Question 82 What are your preferred process and catalyst options to maximize LCO yield? Among the options, please discuss the ramifications of lowering the riser outlet temperature by 40-50 F on the heat balance, including suggestions on how to best utilize any excess air blower capacity at the lower riser temperature.

Matthew Meyers (Western Refining)

One way to increase refinery distillate yield if there is not an O2 or regenerator temperature limit is to increase the upstream distillation efficiency to minimize the amount of 700 F minus boiling point material to the FCC. Reducing lighter material in the VGO reduces the crackability of the feed. The typical results of this are lowering the API gravity and the aniline point while slightly increasing the VGO tail, sulfur and Conradson carbon number. The end point should be monitored to make sure the feed nozzles can maintain good vaporization. The effects of this shift alone will cause higher LCO, slurry bottoms and coke yields. The best way to mitigate the increased slurry yield is by changing the catalyst formulation to target the optimum zeolite/matrix surface area ratio. As more bottoms are converted to LCO, the coke yield will increase. If the feed is left alone and riser temperature dropped by 40 – 50 F, the increased coke yield from increasing the matrix can utilize the air blower capacity to some extent. If blower capacity still remains, the refiner may increase the VGO draw from the crude unit and thus the amount of residue in the VGO while increasing catalyst addition rate to guard against metals and not allow activity to drop too much. Care should be taken not to exceed the feed nozzle vaporization limit or the metallurgical temperature limits in the regenerator. It’s also important to closely monitor sodium levels in the HVGO as well as metals on ecat.

Another option, if available, is to recycle slurry bottoms or HCO after the riser temperature has been decreased. If the air blower or regenerator temperature is near a limit or there are environmental concerns with increasing SOx, recycling HCO might be a better option since it will produce less coke with less sulfur. However, the slurry API and viscosity must be watched to make sure it doesn’t go off spec. Also, the slurry reflux and LCO pump down might need to be increased and the heat balance of the column will require adjustment to maintain good LCO distillation spec. As HCO is removed, the pump down will decrease, allowing the potential for an increase in LCO end point. It should be noted that the cracked stock will make more coke and dry gas and can rapidly deplete the excess air availability or wet gas compressor capacity. Also, decreasing riser temperature will increase the crackability of the slurry bottoms circuit, increasing the chances of exchanger fouling. Therefore, the recycle should be added slowly for every 10 deg decrease in riser temperature with 2 to 3 days between each increase to account for diurnal fluctuation.

Western Refining Company recently conducted a trial utilizing the first option above resulting in increasing the LCO yield from 20.2 to 24.3 % while maintaining similar slurry bottoms yield of 4.2%. For the catalyst change to lower z/m to be economical, the value of LCO must be at least 30% over LCC due to a decrease in conversion and loss of volume yield. As the zeolite SA is reduced there is also less of a requirement for rare earth, which can affect the economics, favoring the transition. This also assumes that the alkylation unit is able to remain fully utilized by either zsm additive addition or outside olefin purchase.

Ray Fletcher (Intercat)

The standard process variables influencing LCO production include:

1. Reduce riser outlet temperature (+0.75 wt% for -10°F)

2. Increase preheat temperature (+0.15 wt% for +10°F)

3. Reduce gasoline and point (+1.7 wt% for -10°F)

4. Recycle slurry (LCO ~30-40% of conversion)

5. Increase CRC for partial burn units (~1-2 wt%) 6. Reduce catalyst activity (0.25 wt% for -1 wt%)

FCC optimization rarely proceeds through single variable shifts. The most typical variable shifts for maximum LCO include reduced riser outlet, reduce gasoline and point, reduce catalyst activity via lower catalyst addition rate, and recycle slurry up to the unit constraints (typically main air blower or wet gas compressor) plus optimization of catalyst circulation rate via preheat temperature.

The standard catalytic variables for LCO maximization include:

1. Decrease zeolite concentration

2. Decrease rare earth on zeolite

3. Increase matrix composition (acid sites residing in pores greater than 8 Å)

4. Optimized catalyst architecture. This may be defined as pore volume or accessibility depending on your catalyst supplier.

As stated in the question, the primary impact of reducing riser outlet temperature by 40-50°F is a substantial increase in slurry production. Slurry production, as described above, is best controlled through a balance of process variable and FCC catalyst optimization.

