Catalytic solutions for improving refining competitiveness by Advanced Refining Technologies
About ART

Who we are
- Grace-Chevron joint venture leveraging CLG’s hydrocracking catalyst technology and CB&I’s process technology

What we have
- A complete portfolio of hydroprocessing catalysts
- Substantial resources dedicated to customer support and product development

What we do
- Improve the operation and profitability of our customers in the petroleum refining industry

How we do it
- Exceptional design of catalyst systems
- Fully integrated technical support teams

Why we do it
- To provide a single point of contact for refiners hydroprocessing catalyst needs
Comprehensive line of catalyst systems for:

- **Distillate hydrotreating:**
  - Naphtha / Cracked Naphtha: StART Catalyst System®
  - Kerosene, Jet and ULSD: SmART Catalyst System®
  - FCC Pretreatment: ApART Catalyst System®

- **Hydrocracking:**
  - ISOCRACKING® Catalyst System

- **Lubes Production:**
  - ISODEWAXING® Catalyst Systems
  - ISOFINISHING® Catalyst Systems

- **Resid hydrosprocessing:**
  - Up Flow Reactor (UFR) and On-Stream Catalyst Replacement (OCR) Systems
  - Ebullating Bed Resid Systems
Global Presence

- **ART Global Facility**
  - R&D Center
  - Sales/Tech Service Office
  - Manufacturing Site

### Sales/Technical Services Offices
- Columbia, MD USA
- Richmond, CA USA
- Chicago, IL USA
- Houston, TX USA
- Worms, Germany
- Moscow, Russia
- Milan, Italy
- The Hague, Holland
- Shuaiba, Kuwait
- Dubai, UAE
- Tokyo, Japan
- Hong Kong
- Singapore
- Mumbai, India

### Manufacturing Sites
- Lake Charles, LA USA
- Chicago, IL USA
- Curtis Bay, MD USA
- Hitachi, Japan (Tolling)
- Shuaiba, Kuwait (Tolling - KCC)

### Research and Development
- Curtis Bay, MD USA
- Columbia, MD USA
- Chicago, IL USA
- Richmond, CA USA
- Honmoku, Japan
Hydroprocessing Expertise Based On First Hand Knowledge Of Refinery Operations

<table>
<thead>
<tr>
<th>Initial ART Hydro Processing Catalysts</th>
<th>Modern Hydro Cracking</th>
<th>Fixed Bed Resid Conversion</th>
<th>Ebullating Bed Resid Conversion</th>
<th>Lube Base Oil Production</th>
<th>Lube Isodewaxing</th>
<th>Conventional ART Hydro Processing Catalysts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950s</td>
<td>1960s</td>
<td>1970s</td>
<td>1980s</td>
<td>1990s</td>
<td>2010’s</td>
<td></td>
</tr>
</tbody>
</table>

Catalyst developments go hand in hand with process developments.
The Leader in Hydroprocessing Catalysts

Strong position for ART
- #1 FBR segment
- #1 EBR segment
- #2 HCR segment

ART engineered catalyst systems and operations support lead to long term customer satisfaction

Global Hydroprocessing Market Estimate: 350M LBS

ART
Comp A
Comp B
Comp C
Others
Commitment to Research & Development

Over 60 years of hydroprocessing catalyst experience

<table>
<thead>
<tr>
<th>New Catalysts Launched per Year</th>
<th>Hydrocracking</th>
<th>Lubes</th>
<th>Ebullating Bed Resid</th>
<th>Fixed Bed Resid</th>
<th>Distillate Hydrotreating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-3</td>
<td>1-2</td>
<td>1-2</td>
<td>1-2</td>
<td>2-3</td>
</tr>
</tbody>
</table>

Testing supports innovation and also allows ART to better understand larger refinery picture
Alignment of Catalyst Segments

Distillate Hydrotreating (DHT)
- Contaminant removal crucial for maximum unit run length
- Maximum desulfurization for transportation fuel specifications
- Balanced aromatics saturation activity for volume swell

