Corrosivity of Dilbit and Conventional Crude Oil in Transmission Pipelines

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Alberta Innovates – Technology Futures (AI-TF)
World's Largest Oil Reserves in 2010 (Billion Barrels)

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves (Billion Barrels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>260.1</td>
</tr>
<tr>
<td>Venezuela</td>
<td>211.2</td>
</tr>
<tr>
<td>Alberta*</td>
<td>169.3</td>
</tr>
<tr>
<td>Iran</td>
<td>137</td>
</tr>
<tr>
<td>Iraq</td>
<td>115</td>
</tr>
<tr>
<td>Kuwait</td>
<td>101.5</td>
</tr>
<tr>
<td>Abu Dhabi</td>
<td>92.2</td>
</tr>
<tr>
<td>Russia</td>
<td>60</td>
</tr>
<tr>
<td>Libya</td>
<td>46.4</td>
</tr>
<tr>
<td>Nigeria</td>
<td>37.2</td>
</tr>
</tbody>
</table>

*Alberta's total oil reserves were 170.8 billion barrels, of which crude bitumen reserves accounted for 169.3 billion barrels and conventional crude oil reserves for 1.5 billion barrels.

What Are Oil Sands?

- Crude Bitumen is extra heavy oil that in its natural state does not flow to a well
- Oil Sands – combination of
  - Bitumen (3 - 18%)
  - Water (2 - 10%)
  - Sand (50 - 75%)
  - Clay (10 - 30%)

From Oil Sands

To Bitumen
(high viscosity)

To Diluted Bitumen
(lower viscosity)

Diluent:
- 25-30 v% in dilbit
- Light hydrocarbon such as gas condensate
~75% is crude oil
Canadian and U.S. Oil Pipelines

Proposed Pipeline Expansion Projects

Objectives of the Study
Phase I

• Summarize the concerns that have been raised
• Review the corrosivity of dilbit in transmission pipeline transportation as compared to conventional oil
• Describe and analyze the current scientific information to assess the validity of the concerns
Phase II

• Describe and analyze the current scientific information with regard to:
  – Leak Detection Systems and Emergency Shutdown Protocols
  – Spill Cleanup
    • Mitigation and Remediation
    • Dispersion of Oil
    • Flammability of Oil
  – Oil Tanker Corrosion
Concerns on and Claims against Pipeline Transportation of Dilbit

1. Dilbit contains 15 - 20 times higher corrosive acid concentrations
2. Dilbit contains 5 - 10 times more sulfur
3. Dilbit has a high concentration of chloride salts
4. Dilbit contains more abrasive sand particles, which can erode the pipelines
5. Dilbit can be up to 70 times more viscous, leading to higher temperatures
6. The Alberta pipeline system has had ~16 times as many spills, due to internal corrosion, as the U.S. system
7. Dilbit pipelines have an increased risk of internal corrosion due to dilbit sediment composition and characteristics
8. Chemical corrosion combined with physical abrasion can increase the rate of dilbit pipeline deterioration
9. Dilbit pipelines operate at higher temperatures, which would significantly increase the corrosion rate
10. Dilbit pipelines can have a higher incidence of external stress corrosion cracking
Quality Control of Dilbit Entering Pipelines

• **Government:**
  – Regulatory pipeline tariffs by National Energy Board and Federal Energy Regulatory Commission contain petroleum quality specifications (0.5% BS&W, viscosity, density, etc.)

• **Canadian Association of Petroleum Producers (CAPP):**
  – Addresses on an ongoing basis the management of oil quality issues and issues in refining and shipping of crudes
  – Quality specifications of the condensate stream

• **Canadian Crude Quality Technical Association (CCQTA):**
  – Test methods and research

• **Crude Quality Inc (CQI):**
  – Manages crude quality information
  – Data publicly available on [www.crudemonitor.ca](http://www.crudemonitor.ca)
  – Conventional heavy and light crudes, sweet and sour crudes, dilbits
Quality Control of Dilbit Entering Pipelines

• **Pipeline Operators:**
  
  – Manage and control the quality of crude during transportation
  
  – Crude is transported in batches according to a ranking order
  
  – Turbulent flow minimizes the mixing area between batches
  
  – Buffers or interface pigs prevent mixing between batches
  
  – Maximization of batch size
  
  – Minimization of start/stop operations
  
  – Minimization of contamination in tanks
Dilbit and Conventional Oil Crude Properties: the Comparisons

• All data (except viscosity) come from www.crudemonitor.ca

• Comparisons are made between 11 conventional crudes and 4 dilbits

• Conventional crudes: light, medium, and heavy from the Western Canadian Sedimentary Basin (WCSB)

• Dilbit:
  – Dilbit A from SAGD
  – Dilbits B and C from CSS (has been pipelined for 25 years)
  – Dilsynbit A from mining operations, partially upgraded
Concentrations overlap with or are lower than those of conventional crude oils

- Can be corrosive at refinery temperatures (>150 C)
- Too stable to be corrosive at transmission pipeline temperatures
Dilbits are comparable to conventional crude in sediment content.

Most solids are fine at <44 microns, primarily of silica and iron.

No evidence of erosion has been observed in dilbit pipelines.

Solids can precipitate out at low flow conditions to form sludge.

Sludge deposits are mixtures of hydrocarbons, sand, clays, corrosion by-products, biomass, salts, and water.

