Methane Savings from Compressors
Lessons Learned from Natural Gas STAR

Producers Technology Transfer Workshop
Occidental Oil and Gas and EPA’s Natural Gas STAR Program
Midland, TX
June 8, 2006
Compressors: Agenda

- Methane Losses from Reciprocating Compressors
- Methane Savings through Economic Rod Packing Replacement
- Is Rod Packing Replacement Profitable?
- Methane Losses from Centrifugal Compressors
- Methane Savings through Dry Seals
- Is Wet Seal Replacement Profitable?
- Discussion Questions
Compressor Methane Emissions
What is the problem?

Methane emissions from the ~51,000 compressors in the natural gas industry account for 86 Bcf/year or about 24% of all methane emissions from the natural gas industry.
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)
  - Worn packing has been reported to leak up to 900 cf/hour
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

<table>
<thead>
<tr>
<th>Packing Type</th>
<th>Leak Rate (Mcf/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission from Running Compressor</td>
<td>870 Mcf/year-packing</td>
</tr>
<tr>
<td>Emission from Idle/Pressurized Compressor</td>
<td>1270 Mcf/year-packing</td>
</tr>
<tr>
<td>Leakage from Packing Cup</td>
<td>690 Mcf/year-packing</td>
</tr>
<tr>
<td>Leakage from Distance Piece</td>
<td>300 Mcf/year-packing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packing Type</th>
<th>Leak Rate (Mcf/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage from Rod Packing on Running Compressors</td>
<td></td>
</tr>
<tr>
<td>Packing Type</td>
<td>Bronze</td>
</tr>
<tr>
<td>Leak Rate (Mcf/yr)</td>
<td>612</td>
</tr>
</tbody>
</table>

| Leakage from Rod Packing on Idle/Pressurized Compressors |
| Packing Type                          | Bronze  | Bronze/Steel | Bronze/Teflon | Teflon  |
| Leak Rate (Mcf/yr)                   | 614     | N/A          | 1289          | 191     |

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

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

- **Rings Only**
  - Rings: $1,200
  - Rod: $0
  - Gas: $7/Mcf
  - Operating: 8,000 hrs/yr

- **Rod and Rings**
  - Rings: $1,200
  - Rod: $7,000
  - Gas: $7/Mcf
  - Operating: 8,000 hrs/yr

<table>
<thead>
<tr>
<th>Leak Reduction Expected (scfh)</th>
<th>Payback (yr)</th>
<th>Payback (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>315</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>161</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Based on 10% interest rate

Mcf = thousand cubic feet, scfh = standard cubic feet per hour
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/minute) to the atmosphere
  - A Natural Gas STAR partner reported wet seal emissions of 75 Mcf/day (52 cf/minute)
Centrifugal Compressor Wet Seals

- High pressure seal oil circulates 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
Natural 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 very small amount of gas escapes through gap.
- 2 seals often used in tandem.
- Can operate for compressors up to 3,000 psig safely.
Methane Savings through Dry Seals

- Dry seals typically leak at a rate of only 0.5 to 3 cf/minute
  - Significantly less than the 40 to 200 cf/minute emissions from wet seals
- Gas savings translate to approximately $112,000 to $651,000 at $7/Mcf
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><strong>Implementation Costs</strong>¹</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><strong>Annual O&amp;M</strong></td>
<td>$10,000</td>
<td>$73,000</td>
</tr>
<tr>
<td><strong>Annual Methane Emissions</strong> (at $7/Mcf; 8,000 hr/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 dry seals at a total of 6 scfm</td>
<td>$20,160</td>
<td></td>
</tr>
<tr>
<td>2 wet seals at a total of 100 scfm</td>
<td></td>
<td>$336,000</td>
</tr>
<tr>
<td><strong>Total Costs Over 5-Year Period</strong></td>
<td>$390,800</td>
<td>$2,105,000</td>
</tr>
<tr>
<td><strong>Total Dry Seal Savings Over 5 Years</strong></td>
<td>$1,714,200</td>
<td></td>
</tr>
</tbody>
</table>

¹ Flowserve Corporation
Is Wet Seal Replacement Profitable?

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hours/year
  - Net Present Value = $1,216,000
    - Assuming a 10% discount over 5 years
  - Internal Rate of Return = 171%
  - Payback Period = 7 months
    - Ranges from 4 to 15 months based on wet seal leakage rates between 40 and 200 cf/minute

- Economics are better for new installations
  - Vendors report that 90% of compressors sold to the natural gas industry are centrifugal with dry seals
Discussion Questions

- To what extent are you implementing these opportunities?
- How could these opportunities be improved upon or altered for use in your operation?
- Can you suggest other methods for reducing emissions from compressors?
- What are the barriers (technological, economic, lack of information, regulatory, focus, manpower, etc.) that are preventing you from implementing these practices?