Keystone Pipeline – Optimizing Delivered Quality

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Overview

1. Overview of the Keystone Pipeline
2. Inherent System Properties that Act to Preserve Batch Quality
3. Controlled Operational Measures Taken to Preserve Batch Quality
4. Keystone Batch Quality Results
Keystone Pipeline – Current System

Hardisty, Alberta to
- Wood River, Illinois
- Patoka, Illinois
- Cushing, Oklahoma

590,000 bpd Nominal Capacity

Linefill Volumes
- 8,850,000 bbl between Hardisty and Patoka (2,990 km)
- 1,880,000 bbl between Steele City and Cushing (480 km)
Keystone Pipeline Overview – Transit Time

Transit Time [days]

Average Flow Rate Ex Hardisty (kbpd)

Patoka: 2:1 PvsC
Cushing: 2:1 PvsC
Patoka (2:1) curve fit
Cushing (2:1) curve fit
Keystone Pipeline Overview

Keystone Pipeline – Current System

Pump Stations
- 48 Pump Stations between Hardisty and Patoka (578 MW)
- 3 Pump Stations between Hardisty and Patoka (44 MW)

Batch Detection
- Batch Detection Sites Measure: Density, Viscosity, Temperature & Pressure
- Local Batch Detection at all Delivery and Swing Sites (Steele City, Cushing, WR & Patoka)
- Early Batch Detection Upstream of all LBD sites
System Properties that Preserve Batch Quality

Bullet Line Design

- No Breakout Tankage for Mixing of Tank Bottoms
- Less Batch Cuts from Swing Points
- High Flowrates = High Reynolds Numbers = Tight Interfaces
Pre-Charge of Batches

- Pipe Volume between Customer Terminal and Keystone Inlet Manifold Pre-Charged with the next Scheduled Commodity from that Terminal to avoid Contamination.
Operational Measures for Quality Preservation
Operational Measures for Quality Preservation

Batch Sizes and Batch Trains

- Minimum Batch Size of 100,000 bbls.
- Larger Batch Sizes Minimize the Interface/Batch Volume
- Batch Trains of Similar Product Types are Scheduled in Sequence to Minimize Adjacent Contamination.
- As a Guide High TAN Products are Never Shipped Adjacent to Synthetic Products within the Batch Train.
- As a Guide Batches are Scheduled such to Minimize Swings between the Cushing Delivery Leg and the WR/Patoka Delivery Leg (while Maintaining Ratability).
Composite Sample Results for Delivered Light Batches

- Tested for Sulphur using ASTM D4294
- Samples Run on the Interfacing Light Batch within the Batch Train. All Composite Results are for the Single Batch within the Train (100kbbi Batch)
- Data Acquired between June 2011 and May 2012

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Receipt</th>
<th>Delivery</th>
<th>Increase</th>
<th>Delivery Location</th>
<th>Batch Lineup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic Crude</td>
<td>0.316</td>
<td>0.468</td>
<td>0.152</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
</tr>
<tr>
<td>Synthetic Crude</td>
<td>0.210</td>
<td>0.264</td>
<td>0.054</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
</tr>
<tr>
<td>Synthetic Crude</td>
<td>0.132</td>
<td>0.266</td>
<td>0.134</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
</tr>
<tr>
<td>Synthetic Crude</td>
<td>0.263</td>
<td>0.297</td>
<td>0.034</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
</tr>
<tr>
<td>Synthetic Crude</td>
<td>0.216</td>
<td>0.283</td>
<td>0.067</td>
<td>Cushing</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
</tr>
<tr>
<td>Sweet Crude</td>
<td>0.494</td>
<td>0.574</td>
<td>0.080</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
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<tr>
<td>Sweet Crude</td>
<td>0.475</td>
<td>0.509</td>
<td>0.034</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
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<tr>
<td>Sweet Crude</td>
<td>0.493</td>
<td>0.563</td>
<td>0.070</td>
<td>Patoka</td>
<td>Two Heavy Interfaces (appr. 3.75 wt% S each)</td>
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<tr>
<td>Sweet Crude</td>
<td>0.427</td>
<td>0.473</td>
<td>0.046</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
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<tr>
<td>Sweet Crude</td>
<td>0.483</td>
<td>0.500</td>
<td>0.017</td>
<td>Patoka</td>
<td>One Heavy Interface (appr. 3.75 wt% S)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.351</strong></td>
<td><strong>0.420</strong></td>
<td><strong>0.069</strong></td>
<td></td>
<td>-</td>
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</table>
Composite Sample Results for Delivered Heavy Batches

- Tested for TAN using ASTM D664
- Composite Results are for the Single Interfacing Batch within the Train (100kbbbl Batch)
- Data Acquired January 2012

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Receipt</th>
<th>Delivery</th>
<th>Increase</th>
<th>Delivery Location</th>
<th>Batch Lineup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>0.93</td>
<td>1.05</td>
<td>0.12</td>
<td>Cushing</td>
<td>One Heavy Interface (appp. 3.75 mgKOH/g)</td>
</tr>
<tr>
<td>Heavy</td>
<td>0.93</td>
<td>1.10</td>
<td>0.17</td>
<td>Cushing</td>
<td>One Heavy Interface (appp. 3.75 mgKOH/g)</td>
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<tr>
<td>Average</td>
<td>0.930</td>
<td>1.075</td>
<td>0.145</td>
<td>-</td>
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</table>
Keystone Quality Results – Interface Lengths

Batch Interface Profiling

- Viscosity and Density Profiling Conducted on Adjacent Batches
- Interface Lengths/Volumes Tracked as a Metric for Batch Contamination

<table>
<thead>
<tr>
<th>Interface Location</th>
<th>Start</th>
<th>End</th>
<th>Interface Time (h)</th>
<th>Flowrate (m³/h)</th>
<th>Interface Volume (m³)</th>
<th>Interface Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNTPL+36-1 (Head)</td>
<td>13:08:00</td>
<td>14:18:00</td>
<td>1:12:00</td>
<td>3.545</td>
<td>4,254</td>
<td>9.84</td>
</tr>
<tr>
<td>HRTFD (Head)</td>
<td>14:50:00</td>
<td>16:00:00</td>
<td>1:10:00</td>
<td>3.640</td>
<td>4,247</td>
<td>9.82</td>
</tr>
<tr>
<td>SNTPL+36-1 (Tail)</td>
<td>5:01:00</td>
<td>6:16:00</td>
<td>1:15:00</td>
<td>3.500</td>
<td>4,375</td>
<td>10.12</td>
</tr>
<tr>
<td>HRTFD (Tail)</td>
<td>6:55:00</td>
<td>8:04:00</td>
<td>1:09:00</td>
<td>3.550</td>
<td>4,083</td>
<td>9.44</td>
</tr>
</tbody>
</table>
Keystone Quality Results – Interface Lengths

- Observed Interface Lengths on Keystone Pipeline Correlate well to the Interface Lengths Predicted by the “Flat Curve” Austin-Palfrey Equation.
- Resultant Contaminant Pick-Up Measured from Composite Samples upon Delivery Correlate well to that Expected from the Observed Interface Lengths. The Majority of Composite sample Results show Contaminant Pick-Up at Levels Slightly Lower than that Predicted through the Interface Analysis.
• Interface Volume as a Function of Average Keystone Flowrate allows for Prediction of Contaminant Migration and Levels upon Delivery.
Questions