Installing Vapor Recovery Units

Lessons Learned from the Natural Gas STAR Program

Montana Petroleum Association
Producers and Processors
Technology Transfer Workshop

Billings, Montana
August 31, 2009

epa.gov/gasstar

Reduction Opportunities: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Lessons Learned
Sources of Methane Losses

- A storage tank battery can vent 5 to 500 thousand cubic feet (Mcf) of natural gas and light hydrocarbon vapors to the atmosphere each day
- Flash losses
  - Occur when crude oil or condensate is transferred from a gas-oil separator at higher pressure to a storage tank at atmospheric pressure
- Working losses
  - Occur when crude or condensate levels change and when liquid 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

Types of Vapor Recovery Units

- Conventional vapor recovery units (VRUs)
- Venturi ejector vapor recovery units (EVRU™) or Vapor Jet Systems
  - Use Venturi jet ejectors in place of rotary compressors
Conventional Vapor Recovery Unit

Source: Evans & Nelson (1968)

Vapor Recovery Installations

Rock Springs, WY Rotary Vane VRU Installation
Courtesy of Hybon Engineering
Venturi Jet Ejector*

High-Pressure Motive Gas (~850 psig)

Low-Pressure Vent Gas from Tanks (0.10 to 0.30 psig)

Suction Pressure (-0.05 to 0 psig)

Discharge Gas (~40 psia)

Pressure Indicator

Temperature Indicator

Flow Safety Valve

*EVRU™ Patented by COMM Engineering

Adapted from SRI/USEPA-GHG-VR-19

psig = pound per square inch, gauge

psia = pounds per square inch, absolute

Vapor Recovery with Ejector

Gas to Sales @ 1000 psig

281 Mcf/day Net Recovery

900 Mcf/day

Mcf = Thousand cubic feet
Vapor Jet System*

- Utilizes produced water in closed loop system to effect gas gathering from tanks
- Small centrifugal pump forces water into Venturi jet, creating vacuum effect
- Limited to gas volumes of 77 Mcf/day and discharge pressure of 40 psig

*Patented by Hy-Bon Engineering
Criteria for Vapor Recovery Unit Locations

- Steady source and sufficient quantity of losses
- Outlet for recovered gas; or possible onsite use
- Tank batteries subject to air regulations

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%)
Estimated Volume of Tank Vapors

What is the Recovered Gas Worth?

- Value depends on heat content of gas
- Value depends on how gas is used
  - On-site fuel
  - Natural gas pipeline
  - Gas processing plant
- Gross revenue per year = (Q x P x 365) + NGL
  - Q = Rate of vapor recovery (Mcf per day)
  - P = Price of natural gas
  - NGL = Value of natural gas liquids
### Value of Natural Gas Liquids

<table>
<thead>
<tr>
<th>Component</th>
<th>Btu/gallon</th>
<th>$/gallon</th>
<th>$/MMBtu/($/32)</th>
<th>MMBtu/MMcf</th>
<th>$/MMBtu/MMcf</th>
<th>Btu/cf</th>
<th>$/MMBtu/MMcf</th>
<th>MMBtu/MMcf</th>
<th>$/MMBtu/MMcf</th>
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</thead>
<tbody>
<tr>
<td>Methane</td>
<td>59,755</td>
<td>0.06</td>
<td>0.42</td>
<td>7.00</td>
<td>1.01</td>
<td>1.01</td>
<td>7.07</td>
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<td></td>
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<tr>
<td>Ethane</td>
<td>74,010</td>
<td>0.07</td>
<td>0.37</td>
<td>5.21</td>
<td>1.77</td>
<td>1.77</td>
<td>9.23</td>
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<td></td>
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<tr>
<td>Propane</td>
<td>91,740</td>
<td>0.09</td>
<td>0.68</td>
<td>7.58</td>
<td>2.52</td>
<td>2.52</td>
<td>19.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n Butane</td>
<td>103,787</td>
<td>0.10</td>
<td>0.86</td>
<td>8.60</td>
<td>3.27</td>
<td>3.27</td>
<td>28.11</td>
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<td></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>3.26</td>
<td>3.26</td>
<td>29.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentanes+</td>
<td>105,000</td>
<td>0.11</td>
<td>1.01</td>
<td>9.14</td>
<td>4.38</td>
<td>4.38</td>
<td>40.02</td>
<td></td>
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</tr>
</tbody>
</table>

### Vapor Mixture Value

<table>
<thead>
<tr>
<th>Component</th>
<th>Vapor Composition</th>
<th>Mixture Value (MMBtu/MMcf)</th>
<th>Value ($/MMcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>82%</td>
<td>0.83</td>
<td>7.07</td>
</tr>
<tr>
<td>Ethane</td>
<td>8%</td>
<td>0.14</td>
<td>0.73</td>
</tr>
<tr>
<td>Propane</td>
<td>4%</td>
<td>0.10</td>
<td>0.76</td>
</tr>
<tr>
<td>n Butane</td>
<td>3%</td>
<td>0.10</td>
<td>0.86</td>
</tr>
<tr>
<td>iso Butane</td>
<td>1%</td>
<td>0.08</td>
<td>0.27</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>2%</td>
<td>0.09</td>
<td>0.82</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.289</td>
<td>9.25</td>
</tr>
</tbody>
</table>

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1 – Natural Gas Price assumed at $7.00/MMBtu
2 – Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX February 17, 2009

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### Is Recovery Profitable?