Lubes
- Contaminant removal vital to protection of downstream precious metals catalysts
- Wax concentration and aromatic saturation to upgrade lower value stocks to higher value

Hydrocracking (HCR)
- Contaminant removal critical to maintain HCR catalyst activity
- Maximum saturation of feed molecules for volume swell

Fixed Bed Resid (FBR)
- Contaminant removal essential for catalyst activity and downstream RFCC profitability (where applicable)
- Maximum desulfurization activity for transportation fuel specifications

Ebullating Bed Resid (EBR)
- Contaminant removal central to control of sediment formation
- Maximum desulfurization activity for transportation fuel specifications

Customers Profit from Maximum Conversion of Feed to High Quality Products
# Diesel Fuel Specifications for EU

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Emission Stages</td>
<td></td>
<td></td>
<td>Euro 3</td>
<td>Euro 4</td>
<td>Euro V</td>
<td>Euro 5</td>
<td>Euro VI</td>
<td>Euro 6</td>
</tr>
<tr>
<td>Cetane Number, Min.</td>
<td>49 (Temperate) / 45-47 (Arctic)</td>
<td></td>
<td></td>
<td>51 (Temperate) / 47-49 (Arctic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur, ppm, Max.</td>
<td>2000</td>
<td>500</td>
<td>350</td>
<td>50</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyaromatics, Wt %, Max.</td>
<td></td>
<td></td>
<td>11</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density @ 15°C (60°F), kg/m³, Max.</td>
<td>860 (Temperate) / 840-845 (Arctic)</td>
<td>845 (Temperate) / 840-845 (Arctic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T95, °C, Max.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>Cold Filter Plugging Point (CFPP), °C, Max.</td>
<td></td>
<td></td>
<td>+5 (Temperate) to -44 (Arctic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud Point (CP), °C, Max.</td>
<td></td>
<td></td>
<td>-20 to -34</td>
<td></td>
<td></td>
<td></td>
<td>-10 to -34</td>
<td></td>
</tr>
</tbody>
</table>

- Hydrocracker has to produce cleaner products from nastier feeds
Chevron History – Where we are today

• 6 wholly owned Chevron refineries have ~ 73 hydroprocessing reactors
  (41 high pressure and 32 < 1000 psi)
• 6 partially owned Chevron refineries (Caltex) have 40 hydroprocessing reactors
• Over 70 customers worldwide currently running ART HCU & Lubes catalysts
Contaminant Removal Improves Catalyst Function

- ART allocates significant R&D resources for continuous product improvement
- Superior contaminant removal technology in segments with more severe operation rapidly transferred to other segments

### Contaminant Source

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni + V</td>
<td>High End Point Feed</td>
</tr>
<tr>
<td>Si</td>
<td>Silicon Antifoam (cokers)</td>
</tr>
<tr>
<td>Na, Ca</td>
<td>Caustic contamination</td>
</tr>
<tr>
<td></td>
<td>Poor desalting</td>
</tr>
<tr>
<td></td>
<td>Sea water contamination</td>
</tr>
<tr>
<td>FeS_x</td>
<td>Corrosion Products</td>
</tr>
<tr>
<td>Cu, Cr, Ni, Zn</td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>Arsenic in Crude</td>
</tr>
<tr>
<td>P</td>
<td>Corrosion inhibitors</td>
</tr>
<tr>
<td></td>
<td>Well fracturing fluids</td>
</tr>
<tr>
<td>Asphaltenes</td>
<td>Residuum</td>
</tr>
</tbody>
</table>

Protecting downstream catalysts extends run lengths or enables processing of lower cost feedstocks
Grading and Guard Catalyst Systems

- ART offers specially designed guard catalysts to protect downstream catalysts from fouling and poisoning.

**Pressure drop control**
- Ring shaped macroporous particulate traps provide internal and external void space.
- Ring shaped active catalysts provide high external void space and activity grading.

