Reducing Methane Emissions with Vapor Recovery on Storage Tanks

IAPG & US EPA Technology Transfer Workshop

November 5, 2008
Buenos Aires, Argentina
Vapor Recovery Units: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Project Summary for Argentina
- Discussion Questions
Methane Losses from Crude Oil and Condensate Storage Tanks

- Condensate storage tanks account for:
  - 5% of methane emissions in the U.S. production, gathering, and boosting sectors (excl. offshore operations)

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Natural Gas STAR reductions data shown as published in the inventory.
Methane Losses from Crude Oil and Condensate Storage Tanks

- In Argentina methane fugitive emissions account 90% (588,41 MtonCO\textsubscript{2}e/year) from energy sector\textsuperscript{1}
  - 12,45 MtonCO\textsubscript{2}e fugitive methane emissions from oil sector
  - 0,28 MtonCO\textsubscript{2}e fugitive methane emissions from storage systems (2% of Oil Sector)

\textbf{Fugitive Methane Emissions From Oil Sector In Argentina}

\textbf{Production} 72%

\textbf{Storage} 2%

\textbf{Refining} 13%

\textbf{Transportation} 13%

\textsuperscript{1} All data extracted from: Secretaría de Ambiente y Desarrollo Sustentable. Segunda Comunicación Nacional de la República Argentina a la UNFCCC. October, 2007. Fundación Bariloche and Argentina’s Government.
Sources of Methane Losses from Tanks

- A storage tank battery can vent 142 to 14.158 Mm³ of natural gas and light hydrocarbon vapors to the atmosphere each year
  - Vapor losses are primarily a function of oil or condensate throughput, gravity, and gas-oil separator pressure
- 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
  - 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 screw or vane compressor to suck vapors out of atmospheric pressure storage tanks
  - Scroll compressors are new to this market
  - 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 a source of high pressure motive gas and intermediate pressure discharge system
  - Vapor Jet requires high pressure motive water
Conventional Vapor Recovery Unit

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

High-Pressure Motive Gas (~60 kg/cm²)

Flow Safety Valve

Pressure Indicator

Temperature Indicator

Low-Pressure Vent Gas from Tanks (0.7E10⁻² to 2.1E10⁻² kg/cm²)

Suction Pressure (-0.4E10⁻² to 0 kg/cm²)

Discharge Gas (~2.8 kg/cm²)

*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

- 142 Mm$^3$/day Gas
  - 5,000 barrels/day Oil
- 25,49 Mm$^3$/day Oil
- 175,56 Mm$^3$/day Gas
- Ratio Motive / Vent = 3
  - 900/300
- 8,5 Mm$^3$/day Gas
- 7,96 Mm$^3$/day Net Recovery
- 25,49 Mm$^3$/day
- Oil & Gas Well
- Crude Oil Stock Tank
- Compressor
- Oil to Sales
- Oil
- LP Separator
- Ejector
- Gas to Sales @ 70 kg/cm$^2$
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 2 Mm³/day and discharge pressure of 3 kg/cm²

*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
  - Dehydrator still vent
  - Pig trap vent

- 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%)
- 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
Estimated Volume of Tank Vapors

Pressure of Vessel Dumping to Tank (kg/cm²)

Gas/Oil Ratio

Vapor vented from Tanks, m³/barrel

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

<table>
<thead>
<tr>
<th></th>
<th>1 kCal/L</th>
<th>2 MkCal/L</th>
<th>3 US$/L</th>
<th>4 US$/MkCal&lt;sup&gt;1,2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>3.978</td>
<td>3.98</td>
<td>0.11</td>
<td>0.03</td>
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<tr>
<td>Ethane</td>
<td>4.927</td>
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<tr>
<td>Propane</td>
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<td>0.53</td>
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<tr>
<td>n Butane</td>
<td>6.909</td>
<td>6.91</td>
<td>0.66</td>
<td>0.09</td>
</tr>
<tr>
<td>iso Butane</td>
<td>6.669</td>
<td>6.67</td>
<td>0.66</td>
<td>0.10</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>6.990</td>
<td>6.99</td>
<td>0.81</td>
<td>0.12</td>
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### Vapor Composition

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<tr>
<th>Comp.</th>
<th>1  kCal/L</th>
<th>2  MkCal/L</th>
<th>3  US$/L</th>
<th>4  US$/MkCal&lt;sup&gt;1,2&lt;/sup&gt;</th>
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1 – Natural Gas Price assumed at US$0.03/MkCal as on Mar 16, 2006 at Henry Hub
2 – Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX July 11, 2008
# Cost of a Conventional VRU

