Vapor Recovery Units: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Discussion Questions
Sources of Methane Losses from Tanks

- A storage tank battery can vent 5 to 500 MMcf 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
- 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 (~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)

*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

5 MMcf/day Gas
5,000 bbl/day Oil

Oil & Gas Well

LP Separator

Compressor

Gas to Sales @ 1,000 psig
6.2 MMcf/day

300 Mcf/day Gas

Crude Oil Stock Tank

Oil to Sales

Ejector

Ratio Motive / Vent = 3
= 900/300

900 Mcf/day

281 Mcf/day Net Recovery

(19 Mcf/day incremental fuel)

300 Mcf/day Gas

40 psig
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
  - Dehydrator still vent
  - Pig trap vent

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

Vapor Vented from Tanks, Cubic foot / barrel
Gas/Oil Ratio

Pressure of Vessel Dumping to Tank (psig)

API Gravities

• Under 30° API
• 30° API to 39° API
• 40° API and Over

° 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 (MMBtu per day)
  - \(P\) = Price of natural gas (US$/MMBtu)
  - \(NGL\) = Value of natural gas liquids
### Value of Natural Gas Liquids

<table>
<thead>
<tr>
<th>NGL Components</th>
<th>1 Btu/gal</th>
<th>2 MMBtu/gal</th>
<th>3 US$/gal</th>
<th>4 US$/MMBtu(^1,2) (=3/2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>59,755</td>
<td>0.060</td>
<td>0.30</td>
<td>5.00</td>
</tr>
<tr>
<td>Ethane</td>
<td>74,010</td>
<td>0.074</td>
<td>0.26</td>
<td>3.45</td>
</tr>
<tr>
<td>Propane</td>
<td>91,740</td>
<td>0.092</td>
<td>0.45</td>
<td>5.09</td>
</tr>
<tr>
<td>n Butane</td>
<td>103,787</td>
<td>0.104</td>
<td>0.49</td>
<td>4.91</td>
</tr>
<tr>
<td>iso Butane</td>
<td>100,176</td>
<td>0.100</td>
<td>0.53</td>
<td>5.44</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>105,000</td>
<td>0.105</td>
<td>0.57</td>
<td>5.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5 Btu/cf</th>
<th>6 MMBtu/Mcf</th>
<th>7 US$/Mcf (=4*6)</th>
<th>8 US$/MMBtu</th>
<th>9 Vapor Composition</th>
<th>10 Mixture (MMBtu/Mcf)</th>
<th>11 Value (US$/Mcf) (=8*10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>1,000</td>
<td>1.000</td>
<td>$5.00</td>
<td>$5.00</td>
<td>82%</td>
<td>0.82</td>
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<tr>
<td>Ethane</td>
<td>1,773</td>
<td>1.773</td>
<td>$6.12</td>
<td>$3.45</td>
<td>8%</td>
<td>0.14</td>
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<tr>
<td>Propane</td>
<td>2,524</td>
<td>2.524</td>
<td>$12.86</td>
<td>$5.09</td>
<td>4%</td>
<td>0.10</td>
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<tr>
<td>n Butane</td>
<td>3,271</td>
<td>3.271</td>
<td>$16.05</td>
<td>$4.91</td>
<td>3%</td>
<td>0.10</td>
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<tr>
<td>iso Butane</td>
<td>3,261</td>
<td>3.261</td>
<td>$17.74</td>
<td>$5.44</td>
<td>1%</td>
<td>0.03</td>
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<tr>
<td>Pentanes+</td>
<td>4,380</td>
<td>4.380</td>
<td>$23.06</td>
<td>$5.27</td>
<td>2%</td>
<td>0.09</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1.28</td>
<td>6.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 – Natural Gas price assumed at Mexico’s cost US$5/MMBtu
2 – Prices of Individual NGL components estimated based on natural gas price in Mexico.
# 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 (US$)</th>
<th>Installation Costs (US$)</th>
<th>O&amp;M Costs (US$/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 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>25</td>
<td>35,738</td>
<td>7,367</td>
<td>28,398</td>
<td>21,031</td>
<td>20</td>
<td>51</td>
</tr>
<tr>
<td>50</td>
<td>46,073</td>
<td>8,419</td>
<td>56,795</td>
<td>48,376</td>
<td>11</td>
<td>102</td>
</tr>
<tr>
<td>100</td>
<td>55,524</td>
<td>10,103</td>
<td>113,590</td>
<td>103,487</td>
<td>6</td>
<td>185</td>
</tr>
<tr>
<td>200</td>
<td>74,425</td>
<td>11,787</td>
<td>227,181</td>
<td>215,394</td>
<td>4</td>
<td>289</td>
</tr>
<tr>
<td>500</td>
<td>103,959</td>
<td>16,839</td>
<td>567,952</td>
<td>551,113</td>
<td>2</td>
<td>530</td>
</tr>
</tbody>
</table>

1 - Unit cost plus estimated installation of 75% of unit cost
2 - US$6.22 x ½ peak capacity x 365, Assumed price includes enriched gas
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 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

**Total Emissions - 284 MSCFD**

1. FLASH LOSS (125 PSIG - ATM PSIG)
2. FLASH LOSS (200 PSIG - ATM PSIG)
3. FLASH LOSS (40 PSIG – ATM)
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$)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRU Unit (500 Mcfd)</td>
<td>90,000</td>
</tr>
<tr>
<td>Generator</td>
<td>85,000</td>
</tr>
<tr>
<td>Vent Header</td>
<td>25,000</td>
</tr>
<tr>
<td>Labor</td>
<td>200,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>400,000</td>
</tr>
</tbody>
</table>

**O & M (US$)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRU Unit (500 Mcfd)</td>
<td>15,000</td>
</tr>
<tr>
<td>Generator</td>
<td>18,000</td>
</tr>
<tr>
<td>Fuel</td>
<td>73,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>106,000</td>
</tr>
</tbody>
</table>
EnCana Oil & Gas: Project Economics

- Evaluate VRU economics

<table>
<thead>
<tr>
<th>Capacity –</th>
<th>500 Mcfd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Cost -</td>
<td>US$400,000</td>
</tr>
<tr>
<td>O&amp;M-</td>
<td>US$106,000/year</td>
</tr>
<tr>
<td>Value of Gas*-</td>
<td>US$515,594/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gas Price (US$/MMBtu)</th>
<th>3</th>
<th>5</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback (months)</td>
<td>24</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>NPV (US$)</td>
<td>281,682</td>
<td>973,023</td>
<td>1,664,364</td>
</tr>
</tbody>
</table>

*Conservatively based on Mexico natural gas price assumed to be US$5/MMBtu and 1 Mcf = 1 MMBtu
Industry Experience: Anadarko

- Vapor Recover Tower (VRT)
  - Add separation vessel between heater treatier or low pressure separator and storage tanks that operates at or near atmospheric pressure
    - Operating pressure range: 1–5 psig
  - 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
VRT/VRU Photos

Courtesy of Anadarko
Industry Experience: Anadarko

- VRT reduces pressure drop from approximately 50 psi to 1–5 psi
  - 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
  - 20” x 35’
  - 48” x 35’

- Anadarko has installed over 300 VRT/VRUs since 1993 and continues on an as needed basis
Servipetrol/ Petrobras Bolivia

- Installing vapor recovery units in Caranda, Bolivia field later this year.
- 2,000 bopd; 40 API gravity crude; 50 psig separator pressure
- Anticipate average of 141 Mcf/day gas capture
- US$257,800 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 75 Mcf per day gas and discharge pressures below 40 psig