UOP/EMRE Alliance for High Quality Lube and Diesel Production Technology

ExxonMobil Research and Engineering Company
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EMRE and UOP Licensing Alliance

- Licensing Alliance joins UOP Hydroprocessing technology with EMRE Catalytic Lubes technology and Fuels dewaxing for low cloud diesel
- UOP brings extensive knowledge and experience in all refinery hydroprocessing technologies, and extensive catalyst portfolio, to the Alliance
- EMRE brings worldwide lube process, operation, production experience and extensive specialized dewaxing catalyst knowledge for both Fuels and Lubricants
- Alliance allows UOP-EMRE cooperation in two refining areas to give Licensees a cost efficient Fuels & Lubes processes.
- UOP and EMRE working together provides synergy to improve outcome to Licensees.

A One-Stop-Shop for Premium Lubes and Fuels Production

The alliance brings together the UOP hydroprocessing technology, catalysts and equipment with EMRE’s catalytic dewaxing technology and other EMRE hydroprocessing solutions to produce high yields of low sulfur, ultra-clean diesel with excellent cetane and cold flow properties and lube base oils.
EMRE/ UOP Alliance

• Produce High Yields of Ultra-Clean Diesel
  – The integration of UOP Unicracking™ and Unionfining™ solutions with EMRE MIDW™ isomerization dewaxing technology drives impressive yields of high-cetane and ultra-clean diesel. Refiners will be able to upgrade the cold flow properties of distillate boiling range feedstocks and enable blending of distillate products to meet the stringent cold flow specifications required for certain regions.

• Integrated, Cost-Efficient Lubes Production
  – Customers can utilize the UOP Unicracking process and catalysts for high-quality feedstock production along with a suite of EMRE solutions to achieve your lube production goals
  – The EMRE MSDW™ lube hydroisomerization technology upgrades lube blend stock by converting wax to high viscosity index (VI) lubes
  – The EMRE MAXSAT™ lube hydrofinishing technology improves color and stability of lube blend stocks while also saturating polynuclear aromatics
  – Other EMRE lube hydroprocessing technologies such as MWI for wax isomerization, RHC for raffinate hydroconversion, and RHT for raffinate hydrotreating can enable solvent-based lube processing facilities to produce Group II and Group III lubes.
EMRE ADVANCED TECHNOLOGY FOR GROUP II/III LUBE PRODUCTION
Why Make Lube Base Stocks

Nov 1, 2011 US Base Oil Price Report (LGN Publishing)

USGS Basis
Brent Crude $109.22/bbl ($2.60/gal)

<table>
<thead>
<tr>
<th>Base Stock</th>
<th>$/Gal</th>
<th>$/mt</th>
</tr>
</thead>
<tbody>
<tr>
<td>100N Gp 1</td>
<td>$4.23</td>
<td>$1,297</td>
</tr>
<tr>
<td>300-350N Gp 1</td>
<td>$4.44</td>
<td>$1,335</td>
</tr>
<tr>
<td>100N Gp 2</td>
<td>$5.03</td>
<td>$1,563</td>
</tr>
<tr>
<td>325N Gp 2</td>
<td>$5.45</td>
<td>$1,660</td>
</tr>
<tr>
<td>100N Gp 3</td>
<td>$6.16</td>
<td>$1,959</td>
</tr>
<tr>
<td>200N Gp 3</td>
<td>$6.24</td>
<td>$1,942</td>
</tr>
</tbody>
</table>

Wide Chemical Spectrum

Narrow Chemical Spectrum

<table>
<thead>
<tr>
<th>Base Stock API/ACEA Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>80 &lt; VI&lt; 120</td>
</tr>
<tr>
<td>Sat &lt; 90%</td>
</tr>
<tr>
<td>and/or</td>
</tr>
<tr>
<td>S &gt; 0.3%</td>
</tr>
</tbody>
</table>
Modern Base Oil Technology is Hydroprocessing Based

All Catalytic Group II & Group III Lube Plant

Hydroprocessing (Unionfining/Unicracking) → Catalytic Dewaxing (MSDW™) → Hydrofinishing (MAXSAT™)

Reduces Sulfur and Nitrogen, and Raises VI

Gas Oil Feeds

Fuels Manufacture Hydrocracking
Lube Manufacture Hydrocracking
Raffinate Hydroconversion
Raffinate Hydrotreating
Conversion to 360-°C Fuels

