PIPELINE TECHNOLOGY CASE STUDY: FLOW IMPROVERS PROVIDE IMMEDIATE INCREASE TO PIPELINE TAKEAWAY CAPACITY

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OUTLINE

• Company Overview

• Drag Reduction Theory and Technology

• DRA Applications

• DRA Benefits

• PSPI References
Company Overview
PHILLIPS SPECIALTY PRODUCTS INC. (PSPI)

- Worldwide leader in the science of drag reduction
- Manufacturing plant in Bryan, TX
- Offer full service solution for DRA technology
Flow Improvers are stable and safe chemicals available for a range of environmental conditions

- LP™ 100 and LP™ Winter
  - Non-hazardous ¹
  - Non-flammable
  - Non-combustible
  - Non-reactive ²
  - Low toxicity ³
  - Easy to clean up

¹ DOT Transport & EPA Waste Classification Criteria
² Stable under normal ambient and anticipated conditions of use
³ Products are not classified as hazardous per OSHA and EU regulations
• 50 injection sites throughout ND, MT, and SK with 8 different pipeline operators
• North Dakota Strategic Storage
  – Facility with up to 3 months regional product supply
  – Equipment and spare parts inventory
• Field technicians headquartered in ND, MT, and AB

Reliable service and operations throughout the Bakken
DRA EQUIPMENT AND FIELD SERVICES

Temporary and permanent equipment
- All equipment built to Class 1, Division II
- Product tank capacity up to 4500 USG
- Automation and remote operation
- Climate controlled

Field services
- Equipment dedicated to regional technician
- Preventative maintenance program
- Customer training
- Commissioning, decommissioning, and field testing support

PSPI offers a total package DRA solution including product, equipment, logistics, engineering, R&D, and field support
Drag Reduction Theory and Technology
Drag: Frictional losses of a fluid flowing in a pipeline

Drag Reduction occurs due to suppression of energy dissipation by turbulent eddy currents near the pipe wall during turbulent flow.
WHAT ARE DRAG REDUCING AGENTS (DRA)?

DRAs...
- are ultra-high molecular weight polymers
- are not viscosity modifiers
- do not change density of fluids
- do not coat pipeline walls
- change the turbulent flow
- are susceptible to shear points
- will shear degrade

... also known as Flow Improvers

Turbulent flow is required for drag reduction
FLOW IMPROVER PERFORMANCE

Drag reduction equation

\[ \%DR = \left( \frac{P_{f,\text{untreated}} - P_{f,\text{treated}}}{P_{f,\text{untreated}}} \right) \times 100\% \]

- Typical injection rates for Bakken light crude: <20-30 PPM
- At 20 PPM, performance is up to 60% DR
- If the frictional pressure is 1000 psi, then the frictional pressure with DRA is 400 psi at the same pipeline flow rate
Flow increase dependent on pipeline system
EFFECT OF DRAG REDUCTION

![Diagram showing the effect of drag reduction on pump and system curves.]

- **Pump Curve**
- **System Curve**
- **Operating Point**
- **New Operating Point**
- **Flow Increase**
- **Flow Rate**
- **Head**

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**Legend:**
- Pressure Decrease
- Operating Point
- New Operating Point
- System Curve...
- with DRA

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**Caption:**
- EFFECT OF DRAG REDUCTION
- LiquidPower
- FLOW IMPROVERS
DOWNLINE PERFORMANCE PROFILE

Local %DR

Distance Downline

Overall Pipeline %DR

Dissolution controlled
Degradation controlled
DRA Applications
FLOW IMPROVER APPLICATIONS

• Light, medium, and heavy crude oil
• Refined products
• Multiphase
• Condensate
• NGLs
FLOW IMPROVER APPLICATIONS

• 35 years of industry use
• Sold in 49 countries
• 1 billion barrels per year of crude oil treated worldwide
• Majority of U.S. refineries are processing crude oil treated with DRA
• No effects on refinery process
  – Mechanical or operating integrity
  – Water separation
  – Catalyst
  – Finished products
DRA Benefits
FLOW IMPROVER BENEFIT: BAKKEN CASE STUDY

LP™ 100 Test Performance Curve
ND Sweet (42° API, 2.5 cSt), 6", 14 miles

%DR vs. PPMv

- Theoretical %DR
- %DR from Field Test
- Field Data
FLOW IMPROVER BENEFIT: BAKKEN CASE STUDY

LP™ 100 Test Field Data
ND Sweet (42° API, 2.5 cSt), 6", 14 miles

DRA concentration is 20 PPM/12 GPD
FLOW IMPROVER BENEFIT: MANAGE BOTTLENECKS

- Increase flow rates
- Handle seasonal demands

Consider:

- With DRA, it is possible to take a 20” pipeline from 200,000 to 300,000 BPD with the same applied pressure

<table>
<thead>
<tr>
<th>Crude</th>
<th>%Flow Increase</th>
<th>%Drag Reduction</th>
<th>DRA Product</th>
<th>Conc Req PPMv</th>
<th>DRA GPD</th>
<th>$/ Incremental BPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light (API ~ 34)</td>
<td>50%</td>
<td>51.8%</td>
<td>LP™100</td>
<td>30</td>
<td>378</td>
<td>&lt; 0.10</td>
</tr>
</tbody>
</table>

Additional capacity available at the flip of a switch
FLOW IMPROVER BENEFIT: OPTIMIZE PIPELINE DESIGN

• Smaller pipelines

Consider:

• With DRA, more capital investment options are possible in a 200 mile long, one pump station pipeline with 150,000 BPD capacity

<table>
<thead>
<tr>
<th>Light Crude</th>
<th>Nom Dia In</th>
<th>Pipe Grade</th>
<th>Valve Class</th>
<th>Conc Req PPMv</th>
<th>DRA GPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without DRA</td>
<td>24</td>
<td>Seamless, Gr B</td>
<td>400#</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>With DRA</td>
<td>22</td>
<td></td>
<td></td>
<td>15</td>
<td>95</td>
</tr>
</tbody>
</table>

Potential for significant capital savings
FLOW IMPROVER BENEFIT: ENERGY SAVINGS

- Energy Savings
  - Pump station shut down
  - Power consumption management

Hydraulic profile

Head (feet)

~ 50% DR

Pump Station A

Pump Station B

Pump Station C
FLOW IMPROVER BENEFIT: LIFE CYCLE OPTIMIZATION

- Conceptualization/pre-construction
  - Increased capex case options

- Early life cycle
  - Ability to maximize throughput

- Late life cycle
  - Ability to decrease operating pressure while maintaining flow rate

Overcome pressure restrictions with potential to increase capacity
FLOW IMPROVER - BENEFITS SUMMARY

DRA can add value in many ways

\[ \{ \text{Increased capacity} \} \]
\[ \{ \text{Reduced operating pressure} \} \]
\[ \{ \text{Reduced power consumption} \} \]
\[ \{ \text{Increased operational flexibility} \} \]

\[ + \]

= Total Value
Current and Past Customers Span The Globe