Heavy Oil Drag Reducing Agent (DRA):

Increasing Pipeline Deliveries of Heavy Crude Oil
Topics

• Industry need
• Introduction to DRA
  – Nature
  – Mechanism
  – Application
• Scenario 1: Increased delivery of heavy crude oil
• Scenario 2: Enhanced viscosity
• Summary
Industry Need

Heavy Oil is a Transportation Challenge

• Capacity
  – Most lines were designed for light crude oil
• Cost
  – Higher viscosity = lower throughput volumes
    • OpEx increases <overall & per unit>
  – Capital
    • Large CapEx projects
• PL System Performance
  – Scheduling
    • Light/heavy batching
      – Variable operating regime
Drag Reduction Mechanism

Ultra High Molecular Weight Polymers

Laminar Sublayer
Buffer Region
Turbulent Core

w/ DRA

Diminished turbulent bursts
Traditional DRA

- **Light / Medium Crude Oil**
  - Low viscosity
  - High turbulence
  - Excellent performance

- **Heavy Crude Oil**
  - High viscosity
  - Low turbulence
  - Poor or no performance
# Heavy Oil DRA – Key to Performance

<table>
<thead>
<tr>
<th>Crude Oil Sample</th>
<th>LiquidPower™ Flow Improver Compatibility</th>
<th>ExtremePower™ Flow Improver Compatibility</th>
<th>API Gravity</th>
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</thead>
<tbody>
<tr>
<td>West Texas Intermediate</td>
<td>High</td>
<td>Moderate</td>
<td>41.6</td>
</tr>
<tr>
<td>West Texas Sour</td>
<td>High</td>
<td>Moderate</td>
<td>31.6</td>
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<td>Basrah</td>
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<td>Moderate</td>
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<td>Corocoro</td>
<td>None</td>
<td>High</td>
<td>25.1</td>
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<tr>
<td>Albian</td>
<td>None</td>
<td>High</td>
<td>22.4</td>
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<tr>
<td>Marlim Blend</td>
<td>High</td>
<td>High</td>
<td>22.2</td>
</tr>
<tr>
<td>Maya</td>
<td>None</td>
<td>High</td>
<td>21.9</td>
</tr>
<tr>
<td>Bow River</td>
<td>None</td>
<td>High</td>
<td>21.8</td>
</tr>
<tr>
<td>Apiay</td>
<td>Moderate</td>
<td>Moderate</td>
<td>21.8</td>
</tr>
<tr>
<td>WCS (Western Canadian Select)</td>
<td>None</td>
<td>High</td>
<td>20.9</td>
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<tr>
<td>Castilla</td>
<td>None</td>
<td>High</td>
<td>18.0</td>
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<tr>
<td>Merey</td>
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<td>High</td>
<td>16.0</td>
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<tr>
<td>SJVH (San Joaquin Valley Heavy)</td>
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<tr>
<td>Petrozuata</td>
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<td>High</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Interaction between the DRA polymer and the crude oil
Scenario 1:

Increased Delivery of Produced Heavy Crude Oil to Market
Apiay – El Porvenir Pipeline

- 16 – Inch, 120 km, 91M BBL Linefill

- Batching
  - Apiay (“light”, 21 oAPI)
  - Castilla blend (“heavy”, 18 oAPI)
  - PL Schedule
    - 35% light / 65% heavy

- Baseline Capacity
  - 94M BPD avg.
  - 103M BPD using LP™ 300 Flow Improver in Apiay
Pipeline Regime Profile

Reynolds Number

Pipeline Viscosity (cSt)

turbulent
transition
laminar

45°C 29°C

Apiay pump station

Monterrey pump station
Pipeline Model – Capacity Trend with Batch Cycle

- Barrels pumped
- Flowing Capacity (Kbbls/day)

- 118,000 bpd avg.
- 94,000 bpd avg.