An additional independent variable available to the FCC operator is to manipulate the zeolite-to-matrix ratio of the circulating inventory of the use of additives. This can be carried out through various additives currently available on the marketplace. Intercat has experience in utilizing Bottoms Cracking Additives in over 41 cat crackers. One unusual characteristic of Intercat's BCA is the observation that this additive does not negatively impact the main air blower or wet gas compressor thus enabling the refiner to base load 10% of this additive into the circulating inventory within a seven-day period.

This enables the refiner to achieve maximum LCO yield when the market is demanding LCO with the ability to "turn off" the additive when it is no longer profitable. This enables the refiner to avoid long change out times with the base catalyst. It is possible to swiftly return the unit to a more typical zeolite-to-matrix ratio on the back side via the introduction of a maximum zeolite bearing additive.

David Hunt (Grace Davison Refining Technologies)

In general the following process changes should be made as a refinery moves from a maximum FCC:

• Gasoline/ conversion operations to a maximum LCO operation:

• Remove Diesel range material from the FCC feedstock

• Reduced Gasoline endpoint

• Reduce FCC conversion by o Reducing Riser Outlet Temperature; o Higher Feed Temperature and o Lower Ecat Activity

• HCO or Slurry Recycle

• Catalyst Optimization

Increased slurry cracking, maintaining C3+ liquid yield and gasoline octane are key requirements of a maximum LCO catalyst system. In general, a maximum LCO catalyst is a low zeolite/matrix surface area catalyst with low to moderate activity and excellent slurry cracking qualities.

The primary challenge with a maximum LCO operation is high slurry yield when conversion is reduced. Grace recommends a MIDAS® or a zero rare-earth REBEL™ catalyst to ensure low slurry yields while maximizing LCO.

OlefinsUltra®, Grace Davison’s high activity ZSM-5 additive, is often required in maximum LCO operations to maintain C3+ liquid yield and gasoline octane. Operating at reduced conversion to maximize LCO will reduce the total product volume. Lower product total volume can reduce the total profitability during maximum LCO operations despite additional LCO production. OlefinsUltra® is critical to ensure profitability by increasing gasoline octane and liquid yield.

Lower riser outlet temperature in the order to 40 to 50 deg F will greatly increase LCO but will also create other challenges including:

• Lower C3+ liquid yield and gasoline cetane

• Higher slurry yield

• Potentially poor feed vaporization and riser/reactor coking OlefinsUltra® can be used to recover gasoline octane and liquid yield as discussed above. Reduced feed vaporization can be an issue when operating at reduced riser outlet temperature particularly when processing residual feedstocks. There is a practical minimum riser outlet temperature to minimize coking and ensure good catalyst stripping efficiency. Generally, operations less than 920 deg F are not commonly practiced and the minimum riser outlet temperature for some units could be considerably higher than 920 deg F.

Injection of a recycle stream downstream of the FCC feedstock will increase the riser mix temperature at the base of the riser which will increase feed vaporization at reduced riser outlet temperature. Of course, recycle and the use of a good slurry cracking catalyst like MIDAS® or REBEL™ will minimize slurry production. Optimal recycle streams to maximize LCO and total profitability were discussed by Hu. (2) A high porosity catalyst like MIDAS® or REBEL™ can help ensure fast feed vaporization at lower reactor temperature and minimize slurry yield or reactor coking (1). Feed injection nozzles that atomize the feed well are also critical to ensure the feed is efficiently vaporized at reduced riser outlet temperatures.

When reactor temperature is reduced and the feed temperature is increased to boost LCO yield, the air blower demand will be reduced. The wet gas compressor load will also be reduced because of less LPG and dry gas production. The refiner can take advantage of this additional capacity in many ways such as:

• Increased feed rate

• OlefinsUltra® ZSM-5 to increase LPG olefins to the wet gas compressor or alkylation unit constraint

• Heavy cycle oil or slurry recycle to minimize slurry production To ensure full profitability the FCC should operate fully constrained whether it's operating in maximum LPG, gasoline or LCO modes.

(1) Hunt, et al, „Maximizing FCC Light Cycle Oil Operating Strategies", Catalagram No. 104, 2008, pg

(2) Hu, et al, „Strategies for Maximizing Light Cycle Oil", NPRA Annual Meeting 2009, San Antonio TX, AM 09

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