Key Issues for Small Producers: Agenda

- Determining the appropriate emission reduction technologies

- Economic barriers to implementing technologies and practices

- Biggest opportunities for emissions reductions:
  - Pneumatic devices
  - Dehydrators
  - Compressor Rod Packing
Production in Pennsylvania

- In 2007, there were about 52,700 gas production wells producing 182 Bcf of dry gas

- That same year, EPA estimates 12 Bcf of gas may be vented or flared from unconventional well completions in Pennsylvania

- At $5.72 per Mcf, that equals about $70 million of lost revenue due to venting and flaring

How much revenue are you losing?

Where are your opportunities for emissions reductions?

[Diagram showing various sources of emissions and their amounts in Bcf]

- Well Venting and Flaring: 7 Bcf
- Storage Tank Venting: 5 Bcf
- Meters and Pipeline Leaks: 8 Bcf
- Dehydrators and Pumps: 12 Bcf
- Compressor Fugitives, Venting, And Exhaust: 12 Bcf
- Offshore Operations: 29 Bcf
- Other Sources: 7 Bcf
- Pneumatic Devices: 43 Bcf

Note 1: Independent estimate of 28 Bcf well venting methane emissions.


Note: Natural Gas STAR reductions from gathering and boosting operations are reflected in the production sector.
Economic Barriers to Implementation

- Current and future gas prices
- Payback criteria and project feasibility

Additional Barriers to Implementation

- Lack of man-power
- Engaging management
- Lack of information

Pneumatic Devices

Source: EnCana
What is the Problem?

- Pneumatic devices are major source of methane emissions from the natural gas industry.

- Pneumatic devices used throughout the natural gas industry:
  - Over 630,000 in production sector\(^1\)
  - About 13,000 in processing sector\(^1\)
  - About 83,000 in transmission sector\(^1\)


Location of Pneumatic Devices at Production Sites

SOV = Shut-off Valve (Unit Isolation)
LC = Level Control (Separator, Contact, Flash Tank
  Separator, TEG Regenerator)
TC = Temperature Control (Regenerator Fuel Gas)
FC = Flow Control (TEG Circulation, Compressor
  Bypass)
PC = Pressure Control (FTS Pressure, Compressor
  Suction/Discharge)
Methane Emissions

- As part of normal operations, pneumatic devices release natural gas to atmosphere
- High-bleed devices bleed in excess of 6 cf/hour
  - Equates to >50 Mcf/year
  - Typical high-bleed pneumatic devices bleed an average of 140 Mcf/year
- Actual bleed rate is largely dependent on device’s design

Pneumatic Device Schematic

- Gas 100+ psi
- Regulator
- Regulated Gas Supply 20 psi
- Process Measurement
  - Liquid Level
  - Pressure
  - Temperature
  - Flow
- Weak Pneumatic Signal (3 to 15 psi)
- Strong Pneumatic Signal
- Weak Signal Bleed (Continuous)
- Strong Signal Vent (Intermittent)
- Valve Actuator
- Control Valve
- Process Flow

psi = pounds per square inch
How Can Methane Emissions be Recovered?

- **Option 1:** Replace high-bleed devices with low-bleed devices
- **Option 2:** Retrofit controller with bleed reduction kits
  - Field experience shows that up to 80% of all high-bleed devices can be replaced or retrofitted with low-bleed equipment
- **Option 3:** Maintenance aimed at reducing losses

### Economics of Replacement & Retrofitting

<table>
<thead>
<tr>
<th>Implementation¹</th>
<th>Replace at End of Life</th>
<th>Retrofit</th>
<th>Early Replacements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost ($)</td>
<td>Level Control¹</td>
<td>Pressure Control</td>
</tr>
<tr>
<td>Cost ($)</td>
<td>150 – 250²</td>
<td>189</td>
<td>41</td>
</tr>
<tr>
<td>Annual Gas Savings (Mcf)</td>
<td>50 – 200</td>
<td>131</td>
<td>184</td>
</tr>
<tr>
<td>Annual Value of Saved Gas ($)³</td>
<td>350 – 1400</td>
<td>917</td>
<td>1,288</td>
</tr>
<tr>
<td>IRR (%)</td>
<td>138 – 933</td>
<td>&gt;450</td>
<td>&gt;3,100</td>
</tr>
<tr>
<td>Payback (months)</td>
<td>2 – 9</td>
<td>3</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

---

1 - All data based on partners’ experiences. See Lessons Learned for more information
2 - Range of incremental costs of low-bleed over high bleed equipment
3 - Gas price is assumed to be $7/Mcf
4 – Large nozzle to small
Dehydrators

- Methane Losses
- Methane Recovery
- Is Methane Recovery Profitable?
- Partner Experience

Glycol Dehydrators Emit?

