Installing Vapor Recovery Units

Lessons Learned from the Natural Gas STAR Program

Source Reduction Training

Interstate Oil and Gas Compact Commission

Charleston, West Virginia
February 27, 2009

epa.gov/gasstar

Reduction Opportunities: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Lessons Learned
Methane Losses from Storage Tanks

- **U.S. natural gas production sector emissions in 2006**

**Sources of Methane Losses**

- A storage tank battery can vent 5,000 to 500,000 thousand cubic feet (Mcf) of natural gas and light hydrocarbon vapors to the atmosphere each year.

- **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 the tank is agitated.

- **Standing losses**
  - Occur with daily and seasonal temperature and barometric pressure changes.


Natural Gas STAR reductions from gathering and boosting operations have been moved to the production sector.
Tank Venting Emissions

- Video recording of tank venting emissions

Video provided by Hy-Bon Engineering

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
- Use Venturi jet ejectors in place of rotary compressors

Conventional Vapor Recovery Unit

Source: Evans & Nelson (1968)
Vapor Recovery Installations

Venturi Jet Ejector*

- High-Pressure Motive Gas (~850 psig)
- Flow Safety Valve
- Pressure Indicator
- Temperature Indicator
- Low-Pressure Vent Gas from Tanks (0.10 to 0.30 psig)
- Suction Pressure (-0.05 to 0 psig)
- Discharge Gas (~40 psia)

*EVRUTM 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

- 5,000 Mcf/day Gas
- 5,000 barrels/day Oil

LP Separator

Compressor

Gas to Sales @ 1000 psig

6,200 Mcf/day

281 Mcf/day Net Recovery

900 Mcf/day

300 Mcf/day Gas

(19 Mcf/day incremental fuel)

Ejector

Ratio Motive / Vent = 3
= 900/300

Net Recovery Mcf = Thousand cubic feet

Oil & Gas Well

Oil

Gas

Crude Oil Stock Tank

Oil to Sales

Vapor Jet System*

*Patented by Hy-Bon Engineering
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
- Tank batteries not 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

\[ \text{Vapor Vented from Tanks, cubic foot / barrel} = \frac{110}{\text{Gas/Oil Ratio}} \times \text{Pressure of Vessel Dumping to Tank (Psig)} \]

\( ^0 \text{API} = \text{API gravity} \)
Estimated Volume of Tank Vapors

Atmospheric tanks may emit large amounts of tank vapors at relatively low separator pressure

Vasquez-Beggs Equation

\[ \text{GOR} = A \times \left( \frac{G_{\text{tank gas}}}{G_{\text{oil}}} \right) \times (P_{\text{sep}} + 14.7)^B \times \exp \left( \frac{C \times G_{\text{oil}}}{T_{\text{sep}} + 460} \right) \]

where,

- GOR = Ratio of flash gas production to standard stock tank barrels of oil produced, in acfs/bbl oil (barrels of oil converted to 60°F)
- G_{\text{tank gas}} = Specific gravity of the tank flash gas, where \( s = 1 \). A suggested default value for G_{\text{tank gas}} is 1.2 (TNRCC, Vasquez, 1990)
- G_{\text{oil}} = API gravity of stock tank oil at 60°F
- P_{\text{sep}} = Pressure in separator, in psig
- T_{\text{sep}} = Temperature in separator, °F

For G_{\text{oil}} < 30°API, \( A = 0.0362, B = 1.0937, \) and \( C = 23.724 \)
For G_{\text{oil}} > 30°API, \( A = 0.0178, B = 1.187, \) and \( C = 23.931 \)

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

\[ \text{Gross revenue per year} = (Q \times P \times 365) + \text{NGL} \]

- 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>1 Btu/gallon</th>
<th>2 MMBtu/gallon</th>
<th>3 $/gallon</th>
<th>4 $/MMBtu/L1 (gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>59,755</td>
<td>0.06</td>
<td>0.42</td>
<td>7.00</td>
</tr>
<tr>
<td>Ethane</td>
<td>74,910</td>
<td>0.07</td>
<td>0.37</td>
<td>5.21</td>
</tr>
<tr>
<td>Propane</td>
<td>91,740</td>
<td>0.09</td>
<td>0.68</td>
<td>7.58</td>
</tr>
<tr>
<td>n-Butane</td>
<td>103,787</td>
<td>0.10</td>
<td>0.86</td>
<td>8.60</td>
</tr>
<tr>
<td>i-Butane</td>
<td>100,176</td>
<td>0.10</td>
<td>0.91</td>
<td>9.08</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>105,000</td>
<td>0.11</td>
<td>1.01</td>
<td>9.14</td>
</tr>
</tbody>
</table>