Start pumping Castilla
Start pumping Apiay
Start pumping Castilla
Start pumping Apiay

Extreme Power
ecoPETROL
ConocoPhillips
# Field Test Results

<table>
<thead>
<tr>
<th>Pipeline System Condition</th>
<th>Baseline  (Thousands of BPD)</th>
<th>ExtremePower™ DRA Dosage (ppm)</th>
<th>LP™ 300 DRA Dosage (ppm)</th>
<th>Model  (Thousands of BPD)</th>
<th>Result (Thousands of BPD)</th>
<th>Percent Flow Increase</th>
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</thead>
<tbody>
<tr>
<td><strong>Test Pipeline Operations – ExtremePower™ injected into Castilla Blend</strong></td>
<td></td>
<td></td>
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<tr>
<td>100% Castilla Blend</td>
<td>91</td>
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<tr>
<td>ExtremePower™ injection</td>
<td></td>
<td>70</td>
<td>107</td>
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<td>110</td>
<td>21</td>
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<tr>
<td><strong>Normal Pipeline Operation – ExtremePower™ injected into each crude</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65% Castilla Blend/35% Apiay</td>
<td>94</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ExtremePower™ injection in each crude</td>
<td></td>
<td>68</td>
<td>118</td>
<td></td>
<td>121</td>
<td>29</td>
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<tr>
<td><strong>Normal Pipeline Operation – ExtremePower™ injected into Castilla, LP™ 300 injected into Apiay</strong></td>
<td></td>
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<td>94</td>
<td></td>
<td></td>
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<tr>
<td>LP™ 300 in Apiay</td>
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<td>40</td>
<td>*</td>
<td>103</td>
<td>10</td>
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<td>Combination injection 1</td>
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<td>47</td>
<td>47</td>
<td>113</td>
<td>118</td>
<td>26</td>
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<tr>
<td>Combination injection 2</td>
<td></td>
<td>75</td>
<td>75</td>
<td>118</td>
<td>123</td>
<td>32</td>
</tr>
</tbody>
</table>
Scenario 2:

Increased Delivery of Heavy Crude Oil to Market via Viscosity Optimization
Introduction

• Concept introduction
  – “Extended” laminar

• Diluent selection
  – Light crude oil may be better than naphtha

• Paradigm challenge
  – Increase throughput with more diluent
General Pressure Relationship in a Pipeline

Reynolds Number

Increasing Pressure Drop (psi/mile)

- Laminar
- "Extended" Laminar
- Typical Pressure Curve
- DRA Treated

Turbulence
Impact of Common Diluents on Viscosity

WCS Crude Oil Dilution

Viscosity (cSt)

Diluent Level (Volume %)

Naphtha (54 API)  WTI (41 API)
Effect of Viscosity on Capacity

Example Pipeline Throughput Versus Viscosity

Crude Oil Viscosity (cSt)

Pipeline Capacity (BPD) Thousands

Non Treated
DRA Treated

Hypothetical Pipeline – 10 in., 50 Miles
Effect of WTI Diluent Level on Capacity

Dilution Effects on Flow Capacity

WCS with WTI Dilution

Hypothetical Pipeline – 10 in., 50 Miles
Net Heavy Crude Oil Capacity

Dilution Effects on Net Throughput

WCS with WTI Dilution

Hypothetical Pipeline – 10 in., 50 Miles
Summary

• New DRA developed for heavy crude oil
  – ExtremePower™ Flow Improver
  – Strong interaction with heavy crude oil (<23 °API)
  – Performance in transition flow (N_{RE} 2100+)

• Results
  – Production line
    • 20 - 30% flow increase achieved
  – Enhanced viscosity
    • Low Reynolds # performance
      – Heavy crude oil made us go there
Acknowledgements

We would like to thank the API organization and attendees as well as our business partners.

Questions?
Contact Us

ConocoPhillips Specialty Products Inc.

www.ExtremePowerFlowImprovers.com

www.LiquidPower.com