Operational Issues Processing
Western Canadian Crude Oil

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Outline

- Brief description of heavy western Canadian feedstocks
- Proposed destinations for these feedstocks
- Operational challenges observed, and their causes
- Successful solutions to these challenges
Background

- Production of heavy Western Canadian Sedimentary Basin (WCSB) feedstocks expected to continue growing
  - Drop in crude oil price has slowed pace of development
- These feedstocks may be suitable alternatives to other heavy crude oil sources
- May be available at a discount to other, similar crudes
- Presumed security of supply
  - Facilitates long term planning
- Many grades available
- Characteristics vary widely
Types of WCSB Feedstocks

- Heavy conventional
- Oil sands bitumen-derived
  - Mined (slightly over half of bitumen production)
    - Converted to synthetic crudes produced by associated upgraders
  - Produced in-situ
    - Thermal methods
      - Cyclic steam
      - SAGD
    - Non-thermal methods
      - CHOPS
  - Can be upgraded to synthetic crude oil or diluted with condensate or light syncrude
Types of WCSB Feedstocks

- Different characteristics and operational challenges, depending on source and transportation history
- Majority of diluted bitumens today are not upgraded prior to refining

Source: Purvin & Gertz Inc.
Projected Growth in WCSB Supply

Bitumen blend forecasted to increase to 2.4 MM BPD by 2025

Source: Canadian Association of Petroleum Producers, June 2009 Crude Oil Report

* Bitumen Blend includes some volumes of upgraded heavy sour crude oil and bitumen blended with diluent or upgraded crude oil.
Market Demand for WCSB Supply through 2015

Source: Canadian Association of Petroleum Producers, June 2009 Crude Oil Report
All Proposed WCSB Pipeline Projects

Source: Canadian Association of Petroleum Producers, June 2009 Crude Oil Report
Some Variables Affecting WCSB Supply Growth

- Supply (production) side:
  - Oil price and demand
  - Costs and availability of labor and materials
  - Government duties
  - Regulatory environment (GHG restrictions)
  - Bitumen upgrade vs. export decisions
  - Pace of pipeline projects

- Demand (refinery uptake) side:
  - Overall petroleum demand
  - Pricing and supply vs. alternatives
  - Substitutability for existing feedstocks
  - Number, size, timing of refinery projects enabling WCSB processing
### What are the Challenges?

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>CONSTRAINT (1)</th>
<th>MODIFICATION</th>
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</thead>
<tbody>
<tr>
<td>DILBit</td>
<td>- % resid</td>
<td>- Larger cokers, ancillaries</td>
</tr>
<tr>
<td></td>
<td>- % sulfur</td>
<td>- More HDS, recovery</td>
</tr>
<tr>
<td></td>
<td>- TAN (3)</td>
<td>- Metallurgy</td>
</tr>
<tr>
<td></td>
<td>- Asphalt (4)</td>
<td>- Blending</td>
</tr>
<tr>
<td>SynBit</td>
<td>- % VGO</td>
<td>- Larger FCC, ancillaries</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>- Asphalt (4)</td>
<td>- Blending</td>
</tr>
<tr>
<td>SCO (Sweet, bottomless)</td>
<td>- % VGO</td>
<td>- Hydrocracking</td>
</tr>
<tr>
<td></td>
<td>- % Distillate</td>
<td>- Hydrocracking</td>
</tr>
<tr>
<td></td>
<td>- Diesel aromatics</td>
<td>- Aromatics saturation</td>
</tr>
</tbody>
</table>

Source: Purvin & Gertz, Inc.
Other Operational Challenges

- **Desalter performance**
  - Oily solids in effluent water
  - BS&W carryover
  - Stable emulsions
    - Unstable asphaltenes
    - High filterable solids content
    - Crystalline salts

- **Wastewater treatment plant performance**
  - Oily solids buildup
  - Low DO levels/biological plant upsets
  - Exceed effluent limits
Other Operational Challenges

- High temperature naphthenic acid corrosion
  - For some WCSB types
  - Normally in high ratio blends only

- Crude unit overhead corrosion
  - Higher chloride, low MW organic acid loadings
  - Higher neutralizing agent consumption
    - Higher salt formation potential
    - Column and overhead system fouling and corrosion

