Methane Losses from Compressors

Lessons Learned from Natural Gas STAR

Producers Technology Transfer Workshop

Marathon Oil and EPA’s Natural Gas STAR Program

Houston, TX

October 26, 2005
Compressors: Agenda

- Methane Emissions
- Reciprocating Compressors
- Centrifugal Compressors
- Directed Inspection and Maintenance (DI&M)
- Discussion Questions
Natural Gas Losses by Equipment Type

- Control Valves: 4.0%
- Pressure Relief Valves: 3.5%
- Orifice Meters: 0.1%
- Other Flow Meters: 0.2%
- Open-Ended Lines: 11.1%
- Compressor Seals: 23.4%
- Crankcase Vents: 4.2%
- Pump Seals: 1.9%
- Pressure Regulators: 0.4%
- Valves: 26.0%
- Blowdowns: 0.8%
- Connectors: 24.4%

Clearstone Engineering, 2002
Compressor Emissions
What is the problem?

☆ Fugitive emissions from compressors in all sectors are responsible for approximately 86 Bcf/yr
☆ Over 45,000 compressors in the natural gas industry

The Natural Gas Industry

- Production: 32,000 Compressors
- Processing: 5,000 Compressors
- Transmission & Storage: 8,500 Compressors
- Distribution: 0 Compressors

Reducing Emissions, Increasing Efficiency, Maximizing Profits
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/h)
❖ Worn packing has been reported to leak up to 900 cf/h
Reciprocating Compressor Rod Packing

★ A series of flexible rings fit around the shaft to prevent leakage
★ Leakage still occurs through nose gasket, between packing cups, around the rings and between rings and shaft
# Methane Losses from Rod Packing

| Source: Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations – PRCI/ GRI/ EPA |

| Emission from Running Compressor | 870 Mcf/year-packing |
| Emission from Idle/Pressurized Compressor | 1270 Mcf/year-packing |
| Leak from Packing Cup | 690 Mcf/year-packing |
| Leak from Distance Piece | 300 Mcf/year-packing |

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<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 (Mcf/yr)</td>
<td>612</td>
<td>554</td>
<td>1317</td>
<td>210</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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<th>Bronze</th>
<th>Bronze/Steel</th>
<th>Bronze/Teflon</th>
<th>Teflon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Rate (Mcf/yr)</td>
<td>614</td>
<td>N/A</td>
<td>1289</td>
<td>191</td>
</tr>
</tbody>
</table>

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Reducing Emissions, Increasing Efficiency, Maximizing Profits
Methane Recovery Through Economic Rod Packing Replacement

☆ Assess costs of replacements

◆ A set of rings: $500 to $800
  (with cups and case) $1500 to $2500

◆ Rods: $1800 to $10000
  - Special coatings such as ceramic, tungsten carbide, or chromium can increase rod costs

◆ Determine economic replacement threshold

◆ Partners can determine economic threshold for all replacements

\[
\text{Economic Replacement Threshold (scfh)} = \frac{CR \times DF \times 1,000}{(H \times GP)}
\]

Where:

- \(CR\) = Cost of replacement ($)
- \(DF\) = Discount factor (%) @ interest \(i\)
- \(H\) = Hours of compressor operation per year
- \(GP\) = Gas price ($/Mcf)

\[
DF = \frac{i(1+i)^n}{(1+i)^n - 1}
\]
Is Rod Packing Replacement Profitable?

Periodically measure leakage increase

<table>
<thead>
<tr>
<th></th>
<th>Rings Only</th>
<th>Rod and Rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings:</td>
<td>$1,200</td>
<td>$1,200</td>
</tr>
<tr>
<td>Rod:</td>
<td>$0</td>
<td>$7,000</td>
</tr>
<tr>
<td>Gas:</td>
<td>$3/Mcf</td>
<td>$3/Mcf</td>
</tr>
<tr>
<td>Operating:</td>
<td>8,000 hrs/yr</td>
<td>8,000 hrs/yr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leak Reduction Expected (scfh)</th>
<th>Payback Period (yrs)</th>
<th>Leak Reduction Expected (scfh)</th>
<th>Payback Period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>1</td>
<td>376</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>2</td>
<td>197</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>137</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>108</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>90</td>
<td>5</td>
</tr>
</tbody>
</table>

Based on 10% interest rate
Mcf = thousand cubic feet, scfh = standard cubic feet per hour

Reducing Emissions, Increasing Efficiency, Maximizing Profits
Methane Losses from Centrifugal Compressors

