Troubleshooting FCC Units Processing Light Tight Oils And Unconventional Canadian Crudes
Agenda

• LTO & Canadian Crude Oil Quality
• Problem Areas & Solutions
  – Main Fractionator
  – Riser / Reactor
  – Catalyst Losses
FCC Feed Quality

**Light Tight Oil**
- Very paraffinic
- High solids content
- Extreme variability in quality
- Fe & V concerns
- Nitrogen (Bakken)
- Low in carbon residue
- Low gas oil and residual oil content

Waxes and Sediment
FCC Feed Quality

Light Tight Oil

- Very paraffinic
- High solids content
- Extreme variability in quality
- Fe & V concerns
- Nitrogen (Bakken)
- Low in carbon residue
- Low gas oil and residual oil content

Both Samples are Eagle Ford Crude
Mostly inorganic particulate Fe. Contributes to increased catalyst additions.
FCC Feed Contaminants in LTO

Low Ni levels, but highly variable. Contributed to increased hydrogen production.
FCC Feed Contaminants in LTO

Highly variable V level. Contributes to increased catalyst additions.
Nitrogen causes temporary deactivation of catalyst. Na forms an eutectic with V, increasing zeolite destruction. Ca acts with Fe to plug pores and reduce bottoms cracking.
FCC Feed Quality

**Heavy Canadian Crude**
- Quality depends on source
- High inorganic solids content
- High Ni & V
- Nitrogen
- High carbon residue
## Canadian Crude Quality Depends On Source

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Unconventional</th>
<th>Heavy Sour Synbit</th>
<th>Heavy Low Resid</th>
<th>Syncrude</th>
<th>Heavy Sour Dilsynbit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravity (° API)</strong></td>
<td>18 - 21</td>
<td>19.9 - 22.5</td>
<td>18 - 19</td>
<td>18 - 19</td>
<td>30 - 35</td>
<td>18 - 20</td>
</tr>
<tr>
<td><strong>Sulfur (wt%)</strong></td>
<td>3.1 - 4.8</td>
<td>3.4 - 4</td>
<td>3.1 - 3.2</td>
<td>3.1 - 3.2</td>
<td>0.1 - 0.2</td>
<td>2.5 - 3</td>
</tr>
<tr>
<td><strong>Carbon Residue (wt%)</strong></td>
<td>8.72 - 10.55</td>
<td>9.9 - 13.8</td>
<td>8 - 9</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>10 - 15</td>
</tr>
<tr>
<td><strong>Ni (mg/L)</strong></td>
<td>47 - 61</td>
<td>57 - 76</td>
<td>55 - 60</td>
<td>4</td>
<td>&lt; 1</td>
<td>50 - 60</td>
</tr>
<tr>
<td><strong>V (mg/L)</strong></td>
<td>110 - 166</td>
<td>134 - 194</td>
<td>150 - 160</td>
<td>8</td>
<td>&lt; 1</td>
<td>100 - 120</td>
</tr>
<tr>
<td><strong>Nitrogen</strong></td>
<td>2,400 - 3,400</td>
<td>3,500 - 4,500</td>
<td>3,000 - 3,500</td>
<td>500 - 600</td>
<td>1,200 - 1,500</td>
<td></td>
</tr>
</tbody>
</table>
FCC Feed Quality

LTO
• Metals (Fe, V)
• Nitrogen (Bakken)
• Low Carbon Residue

Canadian Crude
• Metals (Ni, V)
• Nitrogen
• High Carbon Residue
FCC Problems From LTO & Canadian Crudes

• Metals → Increased catalyst makeup, hydrogen yield, & ash in slurry
• Nitrogen → Reduced bottoms cracking, fouling (salting), & corrosion
• Changes in carbon residue impact the heat balance
FCC Problems From LTO & Canadian Crudes

- Metals → Increased catalyst makeup, hydrogen yield, & ash in slurry
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Impacts the Riser / Reactor / Regenerator
FCC Problems From LTO & Canadian Crudes

- Metals → Increased catalyst makeup, hydrogen yield, & ash in slurry
  Impacts the Riser / Reactor / Regenerator

- Nitrogen → Reduced bottoms cracking, fouling (salting), & corrosion
  Impacts the Riser / Reactor / Regenerator & the Main Fractionator

- Changes in carbon residue impact the heat balance
FCC Problems From LTO & Canadian Crudes

- Metals: Increased catalyst makeup, hydrogen yield, & ash in slurry
- Nitrogen: Reduced bottoms cracking, fouling, salting, & corrosion
- Changes in carbon residue impact the heat balance
Salting, corrosion and fouling

- Find fouling and corrosion potential and measure impact
- Evaluate column performance
Salting, corrosion and fouling

- Find fouling and corrosion potential and measure impact
- Evaluate column performance

Troubleshooting Tools
PATHFINDER® & MONITOR™ simulation
Permasense corrosion monitoring
Slurry characterization
Gamma Scan
Thermography Scan
Scan Found Damage to Stripper Column

- Our Report:
  - Trays 9-12 Damaged/Missing
  - Trays 4-8 Damaged
Scan Found Damage to Stripper Column

- Our Report:
- Trays 9-12 Damaged/Missing
- Trays 4-8 Damaged

View from Bottom Manway
Corrosion and Salt Control Program

• Increase in Nitrogen results in greater salting potential, which can result in throughput reductions and corrosion.