- Preheat exchanger and heater fouling
  - Asphaltene instability, high solids
  - No exceptional problems experienced to date
Challenging Feedstocks for Desalting

- Crude quality issues
  - Filterable solids
  - Asphaltenes
  - Non desaltatable chlorides

- Observed problems:
  - Stable emulsions
  - Oil and solids in effluent water
  - Undersized WWTP
  - Mud build-up
  - Increased conductivity
  - Dehydration – normally not an issue
  - Salt removal – normally good
Filterable Solids

- Typical Analysis
  - Iron Oxide and Iron Sulfide
  - Sand
  - Clay
  - Silt
  - Scale
  - Salt Crystals
Filterable Solids Variations
Over Three Months
Desalting Operating Strategies

- Wash water quality
- Wash water rate
- Mixing energy
- Temperature
- Mud wash practices
- Chemical treatment programs
Wash Water Characteristics

- **Quality**
  - pH 5 – 8
  - Hardness < 150 ppm as CaCO$_3$
  - Suspended Solids < 30 ppm
  - Ammonia <35 ppm

- **Rate**
  - Higher rates needed for heavy crude oils
  - Higher rates needed for salt removal and dehydration
## Desalter Wash Water Study, Heavy Canadian Crude Oil

<table>
<thead>
<tr>
<th>Settling Time</th>
<th>3% Water</th>
<th>5% Water</th>
<th>7% Water</th>
<th>9% Water</th>
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</thead>
<tbody>
<tr>
<td>20 min</td>
<td>1.2%</td>
<td>3.4%</td>
<td>4.5%</td>
<td>8.0%</td>
</tr>
<tr>
<td>30 min</td>
<td>1.7%</td>
<td>3.7%</td>
<td>5.5%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Desalted Crude BS&amp;W</td>
<td>1.2%</td>
<td>0.8%</td>
<td>0.8%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>
Mixing Energy

- Most operations rely on mix valve for mixing
- In line mixer unusual
- Wide range of $\Delta P$ used in WCSB processing
  - 1 psi
  - 19 – 22 psi
- Higher charge rates might require adjustments

Desalter Mix $\Delta P$ vs. Desalted Crude Salt and BS&W Content

% SALT IN DESALTED CRUDE

% BS&W IN DESALTED CRUDE

INCREASING MIXING PRESSURE
Desalter Temperature

- Typical range 110 - 155°C (230 - 310°F)
  - Higher temperature decreases viscosity
  - Water separation increases as viscosity decreases
  - Asphaltenes can destabilize at higher temperatures
  - Water is more soluble at higher temperature
  - Conductivity increases with temperature

- Most refineries processing heavy Western Canadian crude oils run below upper limit

- Work with knowledgeable supplier to develop optimal operating range
Mud Wash Practices

- Solids can rapidly build in desalter vessel
- Mud can harden with time
- Best to use recycled effluent water
  - Need mud wash pump
  - Don’t starve wash water
- Desired frequency is at least daily
  - Western Canadian experience
    - 15 minutes per shift
    - Continuous

Design of a Typical Desalter Mudwash System
WCSB Chemical Treatment Strategies

- Pre-screen blends, individual crudes
  - ASIT™ test screenings for asphaltene stability, feedstock compatibility
  - Bench top “EDDA” screenings for emulsion resolution speed, efficiency

- Conventional, oil soluble emulsion breakers (100%)
  - Includes newly developed heavy oil EBs

- Solids wetting agents (~10%)

- Crude oil pre-treatment (~50%)
  - Does not require water draw in tank
  - Improves solids control
  - Stabilizes asphaltenes
  - Reduces oil under carry

- Water soluble polymers, when required (~5%)

ASIT is a trademark of Baker Hughes Incorporated
ASIT Test Indicates Asphaltene Instability

- Some WCSB crudes and blends can contain unstable asphaltenes
  - High asphaltene bitumens
  - Paraffinic materials used to dilute bitumens

- Several potential problems
  - Precipitation in tankage
  - Desalter upsets
  - Fouling
  - Foaming

- Can be used to identify unstable blends

- Also used to screen most effective asphaltene stabilizing chemicals
Additives can greatly increase the stability of an oil.
ASIT Test Results Identify Problematic Blends

