Reducing Methane Emissions with Vapor Recovery on Storage Tanks

Lessons Learned from Natural Gas STAR

Producers Technology Transfer Workshop

Devon Energy and EPA’s Natural Gas STAR Program
Forth Worth, TX
June 6, 2006
Vapor Recovery Units: Agenda

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

- Storage tanks are responsible for 4% of methane emissions in natural gas and oil production sector
  - 96% of tank losses occur from tanks without vapor recovery

- A storage tank battery can vent 4,900 to 96,000 thousand cubic feet (Mcf) 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

### Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2004

- Pneumatic Devices: 60 Bcf
- Other Sources: 14 Bcf
- Offshore Operations: 30 Bcf
- Dehydrators and Pumps: 18 Bcf
- Meters and Pipeline Leaks: 9 Bcf
- Well Venting and Flaring: 9 Bcf
- Gas Engine Exhaust: 12 Bcf
- Storage Tank Venting: 7 Bcf

Bcf = billion cubic feet
Sources of Methane Losses

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 rotary compressor to suck vapors out of atmospheric pressure storage tanks
  - Require electrical power or engine driver

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

Source: Evans & Nelson (1968)
Vapor Recovery Installations
Vapor Recovery Installations
Venturi Jet Ejector*

High-Pressure Motive Gas (~850 psig)

Flow Safety Valve

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

Pressure Indicator

Temperature Indicator

Suction Pressure (-0.05 to 0 psig)

Discharge Gas (~40 psia)

*EVRU™ Patented by COMM Engineering

Adapted from SRI/USEPA-GHG-VR-19

psig = pound per square inch, gauge
psia = pounds per square inch, atmospheric
Vapor Recovery with Ejector

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

LP Separator

Compressor

6,200 Mcf/day

Gas to Sales @ 1000 psig

281 Mcf/day Net Recovery

900 Mcf/day

(19 Mcf/day incremental fuel)

300 Mcf/day Gas

300 Mcf/day Gas

Ejector

Ratio Motive / Vent = 3
= 900/300

281 Mcf/day Net Recovery

Oil & Gas Well

Crude Oil Stock Tank

Oil

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
  - 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
- 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%)
- Measure losses using recording manometer and well tester or ultrasonic meter over several cycles (± 5%)
  - This is the best approach for facility design
Estimated Volume of Tank Vapors

Vapor Vented from Tanks, cubic foot / barrel

Gas/Oil Ratio

Pressure of Vessel Dumping to Tank (Psig)

10 20 30 40 50 60 70 80

API Gravities

°API = API gravity
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
Value of Recovered Gas

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></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu/gallon</td>
<td>MMBtu/gallon</td>
<td>$/gallon</td>
<td>$/MMBtu (^1,2) ((=3/2))</td>
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<tr>
<td>Methane</td>
<td>59,755</td>
<td>0.06</td>
<td>0.43</td>
<td>7.15</td>
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<tr>
<td>Ethane</td>
<td>74,010</td>
<td>0.07</td>
<td>0.64</td>
<td>9.14</td>
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<tr>
<td>Propane</td>
<td>91,740</td>
<td>0.09</td>
<td>0.98</td>
<td>10.89</td>
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<tr>
<td>n Butane</td>
<td>103,787</td>
<td>0.10</td>
<td>1.32</td>
<td>13.20</td>
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<tr>
<td>iso Butane</td>
<td>100,176</td>
<td>0.10</td>
<td>1.42</td>
<td>14.20</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>105,000</td>
<td>0.11</td>
<td>1.50</td>
<td>13.63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu/cf</td>
<td>MMBtu/Mcf</td>
<td>$/Mcf</td>
<td>$/MMBtu</td>
<td>Vapor Composition</td>
<td>Mixture Value (MMBtu/Mcf) ((=8*10))</td>
</tr>
<tr>
<td>Methane</td>
<td>1,012</td>
<td>1.01</td>
<td>$ 7.22</td>
<td>7.15</td>
<td>82%</td>
<td>0.83</td>
</tr>
<tr>
<td>Ethane</td>
<td>1,773</td>
<td>1.77</td>
<td>$ 16.18</td>
<td>9.14</td>
<td>8%</td>
<td>0.14</td>
</tr>
<tr>
<td>Propane</td>
<td>2,524</td>
<td>2.52</td>
<td>$ 27.44</td>
<td>10.89</td>
<td>4%</td>
<td>0.10</td>
</tr>
<tr>
<td>n Butane</td>
<td>3,271</td>
<td>3.27</td>
<td>$ 43.16</td>
<td>13.20</td>
<td>3%</td>
<td>0.10</td>
</tr>
<tr>
<td>iso Butane</td>
<td>3,261</td>
<td>3.26</td>
<td>$ 46.29</td>
<td>14.20</td>
<td>1%</td>
<td>0.03</td>
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<tr>
<td>Pentanes+</td>
<td>4,380</td>
<td>4.38</td>
<td>$ 59.70</td>
<td>13.63</td>
<td>2%</td>
<td>0.09</td>
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<tr>
<td>Total</td>
<td>1,289</td>
<td>1.289</td>
<td>$ 11.28</td>
<td></td>
<td></td>
<td></td>
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</tbody>
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1 Natural Gas Price assumed at $7.15/MMBtu as on Mar 16, 2006 at Henry Hub
2 Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX, January 11, 2006
3 Other natural gas liquids information obtained from Oil and Gas Journal, Refining Report, March 19, 2001, p. 83

