Outline

- Enbridge Liquids Pipelines System
- What is Diluted Bitumen (Dilbit)?
- How “internal corrosion” can occur in a transmission oil pipeline
- Internal corrosion integrity management activities
  - Prevention
  - Monitoring and Mitigation
  - Focused research
- Summary
Began operation in 1950’s
Main operations offices in Edmonton, Alberta and Superior, Wisconsin
Pipeline Integrity and Compliance departments have US and Canadian responsibility
- 35 custody transfer locations
- More than 50 different shippers
- 115 different commodities/crudes
- 225 pump stations
- 652 pumping units
- 1.3 million kW (1.8 million H.P.) of pumping power
- Total line fill capacity of 5.9 million m$^3$ (36.9 million bbl)
What is Diluted Bitumen?

- Bitumen is the raw oil that is produced from the oil/sand separation process
- Diluted Bitumen (Dilbit) is the resulting product from blending a diluting agent with the Bitumen
- The bitumen is diluted to reduce the density and viscosity of the product to allow it to be transported by pipeline
- Dilbit complies with crude oil tariff specification requirements which are filed with both the NEB and FERC
- Enbridge has been transporting crude oil originating from the oil sands since 1968
Internal Corrosion
Why does it occur?

- Crude oil is not an electrolyte, as a result, pipelines do not experience “general internal corrosion” or a global thinning of the pipe wall thickness
- The constituents that potentially contribute to corrosion inside a pipeline include sediment and water that can enter the pipeline with the oil being transported
- Internal corrosion can occur if these constituents settle on the pipe bottom and establish a corrosion cell
- Higher density/viscosity crudes have a greater propensity to carry sediment into the Enbridge pipeline network, which has the potential for deposition and under-deposit corrosion (Note: Dilbit and Synbit, on average, typically carry ~ 25% less sediment than conventional heavies and mediums)

<table>
<thead>
<tr>
<th>Average Sediment Level</th>
<th>Conventional med &amp; heavy</th>
<th>Dilbit &amp; Synbit</th>
<th>Lighter products</th>
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<tbody>
<tr>
<td></td>
<td>277 ppm</td>
<td>205 ppm</td>
<td>169 ppm</td>
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Internal Corrosion Examples

• Typical inside pipe surface. No internal corrosion and no evidence of general wall thinning. In line inspection data confirms this.

• Typical Morphology of Internal Corrosion. Pitting near the bottom of the pipe.
• Pipeline Operators have specifications that dictate the amount of sediment and water that can enter its system (Enbridge’s limit is 0.5% by volume)

• Enbridge assesses the operating conditions of its system (flowrate, temperature, product density) to evaluate the potential for sediment deposition

• Regular cleaning programs (pigging) are established for pipeline segments identified as susceptible to water or solids accumulation,

• For pipelines identified as susceptible to water or solids accumulation, and where internal corrosion processes are identified using integrity management tools, regular cleaning and corrosion inhibition programs may be implemented

• US Code of Federal Regulations Part 195.579 requires operators to complete these assessments
In line inspection is an industry accepted method of monitoring the condition of a pipeline.

Highly specialized tools have been developed using various technologies such as Caliper, Ultrasonic, and Magnetic Flux Leakage to detect and characterize conditions such as corrosion, cracking, and denting.

Analysis of the data generated from these tools provides pipeline operators with information to systematically assess fitness for service of each individual pipe.

Specific to corrosion, the technology is very mature, having been utilized successfully since the 1960’s.
In-Line Inspection Tool Description

- Ultrasonic Sensor / Transducer Carrier
- Drive Cups
- Battery Vessels
- Data Collection, Storage, and Processing vessels
• The entire liquids pipeline mainline system is capable of being inspected with ILI technology
• Inspections are scheduled on the Enbridge pipeline system based on a variety of considerations including the potential for internal corrosion to occur and to meet PHMSA regulations
• Enbridge utilizes both Ultrasonic and Magnetic Flux Leakage technologies for corrosion monitoring
• Internal corrosion that is identified by the ILI tools is measured and either repaired or monitored in accordance with applicable regulations
• Enbridge has never had a release caused by internal corrosion on its piggable pipelines
Internal Corrosion Management
Focused Research

• Enbridge’s main research focus has been on the understanding of how corrosive conditions develop (accumulation and persistence of corrodents)

• Enbridge has and continues to contribute to many industry research efforts
  – Pipeline Research Council International (PRCI) Member
  – PHMSA sponsored Liquid Petroleum Internal Corrosion Direct Assessment Feasibility Study (2005)
  – Joint industry project with inhibitor suppliers and Alberta Research Council (now AITF) to investigate sediment corrosivity and inhibition performance
  – AITF/GE initiated PiCom – a joint industry project investigating corrosive sediments from an active treatment perspective (cleaning and inhibition)

• Enbridge completed crude corrosivity testing in mid 90’s on dozens of crude types which demonstrated exposure to pure crude oil yields virtually immeasurable corrosion
• Transmission grade crude oils (<0.5% S&W) are generally non-corrosive (this includes diluted bitumens)
• Internal corrosion may occur at a very few locations in a pipeline system where the trace amounts of water and sediment accumulate and persist
• Enbridge has a rigorous inspection program that successfully manages the risk of internal corrosion on its system
• Enbridge has a systematic internal corrosion prevention program that includes pipe cleaning and inhibition activities
• No incidents caused by internal corrosion have occurred on Enbridge mainline pipelines carrying conventional crude or diluted bitumen