A combination of erosion and corrosion is improbable.
Corrosivity of Brine in the Presence of Crude Oils

Conventional Bitumen-Derived Brine

Effect of Crude Oil on Brine Corrosion
Jennifer Collier, CANMET, NACE NAEC 2012
Concern #6: Frequency of Pipeline Spills

Data and Analysis

- US Statistics does not report failures in gathering pipelines or spills that are less than 5 gallons.
- In Alberta, all spills are reported, regardless of spill volume and type of pipeline.

Gathering pipelines are different
- Typically smaller, operate at lower pressure to strength ratios and are not subject to same crude quality requirements as transmission pipelines are.
- Higher water content and intermittent operation.
- Generally more susceptible to internal corrosion in comparison to transmission lines and are not statistically comparable.

### Incident/Failure Case

<table>
<thead>
<tr>
<th>Incident/Failure Case</th>
<th>Failures/Year</th>
<th>Failures per 1,000 Pipeline Miles per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U.S. Crude Oil Pipeline Incident History</strong>a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion - External</td>
<td>9.8</td>
<td>0.19</td>
</tr>
<tr>
<td>Corrosion - Internal</td>
<td>22.1</td>
<td>0.42</td>
</tr>
<tr>
<td>All Failures</td>
<td>89.3</td>
<td>1.70</td>
</tr>
<tr>
<td><strong>Alberta Crude Oil Pipeline Incident History</strong>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion - External</td>
<td>2.3</td>
<td>0.21</td>
</tr>
<tr>
<td>Corrosion - Internal</td>
<td>3.6</td>
<td>0.32</td>
</tr>
<tr>
<td>All Failures</td>
<td>22.0</td>
<td>1.97</td>
</tr>
</tbody>
</table>

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aPHMSA includes spill incidents greater than 5 gallons. U.S. has 52,475 miles of crude oil pipelines in 2008.
Temperature and Viscosity

- Crude tariffs specify a maximum viscosity of 350 cSt
- Dilbit viscosity that is accepted for transportation supports operating temperatures within an acceptable range

Temperature and Corrosion Rate

- Corrosion controlled by kinetics or diffusion can be accelerated by an increase in temperature
- Many other factors can affect the corrosion rate positively or negatively: e.g. scale formation, limiting reactant concentrations
- Microbiologically induced corrosion (MIC) may be the controlling mechanism underneath sludge deposits
- Bacteria are most active between 10-40°C (50-104°F); higher temperatures up to 70°C (158°F) may reduce the corrosion rate

Temperature and Coating Protection

- No SCC failures reported for Fusion Bonded Epoxy (FBE) coatings in over 40 years of experience
**Leak Detection**

- Concerned that leaks are more difficult to detect in dilbit pipelines.
  - Concerned that pressure changes within the pipeline can cause the diluent to move from liquid to gas phase, forming a gas bubble that can impede the flow of oil.
  - Concerned that real leaks will go unnoticed and the operator response to increase flow might increase the size of the spill.
Leak Detection Methods

- SCADA Monitoring (25%-30% of the pipeline flow rate)
- Model Based Leak Detection and Batch Tracking (~1% of the nominal flow rate)
  - API 1149 Computational Pipeline Monitoring (CPM)
  - pipeline variable uncertainties and their effects on leak detection
    - density and temperature
    - less temperature compensation is required in leak modeling with dilbit than with other conventional heavy crude oils or West Texas Intermediate
- Volume Batch Tracking (~5% of the nominal flow rate)
- Volume Trending (smaller leaks but slower response)
- Actual leak rates are a function of the pipeline operating conditions and flow rates and may vary
• Slack line condition does not manifest itself during normal turbulent flow operating conditions.

• The CPM LDS will largely account for the void fractions.
Spill Hazards

- Crude oils are initially flammable when released
- The heavier the oil, the less flammable it is (becomes non-flammable in less than 9 hours)
- Dilbit contains both heavy and light ends
- Dilbit behaves initially similar to a diluent
- After evaporation of the light ends, the dilbit behaves similar to conventional heavy crudes
- The majority of the flammable components will have been lost after 24-72 hours
- Heavy ends collect debris and can sink in water environments
- This is not a unique property associated with dilbit as this phenomenon also occurs with other conventional crude oils.
Over 65% of large scale global oil spills (> 5000 barrels) were attributed to collisions or grounding between 1970 – 2009

- Within the U.S.A., groundings alone account for 65% of the total volume of oil spilled
- Third likely cause of large global oil spills were related to hull failures (12%)
- Corrosion-related incidents of oil spills not directly referenced
Corrosion in Cargo Oil Tankers

Upper Deck
- Wet/Dry Cycling
- Inert Gases (CO₂, H₂S, H₂O and ≤ 8% O₂)
- Corrosion by-products are iron oxide and elemental sulphur
- Typically, 0.1 mm/yr

Inner Bottom
- Bottom plate is covered with an oil layer containing sludge.
- In general, the oil layer inhibits corrosion.
- Defects present in the oil layer lead to more corrosive environment (water-wetted).
- Microbial induced corrosion (MIC) could accelerate the corrosion of the cargo oil tank bottoms (2 – 3 mm/yr).


Corrosion Prevention
- Corrosion Resistant Steels
- Coating Systems
- Corrosion Inhibitors and Biocides
Conclusion

• In the context of pipeline transportation, characteristics of dilbit are not unique and are comparable to conventional crude oils

• Comparison of equivalent crude oil transportation systems shows no evidence that dilbit causes more failures or internal corrosion than conventional crudes
Thank You!