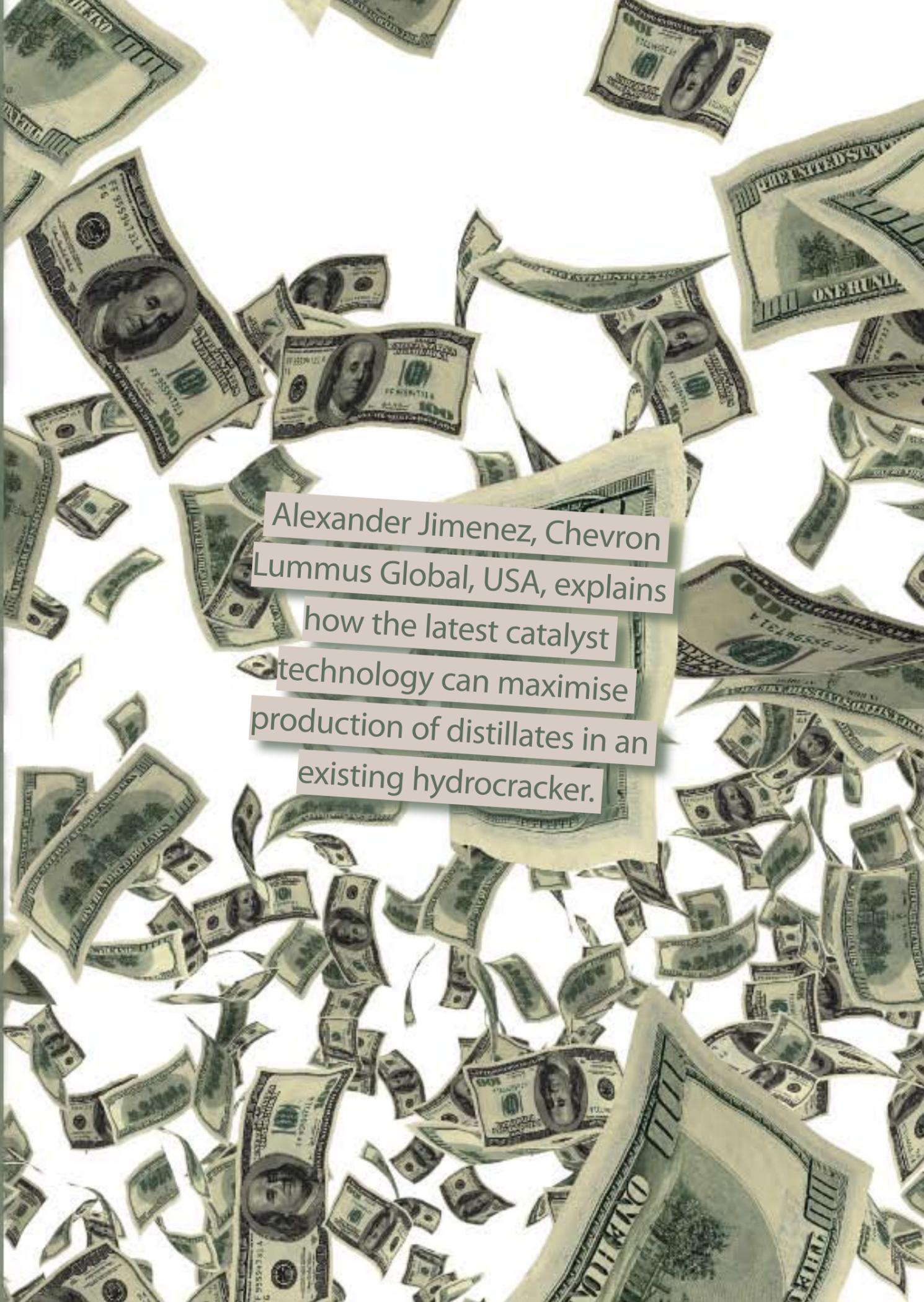


CASHING IN WITH CATALYSTS

Global demand for refined products is projected to increase at an annual growth rate of 1.46% or 1.46 million bpd annually from 2008 - 2030. Demand is expected to reach 121 million bpd by 2030 from the 2008 level of 86 million bpd. The Asia-Pacific region will experience the largest volume of growth as those regional economies continue to expand. Regional trends in demand are shown in Figure 1.¹

The global refined product slate is expected to experience a significant change over the next 10 years. The primary trend will be the shift from gasoline to diesel. Figure 2¹ shows the demand trend for gasoline and diesel from 1999 - 2020.