**Unique guard catalysts used to trap catalyst poisons**
- Macroporous catalysts with high capacity for Nickel and Vanadium.
- High surface area catalysts with high capacity for Silicon.
- High Ni content catalysts with high capacity for Arsenic.

System design comes from first hand experience and represents an optimum balance between cycle length and activity requirements.
ART HCR catalyst performance model incorporates commercial operating data from partner operating units

Outputs
- Candidate case performance guarantee
- Optimum catalyst system to maximize profits
Hydrocracking Pretreat Reactions

- **Olefins Saturation**
  - Mitigate pressure drop

- **Demetallization (HDM)**
  - Maintain clear reaction pathways

- **Desulfurization (HDS)**
  - Enable aromatics saturation

- **Denitrification (HDN)**
  - Enable aromatics saturation
  - Deactivates cracking catalyst

- **Aromatics Saturation**
  - Prerequisite for Hydrocracking

Hydrocracking Objectives:
- Safety of Operation
- Conversion of heavy feed to lighter products
- Feed flexibility
- Upgrade low value stocks
- Produce clean products
- Volume gain
- Minimum hydrogen consumption
- Long operating cycle

ART pretreat catalysts are arranged to optimize preparation of feed for cracking
Expertise in Conditioning Feeds

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>FCC Pretreat</th>
<th>EBR</th>
<th>FBR</th>
<th>Lubes</th>
<th>Hydrocracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading</td>
<td>Grading</td>
<td>Active Guard Material (Si,As, Ni, V)</td>
<td>Active Catalyst (NiMo)</td>
<td>Active Guard Material (Fe, Ca, Na)</td>
<td>Active Guard Material (PCA, N)</td>
<td>Grading (Si, As, Ni, V)</td>
</tr>
<tr>
<td>Active Guard Material (CoMo)</td>
<td>Active Catalyst (NiMo)</td>
<td>HDM Catalyst (NiMo)</td>
<td>HDM/HDS Transition Catalysts (NiMo)</td>
<td>HDS/HDN/CCR Removal Catalyst (NiMo)</td>
<td>Finishing Catalyst</td>
<td></td>
</tr>
<tr>
<td>Active Catalyst (NiMo)</td>
<td>Active Catalyst (CoMo)</td>
<td></td>
<td></td>
<td></td>
<td>Bottom Support</td>
<td></td>
</tr>
<tr>
<td>Bottom Support</td>
<td>Bottom Support</td>
<td></td>
<td></td>
<td></td>
<td>Bottom Support</td>
<td></td>
</tr>
</tbody>
</table>

Evolution of ART products based on performance extensions in key functions across segments
# Impact of ISOCRACKING® Catalyst Systems

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Single Stage</th>
<th>Two Stage, tail end distillation</th>
<th>Two Stage, intermediate distillation</th>
<th>Two Stage, intermediate distillation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>single stage only</td>
<td>mainly hydrotreating then hydrocracking</td>
<td>mainly hydrotreating then clean hydrocracking</td>
<td>mainly hydrotreating then sour hydrocracking</td>
</tr>
<tr>
<td>Run length</td>
<td>Short</td>
<td>Intermediate</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td>Hydrogen consumption</td>
<td>Low</td>
<td>Intermediate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Contribution of pretreat catalyst to unit objectives</td>
<td>High</td>
<td>High</td>
<td>Intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Hydrocracking catalyst system</td>
<td>mostly crystalline</td>
<td>optimum crystalline / amorphous system</td>
<td>mostly amorphous</td>
<td>optimum crystalline / amorphous system</td>
</tr>
</tbody>
</table>

All unit configurations achieve unmatched industry performance with ART Catalyst Systems.
ICR 513 Offers Significantly Higher Activity and Enhanced Stability vs. Previous Generations of HDT Catalysts
Next Generation ISOCRACKING® Catalyst
Improved Diesel yield

