Crude Column Reflux and Pumparound Optimization

In Light of Low Naphtha Values

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Introduction

With lighter crudes and much lower naphtha value (as opposed to kerosene value) it is time to re-evaluate and re-engineer Crude Unit OH versus pumparound (PA) heat recovery designs. This study presents curves of kerosene losses to OH naphtha product versus PA duties for a hypothetical 100,000 BPSD single column Crude Unit (with no Preflash Column).

Summary

This study points out that today’s grass roots designs should not be optimized at yesterday’s product values, and existing designs should be re-evaluated to shift PA duty to OH to increase reflux to greatly increase fractionation and profits.

If a 100,000 BPSD single column Crude Unit, charging 37.5 API crude, was optimally designed when kerosene was worth $2/BBL more than OH naphtha and fuel gas was worth $3/MMBTU, then it probably had about a 1.0 OH reflux ratio, and had about half of its total heat removal installed as PA duty. Today, in a world where kerosene can be valued at $20/BBL more than naphtha, and fuel gas is worth about $5/MMBTU, the curves presented show that raising the reflux ratio to 2.0 by lowering the PA duty to 34% of the total, allows about 1,200 BPSD of naphtha to be recovered to kerosene, while still maintaining a 105°F flash point kerosene product at a constant stripping steam rate. This is worth a net savings (taking increased fuel gas usage into account, and assuming 50% of the OH duty remains recovered to crude preheat) of about $7.2 million/year! If the current PA duty is higher, at 58% of the total, and the reflux ratio is lower, at about 0.5, then the recovery jumps to 3,100 BPSD, for a net savings of about $19.3 million/year!

Study Basis

To do these curves, MPEC set up a Crude Unit simulation with no side PA duty as documented on the attached Figure 1, where each column stage represents 1 theoretical stage at 100% efficiency. PA duty was then added; first 5, 10, 20, 40, and 60 MMBTU/Hr to the kerosene section, then an additional 5, 10, 20, 40, and 60 MM BTU/Hr to the diesel section, then an additional 5, 10, 20, 40, and 50 MMBTU/Hr to the AGO section. These runs are designated as “Adding PA Top to Btm”. Since the order in which PA duty was added greatly affected the naphtha recovery, a second set of curves were produced by reversing the order, adding the AGO PA first and the kerosene PA last. These runs are designated as “Adding PA Btm to Top”.

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For all runs, the feed heat, theoretical stages, pressures, OH drum temperature, overflash rate, and stripping steam rates were all held constant. The product rates were solved to maintain constant specifications as follows:

- Naphtha – Varied to maintain kerosene flash point of 105°F
- Kerosene – Varied to maintain kerosene D-86 90% point of 480°F
- Diesel – Varied to maintain diesel D-86 90% point of 640°F
- AGO – Varied to maintain overflash to flash zone at 5,000 BPSD (5% of crude)

Study Results

Figure 1A documents the “Top to Btm” simulation run with 60 MMBTU/Hr of kerosene PA duty, 60 MMBTU/Hr of diesel PA duty, and 40 MMBTU/Hr of AGO PA duty added. As shown, the poorer fractionation drops the kerosene from 27,126 BPSD to 19,665 BPSD, or by 7,461 BPSD. Some of the decreased kerosene production drops to diesel, which is typically worth more than kerosene (and some of the kerosene is typically blended into diesel, anyway). So, ignoring this benefit, this study just focuses on the loss of kerosene to low-value naphtha. Since the increased naphtha now absorbs all the offgas, the delta naphtha is calculated as Fig. 1A naphtha – (Fig. 1 naphtha + Fig. 1 dry offgas). This increased naphtha is then 4,102 BPSD, which, at a $20/BBL loss, amounts to $82,040/day, or $28.7 million/year (at 350 days/year on-stream). (This ignores the heat recovery losses that will be taken into account below in Figures 3-A through 3-D).