- Centrifugal compressor wet seals leak little gas at the seal face
  - Seal oil degassing may vent 40 to 200 cubic feet per minute (cf/m) to the atmosphere
  - A Natural Gas STAR partner reported wet seal emissions of 75 Mcf/day (52 cf/m)
Centrifugal Compressor Wet Seals

- High pressure seal oil is circulated between rings around the compressor shaft
- Gas absorbs in the oil on the inboard side
- Little gas leaks through the oil seal
- Seal oil degassing vents methane to the atmosphere
Gas STAR Partners Reduce Emissions with Dry Seals

- Dry seal springs press the stationary ring in the seal housing against the rotating ring when the compressor is not rotating.
- At high rotation speed, gas is pumped between the seal rings creating a high pressure barrier to leakage.
- Only a very small amount of gas escapes through the gap.
- 2 seals are often used in tandem.
- Can operate for compressors up to 3,000 psig safely.
Methane Recovery with Dry Seals

★ Dry seals typically leak at a rate of only 0.5 to 3 cf/m

◆ Significantly less than the 40 to 200 cf/m emissions from wet seals

★ Gas savings translate to approximately $49,000 to $279,000 at $3/Mcf
Other Benefits with Dry Seals

☆ Aside from gas savings and reduced emissions, dry seals also:

◆ Lower operating cost
  ▪ Dry seals do not require seal oil make-up

◆ Reduced power consumption
  ▪ Wet seals require 50 to 100 kiloWatt per hour (kW/hr) for ancillary equipment while dry seals need only 5 kW/hr

◆ Improve reliability
  ▪ More compressor downtime is due to wet seals with more ancillary components

◆ Eliminate seal oil leakage into the pipelines
  ▪ Dry seals lower drag in pipelines (and horsepower to overcome)
Economics of Replacing Seals

☆ Compare costs and savings for a 6-inch shaft beam compressor

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Dry Seal ($)</th>
<th>Wet Seal ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seal costs (2 dry @ $10,000/shaft-inch, w/testing)</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>Seal costs (2 wet @ $5,000/shaft-inch)</td>
<td></td>
<td>60,000</td>
</tr>
<tr>
<td>Other costs (engineering, equipment installation)</td>
<td>120,000</td>
<td>0</td>
</tr>
<tr>
<td>Total Implementation Costs</td>
<td>240,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Annual O&amp;M</td>
<td>10,000</td>
<td>73,000</td>
</tr>
<tr>
<td>Annual methane emissions (at $3.00/Mcf; 8,000 hrs/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 dry seals at a total of 6 scfm</td>
<td>8,640</td>
<td></td>
</tr>
<tr>
<td>2 wet seals at total 100 scfm</td>
<td></td>
<td>144,000</td>
</tr>
<tr>
<td>Total Costs Over 5-Year Period ($)</td>
<td>333,200</td>
<td>1,145,000</td>
</tr>
<tr>
<td>Total Dry Seal Savings Over 5 Years:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings ($)</td>
<td>811,800</td>
<td></td>
</tr>
<tr>
<td>Methane Emissions Reductions (Mcf) (at 45,120 Mcf/yr)</td>
<td>225,600</td>
<td></td>
</tr>
</tbody>
</table>
Is Wet Seal Replacement Profitable?

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hr/yr
  - Net Present Value = $531,940
    - Assuming a 10% discount over 5 years
  - Internal Rate of Return = 86%
  - Payback Period = 14 months
    - Ranges from 8 to 24 months based on wet seal leakage rates between 40 and 200 cf/m
- Economics are better for new installations
  - Vendors report that 90% of compressors sold to the natural gas industry are centrifugal with dry seals
Directed Inspection and Maintenance at Compressor Stations

★ What is the problem?
   ◆ Gas leaks are *invisible, unregulated* and *go unnoticed*

★ STAR Partners find that valves, connectors, compressor seals and open-ended lines (OELs) are major sources
   ◆ About 40 Bcf methane emitted per year from OELs
   ◆ About 10 Bcf methane emitted per year from compressor seals

★ Facility fugitive methane emissions depend on operating practices, equipment age and maintenance
Natural Gas Losses by Equipment Type

- Pressure Relief Valves: 3.5%
- Orifice Meters: 0.1%
- Other Flow Meters: 0.2%
- Open-Ended Lines: 11.1%
- Control Valves: 4.0%
- Compressor Seals: 23.4%
- Crankcase Vents: 4.2%
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- Pressure Regulators: 0.4%
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- Connectors: 24.4%

