Methane Emissions Reductions through Vapor Recovery from Oil and Condensate Storage and Holding Tanks

Methane to Markets Partnership Expo
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Larry Richards, President
Hy-Bon Engineering Company
Vapor Recovery: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Lessons Learned
- Discussion
Storage Tank Methane Losses

- A storage tank battery can vent 140 m³ to 2,720 thousand m³ (Mcm) of natural gas and light hydrocarbon vapors to the atmosphere each year
  - Vapor losses are primarily a function of oil throughput, gravity, and gas-oil separator pressure
- Flash losses
  - Occur when crude is transferred from a gas-oil separator at higher pressure to a storage tank at atmospheric pressure
- Working losses
  - Occur when crude levels change and when crude in tank is agitated
- Standing losses
  - Occur with daily and seasonal temperature and barometric pressure changes
Methane Savings: Vapor Recovery

- Vapor recovery can capture up to 95% of hydrocarbon vapors from tanks
- Recovered vapors have higher heat content than pipeline quality natural gas
- Recovered vapors are more valuable than natural gas and have multiple uses
  - Re-inject into sales pipeline
  - Use as on-site fuel
  - Send to processing plants for recovering valuable natural gas liquids
Types of Vapor Recovery Units

- Conventional vapor recovery units (VRUs)
  - Use special designed packages configured to capture low pressure, wet gas streams with no oxygen ingress
  - Use rotary screw or rotary vane compressor for wet gas
  - Scroll compressors are new to this market & work well
  - Require electrical power or engine driver

- Venturi ejector vapor recovery units (EVRUTM) or Vapor Jet
  - Use Venturi jet ejectors in place of rotary compressors
  - Contain no moving parts
  - EVRUTM requires a source of high pressure motive gas and intermediate pressure discharge system
  - Vapor Jet requires a high pressure motive water
Conventional Vapor Recovery Unit

Source: Evans & Nelson (1968)
Vapor Recovery Installations

Source: Hy-Bon Engineering
Criteria for Vapor Recovery
Unit Locations

- Steady source and sufficient quantity of losses
  - Crude oil stock tank
  - Flash tank, heater/treater, water skimmer vents
  - Gas pneumatic controllers and pumps

- Outlet for recovered gas
  - Access to low pressure gas pipeline, compressor suction, or on-site fuel system

Dual VRU bound for Venezuela - one of 17 units capturing gas currently for Petroleos de Venezuela. Flooded screw compressor for volumes to 0.14 million m³ per day; up to 15 atm.
Source: Petroleos de Venezuela S.A
Quantify Volume of Losses

- Estimate losses from chart based on oil characteristics, pressure, and temperature at each location (± 50%)
- Estimate emissions using the E&P Tank Model (± 20%)
- Engineering Equations – Vasquez Beggs (± 20%)
- Measure losses using recording manometer and well tester or ultrasonic meter over several cycles (± 5%)
  - This is the best approach for facility design

Petroleos de Venezuela S.A has installed vapor recovery in the majority of its production facilities in Eastern Venezuela.
Source: Petroleos de Venezuela S.A
What is the Recovered Gas Worth?

- Value depends on heat content of gas
- Value depends on how gas is used
  - On-site fuel
    • Valued in terms of fuel that is replaced
  - Natural gas pipeline
    • Measured by the higher price for rich (higher heat content) gas
  - Gas processing plant
    • Measured by value of natural gas liquids and methane, which can be separated

- Gross revenue per year = \((Q \times P \times 365) + NGL\)
  - \(Q\) = Rate of vapor recovery \((m^3\) per day\)
  - \(P\) = Price of natural gas
  - \(NGL\) = Value of natural gas liquids
## Value of Natural Gas Liquids

Recovered Btu-rich tank vapors worth approximately $207/Mcm ($5.87/Mcf)