Figure 2 graphs all the run’s losses of kerosene to naphtha versus the lower reflux ratios as the PA duty is added (from left to right), with each run representing a single data point. Interpolating this graph along the “Top to Btm” line, it can be seen that increasing the OH reflux ratio from 0.5 to 1.0 (moving left) recovers 1,900 BPSD of naphtha to kerosene. Further increasing the OH reflux ratio to 2.0 recovers an additional 1,200 BPSD. Interpolating along the “Btm to Top” line gives similar to higher results at 1,900 and 1,450 BPSD, respectively.

Figures 3A through 3D re-graph the kerosene to naphtha losses, but this time, versus the % of total heat removal installed as PA (Total Q as PA). These lower curves on each figure remain the same, but 4 new curves are added to each graph that plot the savings (or loss) per year on the right ordinate versus the “% of Total Q as PA”, assuming different delta kero-naphtha and fuel gas values as follows:

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Kero-Naphtha Differential $/BBL</th>
<th>Fuel Gas $/MMBTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>2</td>
<td>3.0</td>
</tr>
<tr>
<td>3B</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>3C</td>
<td>10</td>
<td>4.0</td>
</tr>
<tr>
<td>3D</td>
<td>20</td>
<td>5.0</td>
</tr>
</tbody>
</table>

When many crude units were built, the values of Figure 3A were good for optimizing heat recoveries, and many crude units were built with no OH exchangers installed to preheat crude. The top curve on Figure 3A (with dots) represents this case. It assumes 0% OH heat recovery, 100% PA heat recovery, and adds incremental PA from “Top to Btm”. As shown, there is still a positive savings for this case, even at 62% “Total Q as PA”. This is
because the fuel gas savings (assuming a 75% heater efficiency, and 350 days/year) from preheat outweighs the product value loss, even at up to 6,550 BPSD of kerosene loss to naphtha. For light crudes, many crude units did exchange OH condensing against crude preheat, although only up to about 50% was practical. Assuming that 50% of the OH preheats crude, the heat recovery value of the PA’s decreases appreciably, so losses increase. Nevertheless, Figure 3A’s third curve from the top shows that installing the PA’s still saves money, all the way up to 59% of “Total Q as PA”. This same exercise, but adding PA’s “Btm to Top” is represented by the top curves with square data points. Note that it shows about the same results, so where the PA duty is added makes little economic difference.

Figure 3B shows that raising the kero-naphtha differential to $5 notably decreases the payout for PA’s, even though the fuel gas price was also increased to $3.5/MMBTU. It also separates the curves, so that adding PA “Btm to Top” is notably worse that “Top to Btm”. Also, whether or not OH heat is exchanged against crude makes a much bigger difference in the economic losses. For the top line, representing no OH heat recovery and PA added “Top to Btm”, the “Total Q as PA” breakeven point has shifted down to 57%. For the lowest curve, representing 50% OH heat recovery and PA added “Btm to Top”, the breakeven point has shifted down to 30%.

Figure 3C shows that raising the kero-naphtha differential to $10/BBL and the fuel gas to $4/MMBTU shifts the top curve (0% OH heat recovery and “Top to Btm”) breakeven point down to 50% “Total Q as PA”, and the bottom curve down all the way to about 0%.

Figure 3D shows that when the kero-naphtha differential gets to $20/BBL, losses become so significant that any PA heat only pays out for the case where there is no recovery of OH against crude, and PA is added “Top to Btm”. Even then, it is only justified to 39% of “Total Q as PA”. All the other cases show economic losses, almost from the beginning.

An Example

Using the curves, you can evaluate your own crude unit. If you currently have a 1.0 OH reflux ratio, the “Top to Btm” curve on Figure 2 shows about 1,800 BPSD of naphtha could be recovered to kerosene if all the PA duty were removed, and all the heat removal was shifted to OH reflux, at about a 3.9 reflux ratio. If the OH reflux was changed to 2.0 by decreasing PA duty and increasing OH duty, only 600 BPSD of naphtha could be further recovered to kerosene by going to 100% OH reflux. The difference between the 1.0 reflux versus the 2.0 reflux case is then 1,800 – 600, or 1,200 incremental BPSD of naphtha recovery to kerosene.