Solvent Plant Raffinate Feeds

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Technology Routes for Group II/III Production

Group II/III Production

Vacuum Gas Oil → Lube Hydrocracking (Unicracking Process) → Raffinate Hydrotreating or Hydroconversion (RHT or RHC) → Catalytic Dewaxing (MSDW/MWI) → Hydrofinishing (MAXSAT) → Fuel HC Bottoms

Solvent-Extracted Vacuum Gas Oil → Lube Hydrocracking (Unicracking Process) → Raffinate Hydrotreating or Hydroconversion (RHT or RHC) → Catalytic Dewaxing (MSDW/MWI) → Hydrofinishing (MAXSAT) → Slack or Scale Wax
Catalytic Dewaxing for Pour Point Reduction and VI Boost

All Catalytic Group II & Group III Lube Plant

Hydroprocessing (Unionfining/Unicracking) → Catalytic Dewaxing (MSDW) → Hydrofinishing (MAXSAT)

<table>
<thead>
<tr>
<th>C_{26}H_{54} Isomers</th>
<th>Pour Point</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>nC_{26}</td>
<td>56 C</td>
<td>159</td>
</tr>
<tr>
<td>C_2 – C – C_{21}</td>
<td>30 C</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>C_2</td>
<td></td>
</tr>
</tbody>
</table>

MSDW will Reduce Pour but Maintain High Dewaxed Oil VI
Hydrofinishing (MAXSAT) for Aromatic Reduction and Color Stability

All Catalytic Group II & Group III Lube Plant

- Hydroprocessing (Unionfining/Unicracking)
- Catalytic Dewaxing (MSDW)
- Hydrofinishing (MAXSAT)

Bright and Clear

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**HDT/MSDW: Broad Experience in 23 Commercial Grass Roots and Converted Solvent Plant Applications**

**23 Catalytic Lube Plants In Operation**

**Feed Experience**
- Distillate/LHC
- HC Btms
- HDT Raffinate (VGO/B.S.)
- HDT Slack Wax
- Blocked and Broad Cut

**Product Qualities**
- Vis range 2, 3, 4, 5, 6, 8, 10 cSt. to B.S
- VI’s from Grp II 95 VI to Grp III+ 145
- LN’s Low CCS <1500 cP at -30°C

**Hydrogen Pressure / Saturates Level**

<table>
<thead>
<tr>
<th>Product</th>
<th>HDT/HDF (psig)</th>
<th>Saturates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distillate 1</td>
<td>2200/2200</td>
<td>99+</td>
</tr>
<tr>
<td>Distillate 2</td>
<td>1400/1200</td>
<td>98</td>
</tr>
<tr>
<td>Distillate 3</td>
<td>1000/800</td>
<td>88-92</td>
</tr>
<tr>
<td>Raffinate 4</td>
<td>900/800</td>
<td>95</td>
</tr>
<tr>
<td>HC Btms 5</td>
<td>400 (MSDW)/3000 (HDT)</td>
<td>99+</td>
</tr>
<tr>
<td>HC Btms 6</td>
<td>2000 (MSDW/HDT)</td>
<td>99+</td>
</tr>
</tbody>
</table>

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Catalytic Lube Application of EMRE/UOP Technologies

Operation or in Design/Construction

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lube Hydrocrackers</td>
<td>19</td>
</tr>
<tr>
<td>Raffinate RHC/RHT</td>
<td>8</td>
</tr>
<tr>
<td>MSDW</td>
<td>27</td>
</tr>
<tr>
<td>MAXSAT</td>
<td>18</td>
</tr>
<tr>
<td>MLDW</td>
<td>4</td>
</tr>
</tbody>
</table>

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Summary

• UOP/EMRE now provide commercially proven technology for producing Group II/III Base stocks
  – 30 Licensed units

• Experience includes grass roots lube hydrocracker based plants, Fuel Hydrocracker bottoms processing, wax based plants for Group III+, and conversion of Group 1 Solvent Plants to Group II/III Production

Join Our Satisfied Clients and Let Our Lube Experience Work For You
MIDW™ PROCESS

Commercially Proven Technology for the Production of Low-Cloud/High Cetane ULSD
MIDW - A “New” Dewaxing Process

- First Announced in 1996
- Isomerizes Waxy N-paraffins in Gas Oils
- Proprietary ExxonMobil Family of Catalysts
- Flexible Process Configurations
  - Four process configurations have been commercialized
  - Easy to integrate with other technologies
- Commercially Proven
  - A total of 7 units operating, and 5 more under design or construction
Why Dewax Distillate?