• Salting and corrosion can be controlled through
  – Wash Water
    • 125% of calculated minimum for overhead
    • 3 – 5 gallons / million scf in the Overhead
  – Tower top temperature control over salt formation temperature
  – Salt Dispersants

• Monitor salting through routine lab analysis, software simulation, thermography and tower gamma scans
Corrosion and Salt Control Program

Water Wash Locations

Light Ends Fractionation

Dry Gas

Naphtha Splitter/DE-C₄

LPG

De-C₄

Light Gasoline

Heavy Gasoline

Regenerator

Reactor

Main Fractionator

TPA

Absorber

Stripper

Decant Oil

Slurry Exchanger Train

Feed

Steam

Air Blower
Corrosion and Salt Control Program

Corrosion Inhibitor Injection Locations

Individual Pump
Flow Measurement
Slip Stream
Alloy Injection Nozzles
Filmer Knock Out

Light Ends Fractionation
Dry Gas
Naphtha Splitter/DE-C4
LPG
De-C4

Regenerator
Air Blower
Steam
Feed
Main Fractionator
Heavy Gasoline
Light Gasoline
Decant Oil
Slurry Exchanger Train
Absorber
Stripper
Cyanide Control Program

• Increase in Nitrogen results in greater risk of cyanide formation, which can result in corrosion and blistering.

• Cyanide control considerations
  – Controlling CN levels to < 25 ppm (water wash)
  – Controlling pH < 8.5 (water wash)
  – Cyanide scavenger
  – Passivation additive
Cyanide Control Program

Ammonium Polysulfide

With Water Wash
Retractable Alloy Nozzle
As High As Possible
Mixing Imperative
Where Issues Have Been Observed
Increased hydrogen and coke yield

- Mechanical – Operational – Chemical troubleshooting
- Study riser and regenerator
- Evaluate and treat metals

Stationary Monitoring of Air Bubble Regenerator Standpipe at 62 ft Scan Elevation Between 5 and 6 Aeration Tap
Regenerator Level at 105 inches H2O

Nickel Passivation Results

H2, SCF/BBL

Date

0 5 10 15 20 25

0 50 100 150 200

Start Time 1216 Hours
Stop Time 1251 Hours

I9, M9, 16-I9, 16-M9, 18-M9

10,000

20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
Increased hydrogen and coke yield

- Mechanical – Operational – Chemical troubleshooting
- Study riser and regenerator
- Evaluate and treat metals

**Troubleshooting Tools**
- Riser Inspection
- Fluidization study
- $\text{H}_2$ model
- Proton NMR Slurry testing
- Olefin / Diolefin testing
- Antimony optimization
Thermography
Riser & Regen Stand Pipe
Increased catalyst make up

- Evaluate cyclones, reactor stripper, air distributor
- Determine root causes of cat losses
- Passivate Vanadium
- Minimize feed contaminants
Increased catalyst make up

- Evaluate cyclones, reactor stripper, air distributor
- Determine root causes of catalyst losses
- Passivate Vanadium
- Minimize feed contaminants

**Tools**
- Gamma Scans
- Radioactive gas tracing
- Catalyst tagging and tracing
- Vanadium passivation
- Caustic automation at crude unit
- Iron removal at the desalter
Feed Preparation Sodium Reduction

• Automated caustic injection
• Minimize caustic used to control Crude Unit overhead chloride concentration
Feed Preparation Fe Removal

• Iron Reduction
  – Maximize Solids removal across Desalter with process optimization
  – Further increase Fe removal across 2 stage Desalters with additives technology
Deashing Troubleshooting

Deashing Methods
• Filtration
  – Gulftronics (Electrostatic Precipitators)
  – Mechanical Filtration
• Tank Settling

Tank Settling Considerations
• Temperature > 158 F (70 C)
• Clarified oil viscosity
• Heated/Insulated Tanks Required
• Slurry antifoulant use
• Residence Time
• Placement of Inlet/Outlet Nozzles
• Eventual Cleaning and Waste Disposal
FCC Troubleshooting Tools
Mechanical – Operational – Chemical Diagnosis & Treatment

**Chemical Treatment**
- Corrosion
- Fouling
- Passivation
- Additives

**Monitoring Performance**
- Simulation (PathFinder, Monitor, and H₂ model)
- Lab testing
- Thermography
- Gamma Scans
- Tracer Studies
- Corrosion monitoring

**TAR Support**
- Thermography Scans
- Gamma Scans
- Tracer Studies
Unconventional Crudes Quality Summary

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<th>Crude / Feed</th>
<th>Quality</th>
<th>Impact at FCC</th>
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<td>Canadian Bitumen</td>
<td>High metals (Ni and V)</td>
<td>Increased hydrogen and coke yield</td>
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<td>High in Nitrogen</td>
<td>Increased catalyst make up</td>
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<td>Increased risk of salting and corrosion</td>
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<tr>
<td>Ultra Light Shale Oils</td>
<td>Low MCR</td>
<td>Heat balance may require torch oil injection which promotes corrosion in FCC main fractionators</td>
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<td>Light Tight Oils</td>
<td>Fe, V, and Ca level</td>
<td>Increased catalyst make up, reduced bottoms cracking</td>
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<td>Resid and ATB</td>
<td>High metals (Ni and V)</td>
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<td>High Na</td>
<td>Increased catalyst make up</td>
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<td>High flash point</td>
<td>Potential coking at feed nozzles</td>
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