Clearstone Engineering, 2002
### Summary of Natural Gas Losses from the Top Ten Leakers

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>Gas Losses From Top 10 Leakers (Mcf/d)</th>
<th>Gas Losses From All Equipment Leakers (Mcf/d)</th>
<th>Contribution By Top 10 Leakers (%)</th>
<th>Percent of Plant Components that Leak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43.8</td>
<td>122.5</td>
<td>35.7</td>
<td>1.78</td>
</tr>
<tr>
<td>2</td>
<td>133.4</td>
<td>206.5</td>
<td>64.6</td>
<td>2.32</td>
</tr>
<tr>
<td>3</td>
<td>224.1</td>
<td>352.5</td>
<td>63.6</td>
<td>1.66</td>
</tr>
<tr>
<td>4</td>
<td>76.5</td>
<td>211.3</td>
<td>36.2</td>
<td>1.75</td>
</tr>
<tr>
<td>Combined</td>
<td>477.8</td>
<td>892.84</td>
<td>53.5</td>
<td>1.85</td>
</tr>
</tbody>
</table>

1 Excluding leakage into flare system
How Can These Losses Be Reduced?

- Implementing a Directed Inspection and Maintenance (DI&M) Program
What is a DI&M Program?

- Voluntary program to identify and fix leaks that are cost-effective to repair
- Outside of mandatory LDAR
- Survey cost will pay out in the first year
- Provides valuable data on leakers
### Summary of Screening and Measurement Techniques

<table>
<thead>
<tr>
<th>Instrument/ Technique</th>
<th>Effectiveness</th>
<th>Approximate Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soap Solution</td>
<td>**</td>
<td>$</td>
</tr>
<tr>
<td>Electronic Gas Detectors</td>
<td>*</td>
<td>$$</td>
</tr>
<tr>
<td>Acoustic Detection/ Ultrasound</td>
<td>**</td>
<td>$$$</td>
</tr>
<tr>
<td>Detection</td>
<td>*</td>
<td>$$</td>
</tr>
<tr>
<td>TVA (FID)</td>
<td>*</td>
<td>$$</td>
</tr>
<tr>
<td>Bagging</td>
<td>*</td>
<td>$$$</td>
</tr>
<tr>
<td>High Volume Sampler</td>
<td>**</td>
<td>$$</td>
</tr>
<tr>
<td>Rotameter</td>
<td>**</td>
<td>$</td>
</tr>
<tr>
<td>Infrared Detection</td>
<td>**</td>
<td>$$$</td>
</tr>
</tbody>
</table>
## Cost-Effective Repairs

### Repair the Cost Effective Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Value of Lost Gas $^1$ ($)</th>
<th>Estimated Repair Cost ($)</th>
<th>Payback (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug Valve: Valve Body</td>
<td>12,641</td>
<td>200</td>
<td>0.2</td>
</tr>
<tr>
<td>Union: Fuel Gas Line</td>
<td>12,155</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>Threaded Connection</td>
<td>10,446</td>
<td>10</td>
<td>0.0</td>
</tr>
<tr>
<td>Distance Piece: Rod Packing</td>
<td>7,649</td>
<td>2,000</td>
<td>3.1</td>
</tr>
<tr>
<td>Open-Ended Line</td>
<td>6,959</td>
<td>60</td>
<td>0.1</td>
</tr>
<tr>
<td>Compressor Seals</td>
<td>5,783</td>
<td>2,000</td>
<td>4.2</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>4,729</td>
<td>60</td>
<td>0.2</td>
</tr>
</tbody>
</table>

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*Based on $3/Mcf gas price*

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*Hydrocarbon Processing, May 2002*

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*Reducing Emissions, Increasing Efficiency, Maximizing Profits*
How Much Gas Can Be Saved?

Natural Gas STAR Lessons Learned study for DI&M at compressor stations estimates:

- Potential Average Gas Savings ~ 29,000 Mcf/yr/compressor station
- Value of gas saved ~ $87,000 / compressor station (at gas price of $3/Mcf)
- Average initial implementation cost ~ $26,000 / compressor station
Discussion Questions

★ To what extent are you implementing these opportunities?

★ Can you suggest other opportunities?

★ How could these opportunities be improved upon or altered for use in your operation?

★ What are the barriers (technological, economic, lack of information, regulatory, focus, manpower, etc.) that are preventing you from implementing these practices?