The recent trends and forecast highlight the need for refiners to begin evaluating options for shifting their operations to



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Lummus Global, USA, explains
how the latest catalyst
technology can maximise
production of distillates in an
existing hydrocracker.

produce more distillate products and less gasoline. In addition to the increase in demand for distillate products, refiners are also facing more stringent product requirements, decreasing availability of higher quality feed stocks, and a current global recession. These factors have placed a strong emphasis on utilising the latest catalyst technology. Employing new distillate selective catalyst is one of the most cost effective options for maximising distillates in an existing hydrocracker.

Hydrocracker configurations

The majority of existing hydrocrackers are categorised into two configurations: single stage (with or without a recycle stream) or two stage. A simplified diagram of a two reactor system in series is shown in Figure 3. In this example, and typically in the lead reactor of a multi reactor system, hydrotreating catalyst is loaded in the first reactor to convert organic sulfur and nitrogen from hetero compounds in the feedstock to hydrogen sulfide (H₂S) and ammonia (NH₃), respectively. Hydrocracking catalyst in the second reactor is designed to optimise yields and product properties in the presence of lower amounts of H₂S and NH₃. This configuration provides conversion to the desired product in a single pass and is referred to as single-stage once-through (SSOT). SSOT systems typically

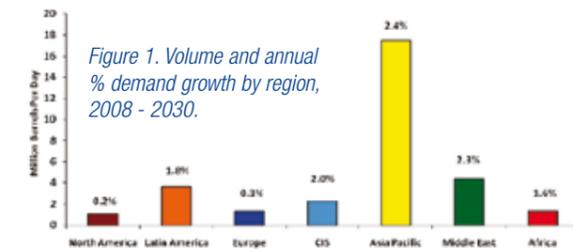


Figure 1. Volume and annual % demand growth by region, 2008 - 2030.

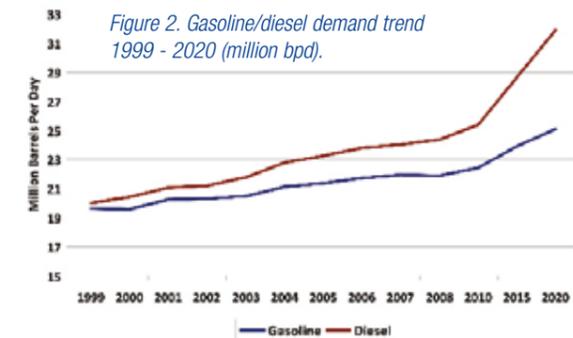


Figure 2. Gasoline/diesel demand trend 1999 - 2020 (million bpd).

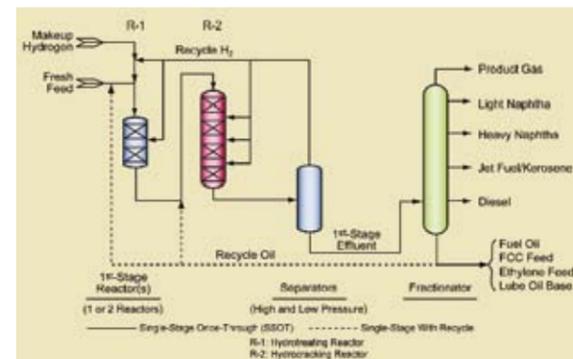


Figure 3. Simplified flow diagram of a two reactor single stage with and without (once through) recycle hydrocracking process.

provide 50 - 60% conversion level. In some single stage units, the unconverted oil may be recycled to either the first or second reactor. This configuration is referred to as a single-stage recycle (SSREC). The purpose of recycling the UCO is to approach full conversion (recycle to extinction) to the desired products. The primary advantage of an SSOT is capital cost. However, mid distillates made by an SSOT are generally higher in aromatics. Improving mid distillate product quality while maintaining desired mid distillate yields can be overcome by choosing a more mid distillate selective hydrocracking catalyst.

The two stage hydrocracking process is a more versatile configuration. A two stage hydrocracking process can employ either one or more reactors in the first stage and typically one reactor in the second stage. A simplified two stage process is shown in Figure 4. In this configuration, deep hydrogenation occurs in the second stage since conversion occurs in an environment relatively free of H₂S and NH₃. The near absence of H₂S and NH₃ allows a two stage unit to utilise either a base or noble metal hydrocracking catalyst.

