Crude Oil Vapor Pressure: Regulatory Impacts and Vapor Pressure Reduction Technologies
Discussion Topics

• Crude Vapor Pressures and Compositions
• Why is High VP Crude a Problem?
• Conventional Vapor Pressure Reduction Technologies
• Hellervik Oil Conditioning Unit (OCU™)
• Questions & Answers
• Summary of Discussion
Crude Sample Temperature vs. eRVP
## Average Sample Analysis

<table>
<thead>
<tr>
<th>Component</th>
<th>Samples 1-15</th>
<th>Samples 16-30</th>
<th>Samples 31-36</th>
<th>Samples 1-36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mol%</td>
<td>Mol%</td>
<td>Mol%</td>
<td>Mol%</td>
</tr>
<tr>
<td>C2</td>
<td>1.0</td>
<td>0.8</td>
<td>0.8</td>
<td>0.87</td>
</tr>
<tr>
<td>C3</td>
<td>8.0</td>
<td>7.1</td>
<td>7.1</td>
<td>7.40</td>
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<tr>
<td>C4</td>
<td>16.4</td>
<td>15.2</td>
<td>15.0</td>
<td>15.54</td>
</tr>
<tr>
<td>C5</td>
<td>16.1</td>
<td>15.7</td>
<td>15.3</td>
<td>15.71</td>
</tr>
<tr>
<td>C6</td>
<td>16.7</td>
<td>17.2</td>
<td>16.7</td>
<td>16.88</td>
</tr>
<tr>
<td>C7</td>
<td>16.3</td>
<td>17.2</td>
<td>18.3</td>
<td>17.28</td>
</tr>
<tr>
<td>C8</td>
<td>13.1</td>
<td>14.2</td>
<td>13.0</td>
<td>13.44</td>
</tr>
<tr>
<td>C9</td>
<td>7.6</td>
<td>7.6</td>
<td>8.2</td>
<td>7.80</td>
</tr>
<tr>
<td>C10</td>
<td>4.8</td>
<td>4.9</td>
<td>5.5</td>
<td>5.07</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>RVP, psia @100°F</td>
<td>28.72</td>
<td>26.24</td>
<td>26.03</td>
<td>27.04</td>
</tr>
</tbody>
</table>
Typical Crude Oil Production Equipment

Production Management
- Gas Injection
- Gas Lift

Oil & Gas Production
- Chemical Injection
- Water Injection

Enhanced Oil Recovery
- EOR Thermal
- EOR Chemical or Miscible

Natural Gas Treatment/Compression
- Compression
- Fuel Gas
- Production Separator

Low Temp Separator
- Dehydration/Acid Gas Removal
- Condensate Stabilizer

Gathering and Custody Transfer
- Vapor Recovery

Oil Treatment and Storage
- Water Treatment
- Tank Dewatering
- Coriolis Flow Measurement

To Pipeline
- LACT

To Gathering
- To Storage
Why is High VP Crude a Problem?

Regulatory and Other Scrutiny

• For Rail
  ❖ NDIC 25417 (4/1/2015) limit of <13.7 psia (94.5 kPa)
  ❖ PHMSA ANPR (1/18/17) limit of 9.0 psia (62.1 kPa)
    - May be applied to all forms of transport

• For Pipelines
  ❖ Break out tankage is limited to <11.5 psia (<79.3 kPa)
    due to floating roofs design limitations
  ❖ Pipelines setting limits 12.5 – 9.0 psia (86.2 – 62.1 kPa)

• At the refinery
  ❖ Process units limited in the conversion of light gases to saleable products
  ❖ Unused light gases flared at no value

• Maritime Limits
  ❖ Must be consistent with SDS and Tanker design specifications
High VP Crude Worth Less than WTI

• Although it is not a simple matter to pinpoint the additional costs associated with the industry’s operation to comply with order NDIC 25417, a few benchmarks are worthy of note:

  ❖ Delivery of “out-of-spec” crude oil to storage terminals can add $2.00 - $5.00 per barrel, due to added conditioning or unplanned transportation.

  ❖ The challenges encompass maintaining heater treaters, ensuring production of low RVP crude oil, and preventing rejection of crude oil relative to midstream shipping requirements. All of which are subject to attendant costs.