- Increases unit flexibility
- Allows feed end-point extension for Diesel/Jet while producing high quality low pour, low cloud product

<table>
<thead>
<tr>
<th>Commercial Example</th>
<th>Summer Operation (no MIDW)</th>
<th>Winter Operation (with MIDW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate, KBSD</td>
<td>30</td>
<td>32.2</td>
</tr>
<tr>
<td>Naphtha, vol %</td>
<td>3.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Diesel, vol %</td>
<td>97.9</td>
<td>95.9</td>
</tr>
<tr>
<td>Total, vol %</td>
<td>101.2</td>
<td>102.1</td>
</tr>
<tr>
<td>H₂Cons. SCFB</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>Cloud, °C</td>
<td>-10</td>
<td>-27</td>
</tr>
<tr>
<td>Feed Cetane</td>
<td>49.5</td>
<td>48.6</td>
</tr>
<tr>
<td>Product Cetane</td>
<td>52.2</td>
<td>51.2</td>
</tr>
<tr>
<td>KBSD Diesel</td>
<td>29.4</td>
<td>30.8</td>
</tr>
</tbody>
</table>
### Why Dewax Distillate cont.?

#### Product Quality

<table>
<thead>
<tr>
<th></th>
<th>Summer Operation (no MIDW)</th>
<th>Winter Operation (with MIDW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed</td>
<td>Product</td>
</tr>
<tr>
<td><strong>API</strong></td>
<td>36.3</td>
<td>38.2</td>
</tr>
<tr>
<td><strong>Sulfur wppm</strong></td>
<td>2,500</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Cetane Index D976</strong></td>
<td>49.5</td>
<td>52.2</td>
</tr>
<tr>
<td><strong>90% point °C</strong></td>
<td>319</td>
<td>319</td>
</tr>
<tr>
<td><strong>Cloud °C</strong></td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td><strong>Naphtha vol%</strong></td>
<td></td>
<td>3.3</td>
</tr>
</tbody>
</table>

Winter Operation (with MIDW)
Additional Benefits of the MIDW Process

- Moderate End-point Reduction Allowing Feed End-point Extension to Produce more Diesel

- High Aromatic Saturation Activity and High Cetane Diesel Achievable

- Substantial Desulfurization Activity-reducing HDS Severity
MIDW Process Configurations

Flexible Process Applications

**Waxy Feed**
- 0.3% S - 130 ppm N
- Low Pour, High Cetane Diesel

**Moderate S, N**
- Lower Reactor Temperatures
- Low Sulfur Distillates

**High S, N**
- H₂S, NH₃
- Lower Reactor Temperatures
- Higher Distillate Yields

**VGO Feed**
- MVGO - HVGO
- 1.2% S - 1800 ppm N
- H₂S, NH₃, Distillate
- Premium Diesel & Kerosene
- Low Pour Point LSHFO

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- Research & Engineering

**UOP**
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MIDW Catalyst Operates with Excellent Diesel Selectivity

Diesel selectivity is controlled by:

- Zeolite type and formulation
- Process conditions

Cloud Point Reduction, °C

![Graph showing Cloud Point Reduction vs. Diesel Yield](image.png)

- **MIDW Operating “Range”**
- **Isomerization Technology**
- **Competing Cracking Technology**

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Summary

• MIDW is a Commercially Proven Technology For Improving Diesel Cold Flow Property, including biodiesel

• MIDW Process is Flexible and Can be a “Alone” Process or Combined with Desulfurization to Produce Premium ULSD with a Low Cloud Point

• Moderate End-point Reduction Capability Allows Some Feed End-point Extension to Produce More Diesel

• Integrated MPHC/MIDW Configuration Can Produce Premium Diesel From HVGO With a High Yield

Join Our Satisfied Clients and Let Our Unicracking and MIDW Experience Work For You
Conclusions

- UOP/EMRE offers high value solutions for improved diesel yield quality and cost efficient lubricant production.

- Integration of the technologies will allow the refiner the simplicity of “one stop shopping”

- The industry response has been highly positive noting the combination of these technologies will be greatly beneficial by offering a wide variety of new solutions to existing challenges.