In general, a two stage hydrocracking configuration offers more flexibility than the single stage configuration. A two stage configuration can typically process heavier feedstocks with higher aromatics, sulfur, and nitrogen. By separating the hydrodesulfurisation (HDS), hydrodenitritication (HDN), aromatic saturation and mild conversion in the first stage from high hydrogenation activity in the second stage, allows more flexibility in the selection of hydrocracking catalysts to maximise product yields. For example, the mid distillate production at a 50% conversion will be roughly the same for an SSOT and a two stage unit. But, at a 90% conversion, mid distillate production will increase approximately 20 - 30 lv% in a two stage unit when compared to an SSOT.

Options for increasing mid distillate production

Decisions on the best available option for increasing mid distillates will fall into three general categories: zero CAPEX, low CAPEX, and high CAPEX.

| Table 1. Incremental increase in naphtha and mid distillate products at higher reactor temperatures (Feed basis: HVGO/HCGO blend, API = 12.5, endpoint = 1100 °F) | | |
|---|------------------------------|--------|
| | Catalyst average temperature | |
| | 725 °F | 750 °F |
| Δ Yields, lv% | | |
| Naphtha (C5 - 350 °F) | Base | +10.8 |
| Mid distillates (350 - 650 °F) | Base | +13.0 |
| Unconverted oil, (650+) | Base | -20.3 |

| Table 2. Incremental increase in mid distillate products at two different recycle cutpoint temperatures (Feed basis: HVGO/HCGO blend, API = 12.5, endpoint = 1100 °F) | | | |
|---|-------------------------|--------|--------|
| | Recycle cut point (RCP) | | |
| | 600 °F | 625 °F | 650 °F |
| Δ Yields, lv% | | | |
| Naphtha (C5 - 350 °F) | Base | -3.3 | -7.1 |
| Mid distillates (350 - RCP °F) | Base | +3.1 | +6.7 |
| Unconverted oil (RCP+) | Base | 0.0 | 0.0 |

- Zero CAPEX option is defined as using no capital expenditures to increase the amount of mid distillates in an existing hydrocracker. It will generally cover operational changes to the process such as adjusting product cut points in a fractionator or adjusting reactor profiles that affects conversion more favorable towards mid distillate production. It will also include changes in catalyst type.
- Low CAPEX options are small investments in hardware to increase mid distillate production. Low CAPEX investments are generally debottlenecking projects such as upgrading reactor internals to improve the liquid/vapour distribution or upgrading fractionation trays to draw more distillates.

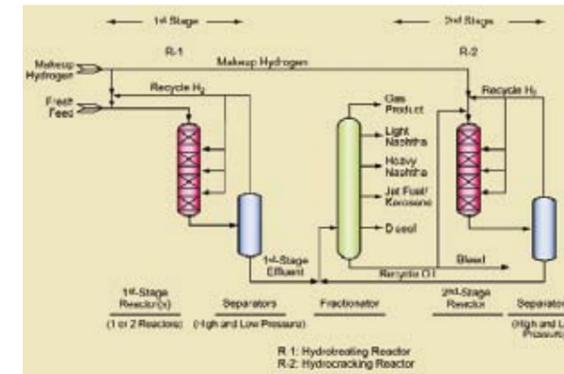


Figure 4. Simplified flow diagram of a two stage hydrocracking process.

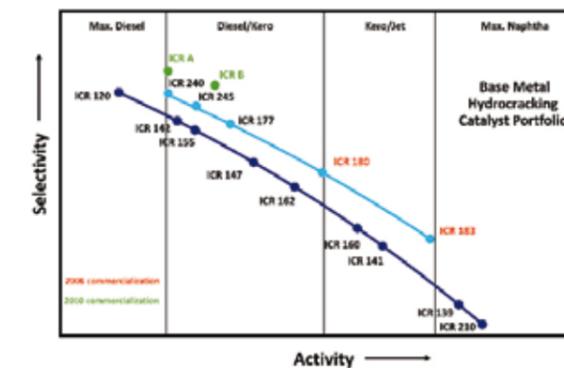


Figure 5. ISOCRACKING® catalysts performance curves. Source: Chevron Lummus Global (CLG).