Statoil Revision Addendum to NDIC 25417 – 4/29/2016
Other Quotations on Bakken Crude

- **Continental Resources Annual Report 2016**
  - “Continental Resources received on average $34.33 for Bakken Crude during 2016 where the WTI benchmark average for 2016 was $43.15; an **$8.82/Bbl discount**

- **Continental Resources 2Qtr 2017 Financial Report**
  - “Continental Resources estimates 2017 price for Bakken Crude to be **$6.50 to $7.50/Bbl reduction** to WTI Nymex”
Conventional Vapor Pressure Reduction Technologies

• **Flash Stabilization**

• **Crude Oil Stabilization**

• **Top Feed and Split Feed Stabilizers**
Crude Oil Stabilization
Top Feed and Split Feed Stabilizers

Top Feed
no reflux

Split Feed
no reflux
Vapor Pressure Reduction Technologies

- **Flash Stabilization**
- **Crude Oil Stabilization**
- **Top Feed and Split Feed Stabilizers**

All of the above technologies are complex processing systems and are required to be located at a central processing location.
Vapor Pressure Reduction Technologies

• Flash Stabilization

• Crude Oil Stabilization

• Top Feed and Split Feed Stabilizers

• RDO-Hellervik Oil Conditioning Unit (OCU™)
   Low Capital, Quick Deployment, Modular, and Movable
RDO-Hellervik Oil Conditioning Unit (OCU™)
OCU™ Process Flow for Crude Oil Vapor Pressure Reduction

Unstabilized Crude from H-T

Surge Drum

Pump

Crude Cross-Exchanger

Degassing Vessel

Light Gases to Gathering System or Flare

Stabilized Crude to Storage for Sales

Water to Disposal or Storage
OCU™ Process Flow for Reduced Flaring

Unstabilized Crude from H-T

Surge Drum

Pump

Crude Cross-Exchanger

Electric Preheaters

Degassing Vessel

Gathering System Light Gases to Flare

Cooler

Propane Separator

Recovered Propane-Plus

Water to Storage Disposal

Stabilized Crude to Storage for Sales
Unstabilized Crude Oil Specifications

- Water content (BS&W)
  - varies from 0.3% to 3.0% (volume)
  - may be set by salt specification
  - no free water

- Salt
  - typical specification is 10 lb/1000 Bbl [30 g/m³]

- H₂S
  - typical spec 50 ppmw
  - don’t confuse with organic sulfur
Oil Conditioning Unit (OCU™)

- Proven Process Technology
  - Uses Widely Accepted Process Equipment Modules
  - Uses a Site Specific Algorithm for Control
  - Uses Site Specific Conditions to Determine Operation Conditions
- Real-time Remote Monitoring
- Real-time Local and Remote Control
- Available for Immediate Installation and Operation
Oil Conditioning Unit (OCU™)

• Safer than Current Operations
  ❖ Conditions Crude to Selected RVP Prior to Sales
  ❖ No direct fired equipment
  ❖ Highly trained staff providing operations support
  ❖ Operations Support available 24/7/365

• Faster
  ❖ Available for Immediate Installation
  ❖ Does not require construction or permitting of a large complex Centralized Processing Plant
  ❖ Does not require the installation of a dedicated pipeline to transport un-conditioned crude to a Central Processing Plant

• Lower Cost
  ❖ Provides cost reductions in staff time and maintenance of existing equipment
Oil Conditioning Unit (OCU™)

- **Flexible**
  - Conditions the Crude to the Client’s Desired Specification
  - Allows transportation of Conditioned Crude by pipeline, rail, or truck

- **Emissions**
  - Utilizes Electric Power, only
  - No fired heaters
  - No direct emissions from the unit (non-flare option)

- **Service and Maintenance**
  - Included in the Lease Agreement
  - Reduces costs of Maintenance on the Existing Heater-Treater
  - Reduces Staff time to address out-of-specification RVP
  - Reduces RVP testing required
Typical OCU™ Performance (FPS Units)

<table>
<thead>
<tr>
<th>Unstabilized Crude</th>
<th>Stabilized Crude to Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flowrate</strong></td>
<td></td>
</tr>
<tr>
<td>500.0 Barrels/day</td>
<td>475.0 Barrels/day</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td></td>
</tr>
<tr>
<td>18.46 psia</td>
<td>44.0 psia</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
</tr>
<tr>
<td>55.0 °F</td>
<td>120.0 °F</td>
</tr>
<tr>
<td><strong>RVP</strong></td>
<td></td>
</tr>
<tr>
<td>15.03 psia</td>
<td>6.95 psia</td>
</tr>
<tr>
<td><strong>Stabilization Temperature</strong></td>
<td>240.0 °F</td>
</tr>
</tbody>
</table>