<table>
<thead>
<tr>
<th></th>
<th>1 Btu/gallon</th>
<th>2 MMBtu/gallon</th>
<th>3 $/gallon</th>
<th>4 $/MMBtu (^{1,2}) (= 3/2)</th>
<th>5 Btu/cf</th>
<th>6 MMBtu/Mcf</th>
<th>7 $/Mcf (= 4\times 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>59,755</td>
<td>0.06</td>
<td>0.18</td>
<td>2.96</td>
<td>1,012</td>
<td>1.01</td>
<td>$3.00</td>
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<tr>
<td>Ethane</td>
<td>74,010</td>
<td>0.07</td>
<td>0.37</td>
<td>5.00</td>
<td>1,773</td>
<td>1.77</td>
<td>$8.86</td>
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<tr>
<td>Propane</td>
<td>91,740</td>
<td>0.09</td>
<td>0.68</td>
<td>7.41</td>
<td>2,524</td>
<td>2.52</td>
<td>$18.71</td>
</tr>
<tr>
<td>n Butane</td>
<td>103,787</td>
<td>0.10</td>
<td>0.86</td>
<td>8.29</td>
<td>3,271</td>
<td>3.27</td>
<td>$27.10</td>
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<tr>
<td>iso Butane</td>
<td>100,176</td>
<td>0.10</td>
<td>0.91</td>
<td>9.08</td>
<td>3,261</td>
<td>3.26</td>
<td>$29.62</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>105,000</td>
<td>0.11</td>
<td>1.01</td>
<td>9.62</td>
<td>4,380</td>
<td>4.38</td>
<td>$42.13</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>8 $/MMBtu</th>
<th>9 Vapor Composition</th>
<th>10 Mixture (MMBtu/Mcf)</th>
<th>11 Value ($/Mcf) (= 8\times 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>2.96</td>
<td>82%</td>
<td>0.83</td>
<td>$2.46</td>
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<tr>
<td>Ethane</td>
<td>5.00</td>
<td>8%</td>
<td>0.14</td>
<td>$0.71</td>
</tr>
<tr>
<td>Propane</td>
<td>7.41</td>
<td>4%</td>
<td>0.10</td>
<td>$0.75</td>
</tr>
<tr>
<td>n Butane</td>
<td>8.29</td>
<td>3%</td>
<td>0.10</td>
<td>$0.81</td>
</tr>
<tr>
<td>iso Butane</td>
<td>9.08</td>
<td>1%</td>
<td>0.03</td>
<td>$0.30</td>
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<tr>
<td>Pentanes+</td>
<td>9.62</td>
<td>2%</td>
<td>0.09</td>
<td>$0.84</td>
</tr>
<tr>
<td>Total</td>
<td>1.29</td>
<td></td>
<td></td>
<td>$5.87</td>
</tr>
</tbody>
</table>

1 – Natural Gas Price assumed at $106/Mcm ($3/Mcf)
2 – Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX February 17, 2009
Is Recovery Profitable?

- Economics of installing vapor recovery units are attractive, particularly for larger units.

<table>
<thead>
<tr>
<th>Capacity (m³/day)</th>
<th>(Mcf/day)</th>
<th>Installation and Capital Costs ($/year)</th>
<th>Operating and Maintenance ($/year)</th>
<th>Value of Gas ($/year)</th>
<th>Payback (Months)</th>
<th>Internal Rate of Return (%)</th>
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<tbody>
<tr>
<td>700</td>
<td>25</td>
<td>35,738</td>
<td>7,367</td>
<td>25,000</td>
<td>25</td>
<td>40</td>
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<tr>
<td>1,400</td>
<td>50</td>
<td>46,073</td>
<td>8,419</td>
<td>50,000</td>
<td>14</td>
<td>86</td>
</tr>
<tr>
<td>2,800</td>
<td>100</td>
<td>55,524</td>
<td>10,103</td>
<td>101,000</td>
<td>8</td>
<td>162</td>
</tr>
<tr>
<td>5,700</td>
<td>200</td>
<td>74,425</td>
<td>11,787</td>
<td>205,000</td>
<td>5</td>
<td>259</td>
</tr>
<tr>
<td>14,200</td>
<td>500</td>
<td>103,959</td>
<td>16,839</td>
<td>510,000</td>
<td>3</td>
<td>474</td>
</tr>
</tbody>
</table>

1 - All costs and revenues are represented in U.S. economics
2 - Unit cost plus estimated installation at 75% of unit cost
3 - $207/Mcm x 1/2 capacity x 365 x 95%
Mcf = thousand cubic feet
Industry Experience: Anadarko

- **Vapor Recover Tower (VRT)**
  - Add separation vessel between heater treater or low pressure separator and storage tanks that operates at or near atmospheric pressure
    - Operating pressure range: 0.07 atm to 0.34 atm
  - Compressor (VRU) is used to capture gas from VRT
  - Oil/condensate gravity flows from VRT to storage tanks
    - VRT insulates the VRU from gas surges with stock tank level changes
    - VRT more tolerant to higher and lower pressures
    - Stable pressure allows better operating factor for VRU
Industry Experience: Anadarko

- VRT reduces pressure drop from approximately 4.4 atm to 1.1 to 1.3 atm
  - Insulates the VRU from crude tank oil movements
  - Captures more product for sales
  - Anadarko netted between $7 to $8 million from 1993 to 1999 by utilizing VRT/VRU configuration

- Equipment Capital Cost: $11,000

- Standard size VRTs available based on oil production rate
  - 51 by 10.7 meters
  - 10.7 by 1.2 meters

- Anadarko has installed over 300 VRT/VRUs since 1993 in the U.S. and continues on an as needed basis
VRT/VRU Photos

Source: Anadarko
VRT/VRU Photos

Source: Anadarko
Lessons Learned

- Vapor recovery can yield generous returns when there are market outlets for recovered gas
  - Recovered high heat content gas has extra value
  - Vapor recovery technology can be highly cost-effective in most general applications

- Venturi jet models work well in certain niche applications, with reduced operating and maintenance costs
Lessons Learned (continued)

- VRU should be sized for maximum volume expected from storage tanks (rule-of-thumb is to double daily average volume)
- Rotary vane, screw or scroll type compressors recommended for VRUs where Venturi ejector jet designs are not applicable
- EVRU™ recommended where there is a high pressure gas compressor with excess capacity
- Vapor Jet recommended where there is produced water, less than 2.1 Mcm per day gas and discharge pressures below 3.7 atm
Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies and practices
- Actual costs and benefits
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