| Table 3. Yield shift ICR 160 versus ICR 162 | |
|---|------|
| Conversion, lv% (<700 °F) | 60 |
| Δ Yields | |
| C4-, wt% | -0.5 |
| Naphtha (C5 - 250 °F), lv% | -4.4 |
| Mid distillates (250 - 700 °F), lv% | +4.5 |

| Table 4. Yield shift ICR 160 versus ICR 180 | |
|---|------|
| Conversion, lv% (<700 °F) | 70 |
| Δ Yields | |
| C4-, wt% | -1.1 |
| Naphtha (C5 - 250 °F), wt% | -2.8 |
| Mid distillates (250 - 700 °F), wt% | +3.9 |

- High CAPEX options are large investments for purchases of new equipment or a reconfiguration of an existing hydrocracker in order to increase throughput. A few examples of high CAPEX projects are revamping an existing SSOT unit to a two stage process or adding additional reactors to an existing SSOT in order to increase the amount of hydrocracking activity.

The decision to choose the best option for increasing mid distillate production will typically require an in house evaluation because hydrocrackers and how they fit into individual refineries are very specific and unique. Addressing how to optimise the balance between gasoline and mid distillate production will depend on several factors such as the refiner's configuration, availability and ability to process heavier feedstocks, hydrogen availability, and regional market position.

Zero CAPEX options for increasing mid distillate production

Operational changes

The simplest option for increasing mid distillate production in an SSOT configuration is by adjusting reactor temperatures to increase total conversion. Table 1 shows the incremental increase in both naphtha and mid distillate products at a higher reactor temperature.

Adjusting the recycle cut point (RCP) in an SSREC or two stage hydrocracking configuration is also a good option for increasing mid distillate production. RCP is defined as the TBP cut point between the bottom sidedraw (diesel product) and the column bottoms (UCO). Adjusting RCP allows a two stage configuration to operate in either a jet/naphtha or diesel mode. The RCP on a two stage configuration is the best operational parameter a refiner can utilise to balance gasoline:mid distillate ratio. Table 2 shows the incremental increase in mid distillate products at two different recycle cutpoint temperatures.

Catalyst options

An excellent zero CAPEX option is changing to a more mid distillate oriented catalyst. A 'flexible' catalyst system can also be chosen to allow a refiner to produce the desired balance of gasoline and mid distillates. This type of system will not be able to maximise either extreme when market conditions change, but can be a very good compromise for fluctuating markets. A 'dedicated' maximum mid distillate selective catalyst system is designed to maximise the production of mid distillate at the expense of the gasoline. Refiners can maximise their margins as long as there is a strong demand for mid distillate products and can recover the incremental distillate in the downstream equipment.

Mid distillate selective catalysts

Amorphous hydrocracking catalysts have historically been used to maximise mid distillates while high zeolite containing catalysts have proven to be highly effective in maximising naphtha production. CLG has been very active in the development of zeolite based catalyst to maximise mid distillate yields and operating stability. Due to its high cracking activity and tolerance to NH₃, zeolite based catalyst has proven to be the catalyst of choice for increasing mid distillate yields from heavier feedstocks.

Figure 5 shows CLG's current base metal ISOCRACKING® catalyst portfolio. It covers a wide range of applications and is suitable in an existing SSOT, SSREC, or two stage hydrocracking configuration. The curve represents the

relationship between selectivity and activity. Hydrocracking catalyst development targets the next generation of catalysts that function at both higher selectivity and activity. Higher selectivity produces more of the desired product while higher activity allows the refiner to extend catalyst life while processing heavier and difficult feedstocks.

ICR 162

ICR 162 was first commercialised in 2003. ICR 162 is a hydrocracking catalyst that maximises the production of high quality kerosene/jet, diesel and lubes depending on the mode of operation. This hydrocracking catalyst is well suited for processing heavy vacuum gas oils (VGO) feedstocks with high concentrations of nitrogen. ICR 162 can be used in an SSOT, SSREC, and in the first stage of a two stage hydrocracking configuration. Table 3 shows pilot data illustrating the gain in mid distillate selectivity of ICR 162 versus ICR 160, a hydrocracking catalyst primarily used for kerosene/jet production.

