms) to maintain overall cycle length, which is expected given the difficulty of treating these streams
- By utilizing LTO feeds, the unit can increase throughput and/or increase cracked stock processing while maintaining constant cycle length.
 - If the unit is hydrogen consumption limited, additional capacity may be available to increase cracked stock percentage, though cycle length may be impacted
- In comparing Asian light sweet diesel versus LTO diesel, the unit performance is similar on a relative basis, but each crude will have a distinct impact on unit performance that should be analyzed.

Using a tool like DHTR-SIM™ can assist the refiner in understanding the reactor performance and product quality impacts of processing LTO crudes at their specific facility.

5.4 Cold Property Management

As shown in the tables above, LTO distillates have poor cold properties, which is common in Asia Pacific light sweet crudes. Though hydrotreating impacts cetane and sulfur, this process does not appreciably change the cold flow properties. The high straight chain paraffinic concentration and yields make these crudes good for diesel production. Straight chain paraffin properties are prone to wax production, thereby creating flocculation observed as high cloud points and, as they crystallize, high pour points. This phenomena is shown graphically below:



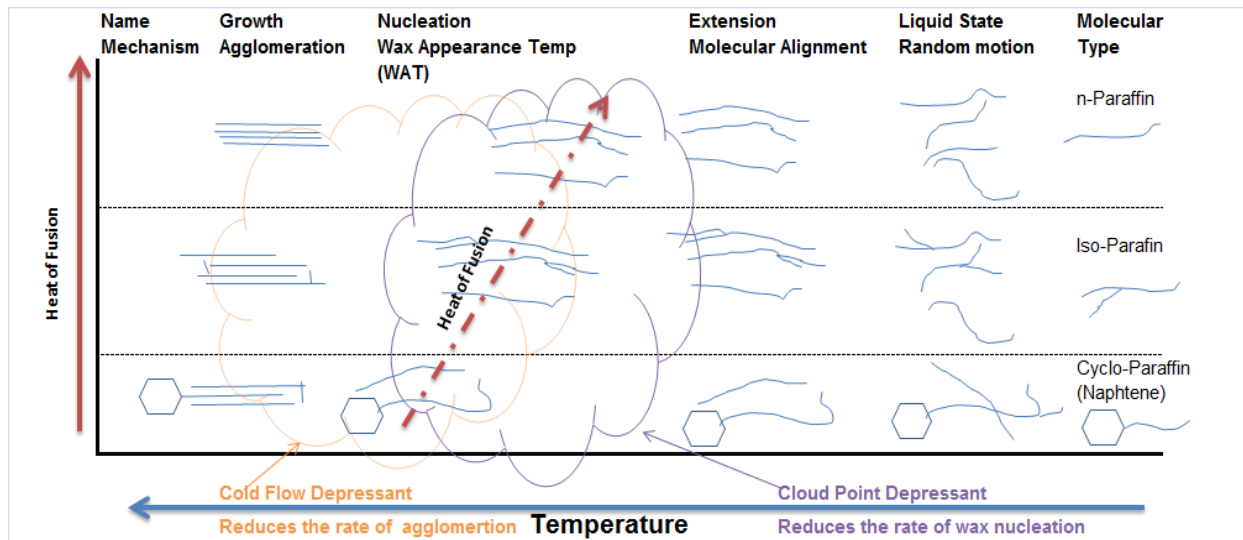


Figure 4: Crystallization Mechanisms

Several mechanisms exist to manage these properties and meet final blending requirements. These include:

- Kerosene Blending
- Pour Point Depressants
- Catalytic Dewaxing

For most refiners, a combination of the first two options are the most typical. However, many refiners are now looking to utilize the final option, given the high percentage of paraffinic and waxy crudes they are processing. A fourth option of reducing back-end cut point also exists, but the economics for reduced diesel recovery normally does not make this option attractive in distillate centric markets.

5.4.1 Kerosene Blending

This option is one of the easiest to utilize. Often, this option is used by default, as most refiners are limited in the amount of Jet or Kerosene that can be sold as a standalone product. Therefore, many refiners naturally blend Kerosene range material into the diesel pool. Of course, with ULSD specifications, the Kerosene must be highly hydrotreated, either within a dedicated hydrotreater or as part of the diesel hydrotreated feed mix. Software like KBC's Petro-SIM tool can be used to understand the blending impacts on cold properties for various crude blends.

5.4.2 Pour Point Depressants

Cold Flow Depressant (CFD) additive chemistry involves blending polymers with the distillate, such that the initial wax formation is modified from large to small wax crystals and inhibits agglomeration. Wax formation starts with a nucleation point for small crystals to collect (i.e. Cloud Point). As the crystal grows, the larger crystals combine or agglomerate into larger collected masses until the fuel begins to gel, as indicated by the Pour Point or CFPP. The thermodynamics are such that the heat of fusion can be measured by the differential temperature of the mixture. The endpoint of the diesel negatively impacts the effectiveness of these suppressant additives.