- Produced gas is saturated with water, which must be removed for gas transmission
- Glycol dehydrators are the most common equipment to remove water from gas
  - 36,000 dehydration units in natural gas production, gathering, and boosting
  - Most use triethylene glycol (TEG)
- Glycol dehydrators create emissions
  - Methane, Volatile Organic Compounds (VOCs), Hazardous Air Pollutants (HAPs) from reboiler vent
  - Methane from pneumatic controllers

Source: www.prideofthehill.com
Basic Glycol Dehydrator System Process Diagram

Methane Recovery
- Optimize glycol circulation rates
- Flash tank separator (FTS) installation
- Electric Pumps

Source: Kimray Inc.
Optimizing Glycol Circulation Rate

- Gas pressure and flow at wellhead dehydrators generally declines over time
  - Glycol circulation rates are often set at a maximum circulation rate
- Glycol overcirculation results in more methane emissions without significant reduction in gas moisture content
  - Partners found circulation rates two to three times higher than necessary
  - Methane emissions are directly proportional to circulation
- Lessons Learned study: optimize circulation rates

Installing Flash Tank Separator (FTS)

- Methane that flashes from rich glycol in an energy-exchange pump can be captured using an FTS
- Many small units are not using an FTS

Note 1: API Survey prior to Glycol MACT; all large, half of medium glycol units now comply with MACT.
Methane Recovery

- Recovers about 90% of methane emissions
- Reduces VOCs by 10 to 90%
- Must have an outlet for low pressure gas
  - Fuel
  - Compressor suction
  - Vapor recovery unit

Flash Tank Costs

- Lessons Learned study provides guidelines for scoping costs, savings and economics
- Capital and installation costs:
  - Capital costs range from $3,300 to $6,700 per flash tank
  - Installation costs range from $1,200 to $3,000 per flash tank
- Negligible Operational & Maintenance (O&M) costs
Electric Pump Eliminates Motive Gas

Overall Benefits

- Financial return on investment through gas savings
- Increased operational efficiency
- Reduced O&M costs (fuel gas, glycol make-up)
- Reduced compliance costs (HAPs, BTEX)
- Similar footprint as gas assist pump
Is Recovery Profitable?

Three Options for Minimizing Glycol Dehydrator Emissions

<table>
<thead>
<tr>
<th>Option</th>
<th>Capital Costs</th>
<th>Annual O&amp;M Costs</th>
<th>Emissions Savings</th>
<th>Payback Period¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimize Circulation Rate</td>
<td>Negligible</td>
<td>Negligible</td>
<td>394 to 39,420 Mcf/year</td>
<td>Immediate</td>
</tr>
<tr>
<td>Install Flash Tank</td>
<td>$6,500 to $18,800</td>
<td>Negligible</td>
<td>1,191 to 10,643 Mcf/year</td>
<td>4 to 11 months</td>
</tr>
<tr>
<td>Install Electric Pump</td>
<td>$1,400 to $13,000</td>
<td>$165 to $6,500</td>
<td>360 to 36,000 Mcf/year</td>
<td>&lt; 1 month to several years</td>
</tr>
</tbody>
</table>

¹ – Gas price of $7/Mcf

Partner Experience (Shell)

- Installed flash tank separators on 106 dehydrators over 8 years
- Project cost = $15,000- $30,000 per FTS
- Annual Emissions reductions = 216 MMcf
- Annual Value Savings: $3.00/Mcf x 216 MMcf = $648,000
- 3 year pay-back period
Reciprocating Compressors

- Methane Losses from Rod Packing
- Implementing Proper Seals
- Rod Packing Replacement Economics
- Low Emission Packing

Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - Newly installed packing may leak 60 cubic feet per hour (cf/hour) in large compressors at processing plants or gathering and booster stations
  - Worn packing has been reported to leak up to 15 times more gas than a newly installed packing

(Side View, Cut in Half)

Distance Piece
Piston Rod
Cylinder
Suction
Discharge
OIL
Rod Packing Case
Reciprocating Compressor Rod Packing

- A series of flexible rings fit around the shaft to prevent leakage.
- Leakage may still occur through nose gasket, between packing cups, around the rings, and between rings and shaft.