5 Btu/cf  6 MMBtu/Mcf  7 $/Mcf  8 $/MMBtu  9 Vapor Composition (MMBtu/Mcf)  10 Value ($/Mcf)  11 Value ($/MMBtu)

<table>
<thead>
<tr>
<th>Component</th>
<th>5 Btu/cf</th>
<th>6 MMBtu/Mcf</th>
<th>7 $/Mcf (4*6)</th>
<th>8 $/MMBtu</th>
<th>9 Vapor Composition</th>
<th>10 Value ($/Mcf)</th>
<th>11 Value ($/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>1.012</td>
<td>1.01</td>
<td>7.07</td>
<td>7.00</td>
<td>82%</td>
<td>0.83</td>
<td>5.81</td>
</tr>
<tr>
<td>Ethane</td>
<td>1.773</td>
<td>1.77</td>
<td>9.23</td>
<td>5.21</td>
<td>8%</td>
<td>0.14</td>
<td>0.73</td>
</tr>
<tr>
<td>Propane</td>
<td>2.524</td>
<td>2.52</td>
<td>19.10</td>
<td>7.58</td>
<td>4%</td>
<td>0.10</td>
<td>0.76</td>
</tr>
<tr>
<td>n-Butane</td>
<td>3.271</td>
<td>3.27</td>
<td>28.11</td>
<td>8.60</td>
<td>3%</td>
<td>0.10</td>
<td>0.86</td>
</tr>
<tr>
<td>i-Butane</td>
<td>3.258</td>
<td>3.25</td>
<td>29.58</td>
<td>9.08</td>
<td>1%</td>
<td>0.03</td>
<td>0.27</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>4.380</td>
<td>4.38</td>
<td>40.02</td>
<td>9.14</td>
<td>2%</td>
<td>0.09</td>
<td>0.82</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.289</td>
<td>9.25</td>
</tr>
</tbody>
</table>

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

### Cost of a Conventional VRU

#### Vapor Recovery Unit Sizes and Costs

<table>
<thead>
<tr>
<th>Capacity (Mcf/day)</th>
<th>Compressor Horsepower</th>
<th>Capital Costs ($)</th>
<th>Installation Costs ($)</th>
<th>O&amp;M Costs ($/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>5 to 10</td>
<td>20,421</td>
<td>10,207 to 20,421</td>
<td>7,367</td>
</tr>
<tr>
<td>50</td>
<td>10 to 15</td>
<td>26,327</td>
<td>13,164 to 26,327</td>
<td>8,419</td>
</tr>
<tr>
<td>100</td>
<td>15 to 25</td>
<td>31,728</td>
<td>15,864 to 31,728</td>
<td>10,103</td>
</tr>
<tr>
<td>200</td>
<td>30 to 50</td>
<td>42,529</td>
<td>21,264 to 42,529</td>
<td>11,787</td>
</tr>
<tr>
<td>500</td>
<td>60 to 80</td>
<td>59,405</td>
<td>29,703 to 59,405</td>
<td>16,839</td>
</tr>
</tbody>
</table>

Cost information provided by United States Natural Gas STAR companies and VRU manufacturers, 2006 basis.
Is Recovery Profitable?

### Financial Analysis for a Conventional VRU Project

<table>
<thead>
<tr>
<th>Peak Capacity (Mcf/day)</th>
<th>Installation &amp; Capital Costs(^1) ($</th>
<th>O&amp;M Costs ($/year)</th>
<th>Value of Gas(^2) ($/year)</th>
<th>Annual Savings ($)</th>
<th>Simple Payback (months)</th>
<th>Internal Rate of Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>$35,738</td>
<td>$7,367</td>
<td>$77,106</td>
<td>$69,739</td>
<td>10</td>
<td>121%</td>
</tr>
<tr>
<td>50</td>
<td>$46,073</td>
<td>$8,419</td>
<td>$154,213</td>
<td>$145,794</td>
<td>6</td>
<td>204%</td>
</tr>
<tr>
<td>100</td>
<td>$55,524</td>
<td>$10,103</td>
<td>$308,425</td>
<td>$298,322</td>
<td>4</td>
<td>352%</td>
</tr>
<tr>
<td>200</td>
<td>$74,425</td>
<td>$11,787</td>
<td>$616,850</td>
<td>$605,063</td>
<td>3</td>
<td>537%</td>
</tr>
<tr>
<td>500</td>
<td>$103,959</td>
<td>$16,839</td>
<td>$1,542,125</td>
<td>$1,525,286</td>
<td>2</td>
<td>974%</td>
</tr>
</tbody>
</table>

\(^1\) – Unit cost plus estimated installation of 75% of unit cost

\(^2\) – $16.90 x \(\frac{1}{2}\) peak capacity x 365, Assumed price includes Btu enriched gas (1.289 MMMBtu/Mcf)

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Industry Experience: EnCana Oil & Gas

- Vapor recovery unit installed in Frenchie Draw, WY
- Captures vapors from
  - Separators
  - Crude oil storage tank
  - Non-condensable dehydrator still gas
- VRU designed to handle 500 Mcf/day
  - Additional capacity over the estimated 284 Mcf/day of total gas from all emission sources
Industry Experience: EnCana Oil & Gas

- Quantify the volume of vapor emissions

![Diagram](Image)

Total Emissions - 284 MSCFD

Source: EnCana Oil & Gas (USA) Inc.

EnCana Oil & Gas: Project Costs

- Determine the cost of VRU project

**Installation**

- VRU Unit (500 Mcfd) - $90,000
- Generator - $85,000
- Vent Header - $25,000
- Labor - $200,000
- TOTAL - $400,000

**O & M**

- VRU Unit (500 Mcfd) - $15,000
- Generator - $18,000
- Fuel - $73,000
- TOTAL - $106,000

Source: EnCana Oil & Gas (USA) Inc.
EnCana Oil & Gas: Project Economics

Evaluate VRU economics

- Capacity: 500 Mcfd
- Installation Cost: $400,000
- O&M: $106,000/year
- Value of Gas*: $788,400/year
- Payback: 7 months
- Return on Investment: 170%

*Gas price assumed to be $7.60 by Encana

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
Industry Experience: Anadarko

- 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

![Image](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

![Image](Courtesy of Anadarko)
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