#### Financial Analysis for a Conventional VRU Project

<table>
<thead>
<tr>
<th>Peak Capacity (Mcf/day)</th>
<th>Installation &amp; Capital Costs¹ ($)</th>
<th>O&amp;M Costs² ($/year)</th>
<th>Value of Gas² ($/year)</th>
<th>Annual Savings ($)</th>
<th>Simple Payback (months)</th>
<th>Internal Rate of Return</th>
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</thead>
<tbody>
<tr>
<td>25</td>
<td>$35,738</td>
<td>$7,367</td>
<td>$42,203</td>
<td>$34,836</td>
<td>13</td>
<td>94%</td>
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<tr>
<td>50</td>
<td>$46,073</td>
<td>$8,419</td>
<td>$84,406</td>
<td>$75,987</td>
<td>8</td>
<td>164%</td>
</tr>
<tr>
<td>100</td>
<td>$55,524</td>
<td>$10,103</td>
<td>$168,812</td>
<td>$158,709</td>
<td>5</td>
<td>286%</td>
</tr>
<tr>
<td>200</td>
<td>$74,425</td>
<td>$11,787</td>
<td>$337,625</td>
<td>$325,838</td>
<td>3</td>
<td>438%</td>
</tr>
<tr>
<td>500</td>
<td>$103,959</td>
<td>$16,839</td>
<td>$844,062</td>
<td>$827,233</td>
<td>2</td>
<td>796%</td>
</tr>
</tbody>
</table>

1 – Unit cost plus estimated installation of 75% of unit cost
2 – $9.25 x ½ peak capacity x 365; Assumed price includes Btu enriched gas (1.289 MMBtu/MMcf)
Industry Experience: ConocoPhillips

- Vapor recovery units installed in Baker, MT
- Anticipated multiple sites, so detailed technical review of options was conducted
- Volumes per site ranged from 30 Mcfd to 350 Mcfd
- Pipeline pressure ranged from 20 to 40 psig
- Captures vapors from
  - Crude oil storage tanks
  - Produced Water tanks
  - All manifolded together in closed loop system
  - Gas blanket system used to backfill tanks

Industry Experience: ConocoPhillips

- Evaluated rotary screw, rotary vane, vapor jet and EVRU
- Selected rotary vane VRU’s due to wide range of volumes of gas and low discharge pressure across the sites
- Pilot project on 3 locations, then added 6 add’tl sites
- Designed for optimum gas capture
  - Pressure transmitter on the tanks
  - Sloping lines to the VRU
  - Package specifically designed for vapor recovery service
  - Automated liquid handling and bypass systems
Baker, MT ConocoPhillips VRU installation; Picture Courtesy of Hy-bon Engineering
Industry Experience: ConocoPhillips

- Payback Economics – Project for 9 Tank Batteries

  - Purchase Price for 9 VRU’s $475,000
  - Estimate Install Cost $ 237,500
  - Total Capital Costs $ 712,500

- Approx Gas Revenue
  - 1,050 mcfd x $6/Mcf (2005 & 6) X 30 days = $189,000/ mo

- Payback on Capital Investment < 4 months
- Installed in 2005 & early 2006 – all locations continue to generate incremental revenue and meet environmental compliance goals today
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: 1 psi to 5 psi
  - Compressor (VRU) is used to capture gas from VRT
  - Oil/Condensate gravity flows from VRT to storage tanks

VRT reduces pressure drop from approximately 50 psig to 1-5 psig
- Reduces flashing losses
- Captures more product for sales
- Anadarko netted between $7 to $8 million from 1993 to 1999 by utilizing VRT/VRU configuration

Courtesy of Anadarko
Industry Experience: Anadarko

- Standard size VRTs available based on oil production rate
  - 20” x 35’
  - 48” x 35’
- Anadarko has installed over 300 VRT/VRUs since 1993 and continues on an as needed basis
- Equipment Capital Cost: $11,000
  - (does not include VRU)

Lessons Learned

- Vapor recovery can yield generous returns when there are market outlets for recovered gas
- Potential for reduced compliance costs can be considered when evaluating economics of VRU, EVRU™, or Vapor Jet
- 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 75 Mcf per day gas and discharge pressures below 40 psig
Discussion

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