Methane Losses from Rod Packing

Transmission Compressors

<table>
<thead>
<tr>
<th>Emission Type</th>
<th>Rate (cf/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission from Running Compressor</td>
<td>99</td>
</tr>
<tr>
<td>Emission from Idle/Pressurized Compressor</td>
<td>145</td>
</tr>
</tbody>
</table>

Leakage from Idle Compressor Packing

<table>
<thead>
<tr>
<th>Leakage Type</th>
<th>Rate (cf/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage from Idle Compressor Packing Cup</td>
<td>79</td>
</tr>
<tr>
<td>Leakage from Idle Compressor Distance Piece</td>
<td>34</td>
</tr>
</tbody>
</table>

Leakage from Rod Packing on Running Compressors

<table>
<thead>
<tr>
<th>Packing Type</th>
<th>Bronze</th>
<th>Bronze/Steel</th>
<th>Bronze/Teflon</th>
<th>Teflon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Rate (cf/hour)</td>
<td>70</td>
<td>63</td>
<td>150</td>
<td>24</td>
</tr>
</tbody>
</table>

Leakage from Rod Packing on Idle/Pressurized Compressors

<table>
<thead>
<tr>
<th>Packing Type</th>
<th>Bronze</th>
<th>Bronze/Steel</th>
<th>Bronze/Teflon</th>
<th>Teflon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Rate (cf/hour)</td>
<td>70</td>
<td>N/A</td>
<td>147</td>
<td>22</td>
</tr>
</tbody>
</table>

PRCI/ GRI/ EPA. Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations
Steps to Determine Economic Replacement

- Measure rod packing leakage
  - When new packing installed – after worn-in
  - Periodically afterwards
- Determine cost of packing replacement
- Calculate economic leak reduction
- Replace packing when leak reduction expected will pay back cost

Cost of Rod Packing Replacement

- Assess costs of replacements
  - A set of rings: $675 to $1,080
    (with cups and case) $2,025 to $3,375
  - Rods: $2,430 to $13,500
    Special coatings such as ceramic, tungsten carbide, or chromium can increase rod costs

Source: CECO
Calculate Economic Leak Reduction

- Determine economic replacement threshold
- Partners can determine economic threshold for all replacements
- This is a capital recovery economic calculation

Economic Replacement Threshold (cf/hour) = \( \frac{CR \times DF \times 1,000}{(H \times GP)} \)

Where:

- \( CR \) = Cost of replacement ($)
- \( DF \) = Discount factor at interest \( i = \frac{i}{(1 + i)} \)
- \( H \) = Hours of compressor operation per year
- \( GP \) = Gas price ($/thousand cubic feet)

Example: Payback calculations for new rings and rod replacement

- \( CR = $1,620 \) for rings
- \( H = 8,000 \) hours per year
- \( GP = $7/Mcf \)

One year payback

\[ ER = \frac{1,620 \times 1.1 \times 1,000}{(8,000 \times 7)} = 32 \text{ scf per hour} \]

\[ DF @ i = 10\% \text{ and } n = 1 \text{ year} \]
\[ DF = \frac{0.1(1+0.1)^1}{(1+0.1)^1 - 1} = \frac{0.1(1.1)}{1.1 - 1} = \frac{0.11}{0.1} = 1.1 \]

\[ DF @ i = 10\% \text{ and } n = 2 \text{ years} \]
\[ DF = \frac{0.1(1+0.1)^2}{(1+0.1)^2 - 1} = \frac{0.1(1.21)}{1.21 - 1} = \frac{0.121}{0.21} = 0.576 \]
Is Rod Packing Replacement Profitable?

Replace packing when leak reduction expected will pay back cost

“leak reduction expected” is the difference between current leak rate and leak rate with new rings

<table>
<thead>
<tr>
<th>Rings Only</th>
<th>Rod and Rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings: $1,620</td>
<td>Rings: $1,620</td>
</tr>
<tr>
<td>Rod: $0</td>
<td>Rod: $9,450</td>
</tr>
<tr>
<td>Gas: $7/Mcf</td>
<td>Gas: $7/Mcf</td>
</tr>
<tr>
<td>Operating: 8,000 hours/year</td>
<td>Operating: 8,000 hours/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leak Reduction Expected (cf/hour)</th>
<th>Payback (months)</th>
<th>Leak Reduction Expected (cf/hour)</th>
<th>Payback (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>6</td>
<td>425</td>
<td>6</td>
</tr>
<tr>
<td>32</td>
<td>12</td>
<td>217</td>
<td>12</td>
</tr>
<tr>
<td>22</td>
<td>18</td>
<td>148</td>
<td>18</td>
</tr>
<tr>
<td>17</td>
<td>24</td>
<td>114</td>
<td>24</td>
</tr>
</tbody>
</table>

Based on 10% interest rate
Mcf = thousand cubic feet

Industry Experience – Occidental

- Occidental upgraded compressor rod packing at its Elk Hills facility in southern California
- Savings 145 MMcf/yr
- Payback in under 3 years
Discussion Questions

- What industry experiences do you have applying these technologies and practices?
- What are your limitations on applying these technologies and practices?
- Actual costs and benefits