Use Figure 3D to see what this could mean in terms of savings when kerosene is valued at $20/BBL more than naphtha, and when fuel gas is valued at $5/MMBTU. Locate the 1,800 BPSD (at 51% “Total Q as PA”) and the 600 BPSD recovery point (at 34% “Total Q as PA”) on the bottom “Top to Btm” curve of Figure 3D. Then, go to the “Top to Btm” curves at the top of Figure 3D and read the losses per year (at the same % “Total Q as PA”) that these entail. Reading the “Top to Btm” curve that assumes 50% heat recovery in the OH, the losses are about $1.7 million/year at 600 BPSD loss (2.0 reflux ratio), and $8.9 million/year at the 1,800 BPSD loss (2.0 reflux ratio), for a net difference of $7.2
million/year for increasing the OH reflux ratio from 1.0 to 2.0 (done by decreasing the “Total Q as PA” from 51% to 34%).

If you currently have only a 0.5 OH reflux ratio, then the potential gain from raising reflux is much higher. From Figure 2’s “Top to Btm” curve, about 3,700 BPSD of kerosene is lost to naphtha at this 0.5 reflux ratio point, and from Figure 3D’s “Top to Btm” curves, this plots at about 58% “Total Q as PA” and about a $21.0 million/year loss. The delta between this point and going to the 2.0 OH reflux ratio at 34% “Total Q as PA” then increases greatly to delta savings of 3,100 BPSD and $19.3 million/year.

If the “Btm to Top” curves are used instead, savings are even greater, because PA heat taken below the kerosene PA imposes greater kerosene losses than PA heat taken in the kerosene PA. If no heat is recovered from the OH, then the “0% OH Heat Recovery” curves will show less savings, because of the more severe penalty for losing PA heat recovery to OH heat losses. However, as the product values become much higher than the heat values, as they are today, these curves still show very high incentives for raising reflux by lowering PA’s. For instance, if the “0% OH Heat Recovery (Adding PA Top to Btm)” curve of Figure 3D is used for the 0.5 to 2.0 OH reflux ratio example above, the loss at 58% “Total Q as PA” and 0.5 OH reflux ratio is about $17.0 million/year, while at 34% “Total Q as PA” and 2.0 OH reflux ratio, the loss turns into a savings of about $0.8 million/year, for a net delta savings of $17.8 million/year. This is only 7.8% less savings than when the OH was 50% heat recovered in the $19.3 million/year example above.

**Capital Costs Considerations**

Raising OH reflux ratios increases the size requirements of both the Crude Column and its OH Condensers, but it may be possible to live within these constraints with high-capacity trays and/or packing and with low-fin tube bundles or new OH-to-crude exchangers installed for excellent payouts. Unloading the Crude Column OH by installing Preflash drums or Preflash columns is another option that the additional kerosene yield can help payout. Making much lighter than specification kerosene from the Crude Unit and then fractionating the naphtha out in a separate column (recycling the naphtha back to the Crude Column) can also have an excellent payout, especially if an idle column is available.

**Conclusion**

This study points out that today’s grass roots designs should not be optimized at yesterday’s product values, and existing designs should be re-evaluated to shift PA duty to OH to increase reflux to greatly increase fractionation and profits. These graphs are meant to make it easy to quantify how much of an effect this might have for your actual unit. There are a variety of ways to increase naphtha-kerosene fractionation without totally redesigning the Crude Unit. If you would like, MPEC would be happy to discuss your individual situation. Revamping existing crude units to handle different quality crudes and to better optimize product yields has been MPEC’s main focus for over 25 years. Whether revamp or grass-roots, value-driven process design can add significantly to your bottom line.
Figure 1
Simple Crude Column
No PA Q's
Figure 1A
Simple Crude Column
With PA per Run "AGO PA Q-4"

