New Catalyst Technology for Hydrocracking and Diesel Hydrotreating

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Presentation Outline

Introduction
  - Advanced Refining Technologies / Chevron Lummus Global

Review of ISOCRACKING® Catalysts portfolio
  - Developments
  - Improvements
  - Commercial Experience

Conclusions
ART/CLG Overview
Technology Licensing and Catalyst Sales

Catalyst Sales and Manufacturing

Process and Technology Licensing

50% 50% 50%
Current Hydroprocessing Environment

- Running well over design rates
- Producing higher quality fuels
- Requiring longer operating cycles
- Processing more complex feed diet
- Often the unit that makes refinery viable
The Trouble with Synthetic Crude Oil?
Let’s talk Double Bond Equivalent (DBE)

Light VGO
(874-923 °F BP)

Heavy VGO
(930-977 °F BP)

VR
(1074-1121 °F BP)

DBE = \( \frac{2C - H + N + 2}{2} \)

DBE = # rings + # double bonds

# H₂ molecules needed to reach full saturation
Vacuum Gas Oil described as DBE, CN domains

- Non-existent
- Residual oil
- Aromatics
- Aromatics & Naphthenics
- Paraffins
Hydroprocessing Segments distinguished by DBE, CN domains

- **Hydrotreating**
- **Hydrocracking**
- **Hydrodewaxing**

**DBE**

- Non-existent

**CN**

- Diesel
- Residual oil

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New ART Catalysts per Annum per Segment

- Hydrocracking: 2-3
- Hydrotreating: 2-3
- Hydrodewaxing: 1-2

Graph:
- DBE (y-axis)
- CN (x-axis)

Legend:
- Diesel: 2-3
- Hydrocracking: 2-3
- Hydrodewaxing: 1-2
- Fixed Bed: 1-2
- Ebullated Bed: 1-2
- Residual oil: non-existent
Presentation Outline

- Hydrotreating
- Hydrocracking
- Hydrodewaxing

Non-existent

Residual oil

DBE

CN
Optimized Design of Catalyst Systems through tailored Reactivity

- Filtration, Precipitation
- Facile Hydrotreating
- Hydrotreating
- Hydrocracking
- Hydrodewaxing

Increasing Reactivity of Catalyst Beds
Steady Progress through Steady Investment in Hydrotreating

HDN Activity, °C

- 1972
- 1988
- 1996
- 2003
- 2006
- 2009
- 2011
- 2013
- 2016

Base

ICR 513

ICR 514
ICR 1000: step-out Cogel Catalyst for truly deep Hydrotreating

- Filtration, Precipitation
- Facile Hydrotreating
- Hydrotreating
- Deep Hydrotreating
- Hydrocracking
- Hydrodewaxing

- Stock Balance Improvements
- More complex Feed Diet
- Longer Cycle Length
- Refining Capital Avoidance
Heavy Polynuclear Aromatics in Petrolatum by APPI Mass Spectrometry

![Graph showing relative intensity vs. DBE for Petrolatum]
HPNA’s are not the most suitable for Personal Care Products
ICR 1000 eliminates Carcinogens from Petroleum Jelly

~FDA-approvable
What is bad for Personal Care is bad for Operations

Heavy VGO (930-977 °F BP)

VR (1074-1121 °F BP)
Heavy Coker Gas Oil contributes traditional refractory Feed Components
Syncrude contributes truly refractory Feed Components

![Graph showing relative abundance vs DBE]
HPNA’s from opportunity VGO accumulate in recycle Stream

Make-up Hydrogen
Fresh Feed

First Stage
First-Stage Product
Second Stage
Second-Stage Product

Product Gas
Recycle Gas

Light Naphtha
Heavy Naphtha
Kerosene
Diesel

FCC Feed

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ICR 1000 lowers Bleed Rate through faster HPNA Equilibration

ICR1000 preferentially equilibrates HPNA

Traditional Catalysts preferentially convert VGO
ICR 1000 & managed VGO diet affords maximizing margin per cycle
Conclusions Hydrotreating VGO

- ICR 1000 affords a more complex feed diet.
  - facilitates HPNA destruction in kinetic regime
    - affords turning disenfranchised feeds to lubes
  - facilitates HPNA management in thermodynamic regime
    - affords lower bleed rate, longer cycle length
From VGO to Diesel Hydrotreating

- **Hydrodewaxing**
- **Hydrotreating**
- **Residual oil**
- **Diesel**
- Non-existent
ICR 1000 for maximum Volume Swell
maximum H₂ Efficiency

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<th></th>
<th>feed</th>
<th>conventional</th>
<th>ICR 1000</th>
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<tr>
<td>API</td>
<td>33.0</td>
<td>35.1</td>
<td>37.0</td>
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<td>d (g/cc)</td>
<td>0.8595</td>
<td>0.8493</td>
<td>0.8398</td>
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<td>H₂ consumption (scf/b)</td>
<td>427</td>
<td>539</td>
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<tr>
<td>H₂ consumption (Nm³/m³)</td>
<td>76</td>
<td>96</td>
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<td>Paraffins (vol-%)</td>
<td>25</td>
<td>24</td>
<td>26</td>
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<tr>
<td>Naphthenics (vol-%)</td>
<td>53</td>
<td>74</td>
<td>72</td>
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<tr>
<td>Aromatics (vol-%)</td>
<td>21</td>
<td>3</td>
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Conclusions Hydrotreating VGO

- ICR 1000 affords a more complex feed diet.
  - facilitates HPNA destruction in kinetic regime
    - affords turning disenfranchised feeds to lubes
  - facilitates HPNA management in thermodynamic regime
    - affords lower bleed rate, longer cycle length
  - maximizes diesel volume swell
    - opens diesel-range PNA rings
Hydrocracking after thorough Hydrotreating

- non-existent
- residual oil
- hydrocracking
- hydrodewaxing

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A Catalyst Platform

- **Catalyst ABC**
  - **Crystalline Si/Al**
  - **Amorphous Si/Al**
  - **Base Metals**
Trade-off between Yield and Cycle Length Signature of Catalyst Platform

Middle Distillate Yield

Cycle Length / Activity
R&D Target is to reach for Gold

Cycle Length / Activity

Middle Distillate Yield
Hydrodewaxing to make the most from the Hydrocracking Section
Traditional Hydrocracking Catalysts struggle to convert Wax

Wax conversion

VGO conversion

wax in 700F+ SDW to -15 C pp

ICR 160
Modern Catalysts convert Wax into Distillates

Wax conversion

VGO conversion

wax in 700F+ SDW to -15 C pp

ICR 185

ICR 160
Dewaxing Functionality increases Yield by hydrocracking Wax into Distillates

Middle Distillate Yield vs Cycle Length / Activity
Hydrodewaxing converts Wax into more Middle Distillate

![Graph showing Middle Distillate Yield vs Cycle Length / Activity with points for ICR 160 and ICR 185]
Further tailoring of Dewaxing Functionality further increases Distillate Yield
Further tailoring of Dewaxing Functionality further increases Distillate Yield

Middle Distillate Yield

Cycle Length / Activity

ICR 160

ICR 185

ICR 193
Why use ART Catalyst?

- Catalysts for all configurations and technologies
- Enhanced HPNA management through ICR 1000
- Enhanced wax management through latest Catalyst Generations
- Patented reactor internals
- Process design and Operations “know-how”
- Superior Technical Services

System design comes from first hand experience and represents an optimum balance between cycle length and yield requirements.