ICR 180

ICR 180 was first commercialised in 2008. ICR 180 has very similar characteristics to ICR 160. It has been designed to process heavy feedstock with high nitrogen concentrations and maximise the production of high quality kerosene/jet and diesel. ICR 180 can be used in an SSOT, SSREC, and in the first stage of a two stage hydrocracking configuration. The modified formulation of ICR 180 shows a mid distillate selectivity increase of approximately 4.0 wt% when compared to ICR 160. Table 4 shows pilot data illustrating the gain in mid distillate selectivity of ICR 180 versus ICR160, a hydrocracking catalyst primarily used for kerosene/jet production.

ICR 183

ICR 183 was commercialised in 2008. ICR 183 was developed to improve the activity for processing very heavy and difficult feedstocks while maximising the production of high quality naphtha and kerosene. ICR 183 can process vacuum gas oil (VGO), light cycle oil (LCO) and coker gas oil (CGO) feeds with nitrogen concentrations in excess of 3000 wppm. ICR 183 can be used in an SSOT, SSREC, and as well as both the first and second stage of a two stage hydrocracking configuration. ICR 183 was also designed to balance the gasoline:distillate ratio. This catalyst is an excellent choice for refiners who want a flexible catalyst

Table 5. Yield shift ICR 210 versus ICR 183

| | |
|-------------------------------------|------|
| Conversion, lv% (< 650 °F) | 70 |
| Δ Yields | |
| C4-, wt% | -2.1 |
| Naphtha (C5 -250 °F), lv% | -3.4 |
| Mid distillates (250 - 650 °F), lv% | +8.4 |

Table 6. Yield shift ICR 'A' versus ICR 240

| | |
|---|------|
| Second stage per pass conversion (PPC), lv% | 60.1 |
| Δ Yields | |
| C4-, wt% | -0.7 |
| Naphtha (C5 - 250 °F), wt% | -1.3 |
| Mid distillates (250 - 700 °F), wt% | +1.8 |

system. Table 5 shows the gain in mid distillate selectivity when ICR 183 replaces a naphtha selective catalyst ICR 210 in the second stage of a two stage hydrocracking unit.

ICR 240

ICR 240 was commercialised in 2007. ICR 240 is a unique hydrocracking catalyst designed to maximise the production of kerosene and diesel. This catalyst can process heavy feedstocks such as vacuum gas oil (VGO), light cycle oil (LCO) and coker gas oil (CGO) feedstocks with high nitrogen concentrations. ICR 240 is specifically formulated for use in the second stage of a two stage hydrocracking unit. This new formulation in ICR 240 allows this catalyst to produce high distillate yields, excellent distillate properties, low bleed requirements, and low gas make.

Data from a commercial unit using ICR 240 showed an increase in mid distillates of approximately 12 wt% versus an earlier generation mid distillate selective catalyst (ICR 120). ICR 120 was CLG's premier second stage catalyst for mid distillate production for several years. The shift in the product slate has allowed this refiner to improve both the operation and refinery margins. ICR 240 helped debottleneck the refiner's light ends recovery section and increase the throughput of the unit. This is a good example of how utilising improved catalysts can have a positive impact on refinery economics.

ICR 'A' and ICR 'B'

ICR 'A' and 'B' are the next generation mid distillate selective hydrocracking catalysts that are currently in the last phase of development before commercialisation in 2010. These catalysts use the same formulation as their predecessor ICR 240, but with an improved hydrogenation function. The new formulation of ICR 'A' exhibits approximately a 2.0 wt% higher mid distillate yield as compared to ICR 240. The new formulation ICR 'B' exhibits the same yield structure as ICR 240 but with 30 °F higher activity. Table 6 shows the pilot plant data illustrating the gain in mid distillate selectivity of ICR 'A' versus ICR 240.

Summary

Advances in hydrocracking catalyst technology over the past few years have allowed the zero CAPEX catalyst option to be a cost effective solution for producing high quality distillate products from heavier feedstocks. The new state of the art catalysts range from hydrocracking catalyst designed to totally maximise distillates (e.g. ICR 240, ICR A and B) to hydrocracking catalyst designed to balance the gasoline:distillate ratio (e.g. ICR 183). In addition, these new catalysts can function in an existing SSOT, SSREC, or two stage hydrocracking configuration (e.g. ICR 162 and ICR 180). This broad spectrum of new hydrocracking catalysts is available to all refiners looking to meet the demand for premium distillate products in this new and challenging environment. 

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