Btu = British Thermal Units, MMBtu = Million British Thermal Units, Mcf = Thousand Cubic Feet
## Cost of a Conventional VRU

<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>5-10</td>
<td>15,125</td>
<td>7,560 - 15,125</td>
<td>5,250</td>
</tr>
<tr>
<td>50</td>
<td>10-15</td>
<td>19,500</td>
<td>9,750 - 19,500</td>
<td>6,000</td>
</tr>
<tr>
<td>100</td>
<td>15 - 25</td>
<td>23,500</td>
<td>11,750 - 23,500</td>
<td>7,200</td>
</tr>
<tr>
<td>200</td>
<td>30 - 50</td>
<td>31,500</td>
<td>15,750 - 31,500</td>
<td>8,400</td>
</tr>
<tr>
<td>500</td>
<td>60 - 80</td>
<td>44,000</td>
<td>22,000 - 44,000</td>
<td>12,000</td>
</tr>
</tbody>
</table>

Cost information provided by United States Natural Gas STAR companies and VRU manufacturers, 1998 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) ($ / year)</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>Return on Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>26,470</td>
<td>5,250</td>
<td>$ 51,465</td>
<td>$ 46,215</td>
<td>7</td>
<td>175%</td>
</tr>
<tr>
<td>50</td>
<td>34,125</td>
<td>6,000</td>
<td>$102,930</td>
<td>$ 96,930</td>
<td>5</td>
<td>284%</td>
</tr>
<tr>
<td>100</td>
<td>41,125</td>
<td>7,200</td>
<td>$205,860</td>
<td>$ 198,660</td>
<td>3</td>
<td>483%</td>
</tr>
<tr>
<td>200</td>
<td>55,125</td>
<td>8,400</td>
<td>$411,720</td>
<td>$ 403,320</td>
<td>2</td>
<td>732%</td>
</tr>
<tr>
<td>500</td>
<td>77,000</td>
<td>12,000</td>
<td>$1,029,300</td>
<td>$ 1,017,300</td>
<td>1</td>
<td>1321%</td>
</tr>
</tbody>
</table>

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

\(^2\) $11.28 \times \frac{1}{2} \text{ capacity} \times 365, Assumed price includes Btu enriched gas (1.289 MMBtu/Mcf)
Industry Experience

Top five United States companies for emissions reductions using VRUs in 2004

<table>
<thead>
<tr>
<th>Company</th>
<th>2004 Annual Reductions (Mcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company 1</td>
<td>1,273,059</td>
</tr>
<tr>
<td>Company 2</td>
<td>614,977</td>
</tr>
<tr>
<td>Company 3</td>
<td>468,354</td>
</tr>
<tr>
<td>Company 4</td>
<td>412,049</td>
</tr>
<tr>
<td>Company 5</td>
<td>403,454</td>
</tr>
</tbody>
</table>
Industry Experience: Chevron

Chevron installed eight VRUs at crude oil stock tanks in 1996

<table>
<thead>
<tr>
<th>Methane Loss Reduction (Mcf/unit/year)</th>
<th>Approximate Savings per Unit(^1)</th>
<th>Total Savings</th>
<th>Total Capital and Installation Costs</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>21,900</td>
<td>$153,300</td>
<td>$1,226,400</td>
<td>$240,000</td>
<td>3 months</td>
</tr>
</tbody>
</table>

\(^1\)Assumes a $7 per Mcf gas price; excludes value of recovered natural gas liquids. Refer to the Natural Gas STAR Lessons Learned for more information.
Industry Experience: Devon Energy

- For 5 years, Devon employed the Vapor Jet system and recovered more than 55 MMcf of gas from crude oil stock tanks.
- Prior to installing the system, tank vapor emissions were about 20 Mcf per day.
- Installed a system with maximum capacity of 77 Mcf per day, anticipating production increases.
- Revenue was about $91,000 with capital cost of $25,000 and operating expenses less than $0.40 per Mcf of gas recovered.

  At today’s gas prices, payback is less than 5 months.

MMcf = million cubic feet
Industry Experience: EVRU™

Facility Information
- Oil production: 5,000 Barrels/day, 30° API
- Gas production: 5,000 Mcf/day, 1060 Btu/cf
- Separator: 50 psig, 100°F
- Storage tanks: Four 1500 barrel tanks @1.5 ounces relief
- Measured tank vent: 300 Mcf/day @ 1,850 Btu/cf

EVRU™ Installation Information
- Motive gas required: 900 Mcf/day
- Gas sales: 5,638 MMBtu/day
- Reported gas value: $28,190/day @ $5/MBtu
- Income increase: $2,545/day = $76,350/month
- Reported EVRU™ cost: $75,000
- Payout: <1 month
Lessons Learned

zą 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
  ♦ Potential for reduced compliance costs can be considered when evaluating economics of VRU, EVRU™, or Vapor Jet
Lessons Learned (cont’d)

- VRU should be sized for maximum volume expected from storage tanks (rule-of-thumb is to double daily average volume)
- Rotary vane or screw 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 less than 75 Mcf per day and discharge pressures below 40 psig
Discussion Questions

- To what extent are you implementing this technology?
- How can this technology be improved upon or altered for use in your operation(s)?
- What is stopping you from implementing this technology (technological, economic, lack of information, manpower, etc.)?