- ICR 180 and ICR 188 versus ICR 162 ~ 60% conversion

<table>
<thead>
<tr>
<th></th>
<th>ICR 180</th>
<th>ICR 188</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBAT, °F</td>
<td>-10</td>
<td>+5</td>
</tr>
<tr>
<td>C_4^-, Wt%</td>
<td>-0.2</td>
<td>-0.5</td>
</tr>
<tr>
<td>Light Naphtha (C_5^-180°F), LV %</td>
<td>-0.2</td>
<td>-1.2</td>
</tr>
<tr>
<td>Heavy Naphtha (180-400°F), LV %</td>
<td>-1.5</td>
<td>-6.5</td>
</tr>
<tr>
<td>Jet (400-530°F), LV %</td>
<td>-0.7</td>
<td>+0.5</td>
</tr>
<tr>
<td>Diesel (530-700°F), LV %</td>
<td>+2.7</td>
<td>+5.2</td>
</tr>
<tr>
<td>Mid-Distillates (400-700°F), LV %</td>
<td>+2.0</td>
<td>+5.7</td>
</tr>
</tbody>
</table>

Max. Diesel | Diesel/Kero | Kero/Jet | Max. Naphtha

![Graph showing diesel yield comparison]
Next Generation ISOCRACKING® Catalyst
Improved Diesel yield

- ICR 180 and ICR 188 versus ICR 162 ~ 60% conversion

<table>
<thead>
<tr>
<th></th>
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<th>ICR 188</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBAT, °F</td>
<td>-10</td>
<td>+5</td>
</tr>
<tr>
<td>Jet / Smoke Point, mm</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td>Freeze Point, °C</td>
<td>Base</td>
<td>&gt; -10</td>
</tr>
<tr>
<td>Heavy Diesel / Pour Point, °C</td>
<td>-7</td>
<td>-24</td>
</tr>
<tr>
<td>Cloud Point, °C</td>
<td>-3</td>
<td>-5</td>
</tr>
<tr>
<td>Cetane Index</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td>UCO N / S, ppm</td>
<td>Base / Base</td>
<td>Base / Base</td>
</tr>
<tr>
<td>Pour Point, °C</td>
<td>-12</td>
<td>-62</td>
</tr>
</tbody>
</table>
Next Generation ISOCRACKING® Catalyst Enhanced Distillate Yield

- ICR 250, ICR 255 versus ICR 240 ~ 60% Per Pass conversion ➔ 2\textsuperscript{nd} Stage recycle

<table>
<thead>
<tr>
<th></th>
<th>ICR 250</th>
<th>ICR 255</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBAT, °F</td>
<td>Base</td>
<td>-32</td>
</tr>
<tr>
<td>C\textsubscript{4}\textsuperscript{-}, Wt %</td>
<td>-0.7</td>
<td>-0.5</td>
</tr>
<tr>
<td>Naphtha (C\textsubscript{5}-250°F), LV %</td>
<td>-1.3</td>
<td>+0.5</td>
</tr>
<tr>
<td>Jet (250-550°F), LV %</td>
<td>-0.6</td>
<td>+2.6</td>
</tr>
<tr>
<td>Diesel (550-700°F), LV %</td>
<td>+2.4</td>
<td>-2.1</td>
</tr>
<tr>
<td>Mid-Distillates (250-700°F), LV %</td>
<td>+1.8</td>
<td>+0.5</td>
</tr>
</tbody>
</table>

Graph showing the comparison of diesel, kerosene, and naphtha yields between ICR 240, ICR 250, and ICR 255.
ART HCR Catalysts

More stringent product qualities require comprehensive catalyst formulation know-how

- Understanding the chemistry and kinetics across the segments yields greater HCR catalyst system performance
  - Substantial R&D resources dedicated to customer support and product development
  - Ground floor knowledge of adjacent refinery operations

- Proficiency from meter to nanometer level in all ART ISOCRACKING® catalyst systems
  - Understanding of the numerous factors influencing optimum catalyst configuration
  - Improvements in pore architecture that lead to superior catalyst performance
  - Proper position of individual components that lead to better performing catalyst systems

Long term satisfaction of ART customers is both an indicator of success and a goal of the business.