<table>
<thead>
<tr>
<th>Capacity (Mm³/day)</th>
<th>Compressor Horsepower</th>
<th>Capital Costs (US$)</th>
<th>Installation Costs (US$)</th>
<th>O&amp;M Costs (US$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.71</td>
<td>5 to 10</td>
<td>20.421</td>
<td>10.207 to 20.421</td>
<td>7.367</td>
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<tr>
<td>1.42</td>
<td>10 to 15</td>
<td>26.327</td>
<td>13.164 to 26.327</td>
<td>8.419</td>
</tr>
<tr>
<td>2.83</td>
<td>15 to 25</td>
<td>31.728</td>
<td>15.864 to 31.728</td>
<td>10.103</td>
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<tr>
<td>5.66</td>
<td>30 to 50</td>
<td>42.529</td>
<td>21.264 to 42.529</td>
<td>11.787</td>
</tr>
<tr>
<td>14.16</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 (Mm³/day)</th>
<th>Installation &amp; Capital Costs¹ (US$)</th>
<th>O&amp;M Costs (US$/year)</th>
<th>Value of Gas² (US$/year)</th>
<th>Annual Savings (US$)</th>
<th>Simple Payback (months)</th>
<th>Internal Rate of Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.71</td>
<td>35.738</td>
<td>7.367</td>
<td>77.106</td>
<td>69.739</td>
<td>10</td>
<td>121%</td>
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<tr>
<td>1.42</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>2.83</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>5.66</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>14.16</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 – US$0.59 x ½ peak capacity x 365, Assumed price includes MkCal enriched gas (11.49 MkCal/m³)
Industry Experience: EnCana Oil & Gas

- Vapor recovery unit installed in Frenchie Draw, WY, U.S.
- Captures vapors from
  - Separators
  - Crude oil storage tank
  - Non-condensable dehydrator still gas
- VRU designed to handle 14 Mm$^3$/day
  - Additional capacity over the estimated 8 Mm$^3$/day of total gas from all emission sources
Industry Experience: EnCana Oil & Gas

- Quantify the volume of vapor emissions

Total Emissions- 8Mm³/D

1. FLASH LOSS (9 kg/cm²)
2. FLASH LOSS (14 kg/cm²)
3. FLASH LOSS (3 kg/cm²)
4. WORKING & BREATHING LOSS
5. STILL VENT NON CONDENSIBLE

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

- Determine the cost of VRU project

**Installation (US$)**

- VRU Unit (14 Mm³d) - 90,000
- Generator - 85,000
- Vent Header - 25,000
- Labor - 200,000
- **TOTAL** - 400,000

**O & M (US$)**

- VRU Unit (14 Mm³d) - 15,000
- Generator - 18,000
- Fuel - 73,000
- **TOTAL** - 106,000
EnCana Oil & Gas: Project Economics

- Evaluate VRU economics

- Capacity – 14 Mm³d
- Installation Cost - US$400.000
- O&M - US$106.000/year
- Value of Gas* - US$788.400/year
- Payback - 7 months
- Return on Investment - 170%

*Gas price assumed to be US$268.39/Mm³ 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: 0,1 – 0,4 kg/cm²
  - 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 3,5 kg/cm² to 0,1-0,4 kg/cm²
  - Reduces flashing losses
  - Captures more product for sales
  - Anadarko netted between US$7 to US$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
  - 51cm x 11 m
  - 122 cm x 11 m
- Anadarko has installed over 300 VRT/VRUs since 1993 and continues on an as needed basis
VRT/VRU Photos

Courtesy of Anadarko
This dual flooded screw package for PDVSA is designed for volumes to 0.14 MMm$^3$D; moving tank vapors from 0 to 14 kg/cm$^2$ in Eastern Venezuela.
At this location, three vru compressor packages were set in tandem to move 0.42 MMm³D of 630-655 kCal tank vapors.
Project Overview – PDVSA Gas Anaco (Venezuela)

- Vapor recovery units currently capture over 2.12 million cubic meter of previously vented and flared gas across 7 facilities
- Gas Anaco project, begun in 2006, targets over one billion cubic meter of gas across eastern Venezuela
- Conversion of much of the power and transportation infrastructure to natural gas is underway
Eni installed vapor recovery systems in their Dacion East and West facilities in Venezuela, each designed to move 40 Mm$^3$D of gas at pressures to 16 kg/cm$^2$
Vapor recovery units were installed to capture up to 40 Mm$^3$D per site

White paper was written shortly after installation on the economic success of the project

A highly valuable 70 API gravity condensate was recovered from the gas stream and used to blend with the primary low API gravity oil production – at an approximate daily rate of 100 to 150 barrels of condensate per unit.
Initial project will be capturing approximately 350 mcfd of vent gas from the Caricare oil storage and production facility.

Purpose of the project will be incremental capture of natural gas liquids from this gas stream.

Two additional sites are planned following successful installation of the first project.

Subsequent project to utilize flare gas is also being evaluated by Oxy Colombia.
Servipetrol/ Petrobras Bolivia

- Installing vapor recovery units in Caranda, Bolivia field later this year.
- 2,000 bopd; 40 api gravity crude; 3,5 kg/m² separator pressure
- Anticipate average of 4 Mm³d gas capture
- US$252,000 incremental revenue per year, plus value of condensate produced
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

- Potential for reduced compliance costs can be considered when evaluating economics of VRU, EVRU™, or Vapor Jet
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 Mm$^3$ per day gas and discharge pressures below 2,8 kg/cm$^2$