**Recovered Propane-Plus NGL**

<table>
<thead>
<tr>
<th><strong>Flowrate</strong></th>
<th><strong>Gas to Flare/Fuel</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>21.9 Barrels/day</td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td><strong>Flowrate</strong></td>
</tr>
<tr>
<td>39.0 psia</td>
<td>4,922 SCFD</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td><strong>Pressure</strong></td>
</tr>
<tr>
<td>120.0 °F</td>
<td>39.0 psia</td>
</tr>
<tr>
<td><strong>Shrinkage</strong></td>
<td><strong>Temperature</strong></td>
</tr>
<tr>
<td>105.9 MMBtu/day</td>
<td>120.0 °F</td>
</tr>
<tr>
<td><strong>HHV</strong></td>
<td><strong>HHV</strong></td>
</tr>
<tr>
<td>2,640 Btu/SCF</td>
<td></td>
</tr>
</tbody>
</table>

**Utilities**

| **Electricity** | 63.174 kWh |

**RDO Hellervik**
## Typical OCU™ Performance (SI Units)

<table>
<thead>
<tr>
<th>Unstabilized Crude</th>
<th>Stabilized Crude to Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flowrate</strong></td>
<td>500.0 Barrels/day</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>127.3 kPa</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>12.8 °C</td>
</tr>
<tr>
<td><strong>RVP</strong></td>
<td>103.6 kPa</td>
</tr>
<tr>
<td><strong>Stabilization</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Recovered Propane-Plus NGL

| **Flowrate**      | 21.9 Barrels/day |
| **Pressure**      | 268.9 kPa        |
| **Temperature**   | 48.9 °C          |
| **Shrinkage**     | 26,696 kcal/day  |

### Gas to Flare/Fuel

| **Flowrate**      | 139.4 m³/day     |
| **Pressure**      | 268.9 kPa        |
| **Temperature**   | 48.9 °C          |
| **HHV**           | 23,478 kcal/m³   |

### Utilities

| **Electricity**   | 63.174 kWh       |
Blending Strategy vs. OCU™ Capacity

OCU Capacity @ 500 BPD
RDO-Hellervik Oil Conditioning Continuum

Gas, Water, Oil Gravity Separation

Water, Oil Emulsion Breakup

Light Ends Gas Reduction NGL Recovery Possible

H₂S Gas Removal from Oil

Distillation Fractionation

Three Phase Separator

Heater/Treater Conditioning

Stripping Units

Stabilization Plant

Hellervik Field OCU Conditioning

Oil Fully Stabilized

Less

Complexity and Control Capital and Energy Intensity

More
Optimizing Returns Through Oil Conditioning

• The patent-pending **Oil Conditioning Unit (OCU™)**, utilizes a Process Logic Controller and an advanced electric heating element that can condition your crude oil (in a controllable fashion) to 9.0 - 13.6 psi (62.1 – 93.8 kPa).
  - This meets any shipping requirements for: truck, rail, pipeline, or maritime vessel.
  - Additionally, this allows delivery of a higher quality crude to the refinery increasing the value of your crude through a reduction in refining costs.

• The **OCU™** will treat enough crude to create a blending stock that reaches 9.0 – 7.0 psi (62.1 – 48.3 kPa); in a controlled fashion (with no shipment delay).
Utilizing a HIPOWER System Natural Gas Generator Set, RDO-Hellervik OCU™ can reduce or eliminate flaring

- Will comply with Bureau of Land Management directive
- Reduce or eliminate fines
- Reduce electricity charges on well pad
- Utilizes associated gas from OCU™ and heater treaters
OCU™: Benefits and Cost Avoidance

• The OCU™ will treat only enough “batch” crude to create a client specified blending stock, e.g. 13.6, 9.0, 7.0 psi (93.8, 62.1, 48.3 kPa) – in a controlled fashion (with no shipment delay)

• Natural gases driven off can be captured locally and used to power the HIPOWER Generator Set or sold if infrastructure permits

• No high pressure compression required

• No transportation or disposal fees for unwanted natural gases

• Increase your Net Back by delivering “in-spec” crude
Maximizing the Potential of Conditioned Crude

- Creates transparency in the process of outgassing of light weight hydrocarbons
- Utilizing a HIPOWER Generator Set solution can greatly reduce flaring
- Predictable reduction of vapor pressure = safer transport and increased price for conditioned crude at the refinery
- Further regulation is unnecessary
Client Contribution to Deployment Effort

- Identify Locations/Sites for Oil Conditioning Unit Placement
- Site Preparation
  - Level area install secondary containment for OCU™ skid and cover with class 5 base or equivalent
  - Provide piping to and from the skid, including tie-ins
  - Raw Crude from and Conditioned Crude to storage tanks
  - Gas to the flare line or Gathering system
  - Gas to C₃+ recovery (optional)
  - Produced water to water storage
  - Provide 480v, 3-phase power to OCU™ skid
    - Optional power generation utilizing off gases
  - Discuss installation with HSSE staff
  - Review environmental and other operating permits
Questions?
Thank You!

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