Reported effectiveness of pour point additives is summarized below for two paraffinic crudes¹⁹:

Table 7: Pour Point Depressant Performance

| Depressant Type | | IFP, TPE 101 | | Chem Link P 7599 or 7590 |
|----------------------------|-------------|--------------|---------|--------------------------|
| Treatment Concentration | wppm | 500 | 3,000 | 500 |
| Distillate from crude type | | Bombay High | Bach Ho | Bach Ho |
| Pour Point Reduction | Delta T, °F | 18 | 6 | 12 |

Each crude and distillate blend (i.e. virgin vs cracked) responds differently to CFD additives. Therefore, refiners should work with their chemical vendors to complete the necessary testing to select the right additive for their operation while managing the economic impact.

5.4.3 Catalytic Dewaxing

Catalytic Dewaxing has existed for many years and has been applied in many refineries, especially those in Asia processing highly waxy crudes or those refiners making diesel for cold weather climates. With the advent of LTO processing, many refiners should consider utilizing this technology in their refinery.

Given that most refiners need a small amount of cold property improvement, especially cloud point, most facilities can just install a layer of Dewaxing catalyst in one of their existing unit beds. Since the catalyst operates better on low sulfur and nitrogen feedstock, most refiners put the catalyst at the bottom of the last bed.

The catalyst improves cold properties through two potential mechanisms. The first mechanism is through cracking of the straight chain molecules that lead to high cloud and pour point. This mechanism was used by many of the first generation catalysts. Though effective, the downside of this mechanism is that a significant amount of distillate yield is lost to naphtha and gas due to cracking, and the hydrogen consumption increases across the process unit.

The second mechanism is through isomerization. This mechanism changes the normal paraffins to iso paraffins, thereby improving cold properties of the stream. The advantage of this mechanism is that diesel yield is retained and hydrogen consumption is minimal.

Many catalyst vendors offer this technology and will work with refiners to include a Dewaxing layer in their catalyst load. The key challenge of using this catalyst in an existing unit is that the amount of hydrotreating catalyst in the reactor will be reduced. Therefore, the refiner and catalyst vendor will need to determine the impact of this change. If the refiner has spare catalyst activity due to processing LTO, the impact on cycle length may be minimal. However, if the unit is tight on overall activity, the refiner may need to load a higher activity catalyst, which impacts unit performance and catalyst costs.





5.5 Potential Operating Issues

Though the focus of any significant feed change is always on the reactor operation and resulting product yields and properties, processing LTO distillates will have other impacts on the unit operation. As discussed above, the unit heat balance may change significantly, due to the lower hydrogen consumption reducing the exotherm in the reactor. Therefore, the feed furnace load will increase and may become a limiting factor. Including cracked stocks in the feed mix can help mitigate this issue, as these feeds will increase hydrogen consumption and exotherm.

Another impact is on the heat recovery train. Given that these feeds are waxy, deposits can form on the initial preheat exchangers, thereby reducing thermal efficiency. In addition, the LTO crudes may contain other chemical additives that deposit on exchanger surfaces, reducing heat recovery and possibly increasing pressure drop across the exchangers or even reactor bed. Some mitigation options exist, but the most common method is diligent unit monitoring and the ability to clean exchangers on-line.

Finally, trace contaminants can exist in LTO kerosene or diesel streams that will foul or deactivate the catalyst. Some examples include phosphorus, arsenic, and silica. Phosphorus has become a significant problem in the industry and is thought to be caused by oil recovery and transport additives used by the upstream producers. These contaminants show up particularly in the kerosene cut and have been known to cause significant fouling and catalyst deactivation.

6.0 Conclusions

Light Tight Oil has become a commonplace crude source within the U.S. over the last 5 years, and is now poised to become a crude source on a global level. These crudes provide a unique opportunity for refiners to supplement their existing crude basket. Most of the challenges of processing LTO in the distillate train are around managing the impact on unit heat balance and the opportunities that arise to increase throughput or cracked stock processing. Care should be taken to track and monitor trace contaminants that can impact heat recovery, pressure drop formation, and catalyst deactivation. Tools like DHTR-SIM™ and Petro-SIM™ can assist refiners in evaluating the specific impact of these crudes on their unique operation, such that the operational changes can be anticipated and any necessary design, operational, or procedural changes made in advance. Those refiners that can quickly evaluate and manage LTO processing will have a distinct advantage to their peers.

Finally, the authors would like to thank Scott Sayles for his valuable insight on this subject as well as the original genesis for the idea of this paper, as well as John Fagley and Quang Vu for their assistance with DHTR-SIM™.

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