- Information can be used to establish tank farm blending rules

Crude blends not identified; proprietary customer study
Wastewater Plant Operating Challenges

- Higher content of oil and solids from desalter operations is the biggest challenge
- Unchecked, this puts strain on wastewater treatment plant equipment and can affect performance
- Many mitigation options
- Work with your wastewater treatment plant chemical service company to develop the best option for your plant
One Option: Supplemental Primary Separation

- Treats only the emulsified portion of the desalter brine
- Provides for initial three phase separation of oil, solids and water prior to chemical addition
  - Enhances recovered “free” oil quality by not tying solids and oil together into one phase with a polymer or flocculant
- Effluent can the be sent to benzene stripper for NESHAP conformance with little to no fouling potential
- Reduces rate of slop oil generation
- Breaks the internal refinery solids cycle
- Reduces insoluble COD/BOD
- Reduces overall organic loading to wastewater treatment plant
One Option: Supplemental Primary Separation

Free Oil to API or Slop

Max BS&W: 0.5%

Max Oil: 500 ppm

To Deoiler ISF, DNF or IGF

Optional emulsion breaker or wetting agent, if needed

Solids to Roll off box or Coker

SPECTRAFLOC™ Cationic Flocculant

SPECTRAFLOC is a trademark of Baker Hughes Incorporated
High Temperature Naphthenic Acid Corrosion

- Can be a concern with bitumen blends from Athabasca and Peace River areas
- Impact depends on characteristics of overall crude slate processed
- Several mitigation options have been used successfully with WCSB feedstocks:
  - Blending
  - Metallurgy
  - Chemical inhibitors
Areas Most Susceptible to Naphthenic Acid Corrosion

Desalter

Atmospheric Column

Crude Charge

135°C

Hot Crude Preheat Exchangers

Atmospheric Heater

325°C

260°C 345°C

Vacuum Column

Diesel

AGO

LVGO

230°C

HVGO

285°C

315°C

VTB

360°C

260°C

345°C

325°C
Use Conventional Approaches to NAC Control

- Assessment
  - Process equipment evaluation
  - Feedstock/process stream characterization

- Mitigation
  - Crude blending to TAN limit
  - Metallurgy upgrade
  - Chemical inhibition

- Surveillance/Monitoring
  - Design effective monitoring protocols
  - Use data to optimize corrosion management program
Crude Tower and Overhead System Corrosion

- WCSB crudes can increase tower and overhead system corrosion potential in two key ways:
  - Non-desaltable chlorides in WCSB blends
    - Higher chloride loadings in the tower and overhead system
  - Low boiling organic acids from thermal degradation of high TAN crudes
    - Higher organic acid loadings in the tower and overhead system
    - Naphthenic acids also increase hydrolysis of inorganic chloride salts in the desalted crude
  - Both mechanisms increase neutralizing agent demand
  - Both mechanisms increase the risk of neutralizer-hydrochloride salt fouling and under-deposit corrosion
Use Conventional Approaches to Address Higher Tower and Overhead Corrosion Potential

- As with naphthenic acid corrosion, a systematic approach is required to successfully meet overhead system corrosion control challenges
  - Thorough root cause analysis
    - Utilize advanced tools such as Ionic Model simulations
  - Proven mitigation strategies
    - Improved desalter performance
    - Minimize overhead chloride loadings
    - Proper control of operating variables
    - Well-designed corrosion control chemical programs
  - Surveillance/Monitoring
    - Design effective monitoring protocols
    - Use data to optimize corrosion management program
Ionic Model Thermodynamic Simulations

- **Acid corrosion**
  - Dictated by pH
  - Most severe at dew point
  - Rigorous electrolyte simulation to determine pH profile

- **Under-salt corrosion**
  - Dictated by salt deposition
  - Salts are acidic, absorb water
  - Thermodynamic data for organic amine-HCl salts
Many potential benefits for improving your Canadian crude processing capabilities

- Reduced feedstock costs
- Increased feedstock flexibility
- Improved refinery profitability

These benefits can be achieved while minimizing operating risk

- Maintain unit integrity and reliability
- Ensure product quality
- Ensure environmental compliance

These Operational Challenges Are Being Met!