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**Question 25: Besides high reactor temperatures and flow maldistribution, what are other causes of high gas and LPG yields in a hydrocracker have you experienced?**

**Praveen Gunaseelan (Vantage Point Energy Consulting)**

Hydrocrackers typically process heavy gas oils into distillate-range material. The gas oils are catalytically cracked at high pressures in the presence of hydrocracking catalyst and hydrogen. The reaction is exothermic and consumes a relatively large quantity of hydrogen. High gas and LPG yields would be generally undesirable in a properly operating hydrocracker.

In addition to high reaction temperature and flow maldistribution, there are various other potential causes of high gas yields in hydrocrackers, some of which illustrated below:

**•Deviations in feed composition and properties**

- Increase in the light content in the feed
- Decrease in the feed pressure
- Increase in the feed temperature
- Changes in the gas/liquid recycle ratio

**•Deviations in the reaction process**

- Excessive cracking (e.g., high catalyst activity, high recycle rate, etc.)
- Loss of selectivity (e.g., due to catalyst aging)
- Catalyst-related issues
- H<sub>2</sub>-related issues (e.g., drop in H<sub>2</sub> partial pressure)

**Brian Slemp (CITGO)**

- Light material (naphtha) in feed.
  - Light material (naphtha) in recycle oil.
  - High % of recycle oil back to reactor (or really, most things that increase conversion).
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•High catalyst activity - high activity overcracks; low activity needs an increase in temperature causing more thermal cracking.

•Poor catalyst selectivity.

•Low H<sub>2</sub> PP in recycle gas causes coking and light ends generation.

•Low recycle gas to liquid rates - higher residence time on catalyst, consumes H<sub>2</sub>, and drops the H<sub>2</sub> PP, causing coking and light ends generation.

•Uneven temperature profile across each of the cracking beds.

•Catalyst poisons/contamination.

### **Ward Koester (Zeolyst International / Criterion Catalysts & Technologies)**

Several different factors can increase production of lights ends in hydrocrackers. These include changes in makeup gas quality, feed poisons, changes in liquid feed type, increased reactor operating severity, and thermal cracking due to hot spots in either upstream furnaces or reactor catalyst beds.

The amount of C<sub>1</sub> and C<sub>2</sub> introduced with fresh gas determines to a large extent the recycle gas content. Formation of C<sub>1</sub> and C<sub>2</sub> due to cracking reactions is only a few tenths of a percent. Due to its low solubility in oil, C<sub>1</sub> in the recycle gas can increase by more than 5 times the m/u purity. The amount of C<sub>1</sub> can be managed by purging. CO and CO<sub>2</sub> are impurities that can convert to methane and water through the methanation reaction which is highly exothermic and consumes hydrogen. The CO and CO<sub>2</sub> will reduce catalyst activity due to competition for active reaction sites resulting in higher temperature requirements to maintain conversion, resulting in increased LPG production.

It is important to measure recycle gas composition on a regular basis, and to trend the results. If all else is constant, an increase in methane content could be due to the growth of a hot spot. Catalytic conversion will produce very little C<sub>1</sub>, some C<sub>2</sub>, and mainly C<sub>3</sub> and C<sub>4</sub>. Thermal cracking, however, can generate significant amounts of C<sub>1</sub> and C<sub>2</sub>. Note: even if you have a lot of thermocouples, you may not see a hot spot. Strictly speaking, it is impossible to see the highest temperature in a bed. If the reactor outlet temperature is higher than any individual last-bed temperature, you should be worried, even if your measured radial T appears to be 'acceptable.'

Catalyst poisons such as silicon, arsenic, and sodium can affect the activity and selectivity of the catalyst, resulting in higher required temperatures and increased gas and LPG production.

Changes in feed quality will influence product selectivity. C<sub>4</sub>-minus can increase when the feed gets much lighter or when it becomes more difficult to crack. Increasing the amount of a refractory blendstock, such as a feed with a higher endpoint (maybe due to resid entrainment), a pre-hydroprocessed material, or desulphated oil increases the temperature required to maintain a given conversion. This will increase production of C<sub>4</sub>-minus. Conversion that occurs in the pretreat section is also affected by feed quality. As with the cracking section, for a more refractory feed or a feed with a

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higher nitrogen content, keeping the same nitrogen slip requires higher temperatures. Replacing straight-run material with cracked stocks, such as LCO, coker gas oil or coker naphtha, increases pretreatment temperature rise, which can increase non-catalytic conversion.

Lowering the recycle cut point at constant gross conversion (constant bleed oil rate) will increase the severity of the cracking operation resulting in a lighter product package with more LPG and gas.

Excessive local heat flux in furnace tubes creating very high local film temperatures can cause thermal cracking producing increased amounts of C1 and C2. Typically, this is not a big issue because the residence time in the “film” is very short, assuming good turbulent/plug flow in the furnace tubes. However, at certain operating conditions like EOR turndown, it could be more of a factor. Also, this phenomena cures itself as the local hot spots tend to get an insulating layer of coke built up on them which will periodically slough off (especially during unit upsets) and allow the process to repeat.

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