Stream Name | Crude | CC-OFFGAS | NAPHE | KERO-PROD | DSL-PROD | AGO | ATM-BTMS
---|---|---|---|---|---|---|---
Stream Phase | | | | | | | |
Total Std. Lqg Rate \(\text{bbl/day}\) | 100,000.00 | 0.00 | 16,528.34 | 19,604.93 | 17,090.10 | 3,280.71 | 33,459.70
Dry Total Std. Lqg Rate \(\text{bbl/day}\) | 100,000.00 | 0.00 | 16,528.34 | 19,604.93 | 17,090.10 | 3,280.71 | 33,459.70
Dry Liquid Std. API | 37.5 | 67.46 | 44.02 | 34.35 | 28.53 | 18.51 |
Total RVP (ASTMD0191-99) \(\text{PSI}\) | 6.80 | 16.56 | 0.19 | 0.03 | 0.55 | -0.20 |
Flash Point Temperature (Closed Cup) \(\text{°F}\) | --- | -58.07 | 105.60 | 174.42 | 384.27 | 285.48 |
ASTM D86 at 760 MM/HG (°F) | TBP | | | | | | |
| IBP | -99.18 | 23.98 | 277.18 | 343.31 | 288.95 | 501.00 |
| 5% | 93.91 | 37.32 | 327.93 | 445.90 | 476.06 | 621.70 |
| 10% | 136.14 | 91.83 | 348.32 | 480.03 | 542.64 | 664.84 |
| 20% | 163.87 | 161.46 | 380.84 | 537.27 | 632.32 | 776.02 |
| 50% | 258.55 | 209.66 | 403.95 | 564.63 | 665.81 | 857.25 |
| 70% | 717.23 | 244.49 | 431.11 | 592.97 | 694.65 | 970.36 |
| 90% | 1025.73 | 288.00 | 480.00 | 640.00 | 738.31 | 1150.00 |
| 95% | 1189.74 | 308.72 | 501.66 | 652.25 | 768.34 | 1224.09 |
| IBP | 1397.75 | 340.73 | 531.11 | 700.45 | 807.62 | 1298.45 |
Figure 2
Reflux vs. Kero Loss to Naphtha
(100 KBPSD Single Crude Column)

Loss of Kero to Naphtha
(Adding PA Top to Btm)

(From here to left, Kero PA is added.)

Loss of Kero to Naphtha
(Adding PA Btm to Top)
Figure 3A
PA Q vs. Kero Loss to Naphtha
Kero worth $2 More than Naphtha, Fuel Gas Cost $3/MMBTU
(100 KBPSD Single Column Crude Unit)

% of Total Q as PA

Savings/Loss Assuming 50% OH Heat Recovery (Adding PA Top to Btm)

Savings/Loss Assuming 0% OH Heat Recovery (Adding PA Top to Btm)

Savings/loss Assuming 0% OH Heat Recovery (Adding PA Btm to Top)

(From here to right, Kero PA is added.)

Loss of Kero to Naphtha (Adding PA Btm to Top)

Loss of Kero to Naphtha (Adding PA Top to Btm)
Figure 3B
PA Q vs. Kero Loss to Naphtha
Kero worth $5 More than Naphtha, Fuel Gas Cost $3.5/MMBTU
(100 KBPSD Single Column Crude Unit)

| Savings/Loss Assuming 50% OH Heat Recovery (Adding PA Top to Btm) |
| Savings/Loss Assuming 0% OH Heat Recovery (Adding PA Btm to Top) |
| Savings/Loss Assuming 0% OH Heat Recovery (Adding PA Top to Btm) |

(From here to right, Kero PA is added.)

Loss of Kero to Naphtha (Adding PA Btm to Top)
Loss of Kero to Naphtha (Adding PA Top to Btm)
Figure 3C
PA Q vs. Kero Loss to Naphtha
Kero worth $10 More than Naphtha, Fuel Gas Cost $4.0/MMBTU
(100 KBPSD Single Column Crude Unit)
Figure 3D
PA Q vs. Kero Loss to Naphtha
Kero worth $20 More than Naphtha, Fuel Gas Cost $5.0/MMBTU
(100 KBPSD Single Column Crude Unit)