Methane Savings from Compressors
Lessons Learned from the Natural Gas STAR Program

DCP Midstream and the Gas Processors Association

Processors Technology Transfer Workshop
Houston, Texas
April 24, 2007

epa.gov/gasstar
Compressors: Agenda

- Methane Losses from Reciprocating Compressors
  - Methane Savings through Economic Rod Packing Replacement
    - Is Rod Packing Replacement Profitable?
    - Industry Experience – Occidental

- Methane Losses from Centrifugal Compressors
  - Methane Savings through Dry Seals
    - Is Wet Seal Replacement Profitable?
    - Industry Experience – PEMEX
  - Finding More Opportunities

- Discussion
Methane Emissions from Natural Gas Processing Sector (2005)

- Reciprocating Compressors: 14 Bcf*
- Gas Engine Exhaust: 6 Bcf
- Centrifugal Compressors: 5 Bcf
- Blowdowns: 2 Bcf
- Plant Fugitives: 1 Bcf
- Dehydrators and Pumps: 1 Bcf
- Other Sources: >1 Bcf

*Bcf = billion cubic feet


Natural Gas STAR reductions data shown as published in the inventory.
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.

Diagram:
- Two Rings (In Three Segments)
- Springs
- Lubrication
- Gas Leakage
- Flange
- Packing Cup
- Cylinder Wall
- Piston Rod
- High Pressure Gas Inside Cylinder

(Side View, Cut in Half)
# Methane Losses from Rod Packing

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Emission from Running Compressor</td>
<td>99</td>
<td>cf/hour</td>
<td>packing</td>
<td></td>
</tr>
<tr>
<td>Emission from Idle/Pressurized Compressor</td>
<td>145</td>
<td>cf/hour</td>
<td>packing</td>
<td></td>
</tr>
<tr>
<td>Leakage from Idle Compressor Packing Cup</td>
<td>79</td>
<td>cf/hour</td>
<td>packing</td>
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<tr>
<td>Leakage from Idle Compressor Distance Piece</td>
<td>34</td>
<td>cf/hour</td>
<td>packing</td>
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</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>
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<tr>
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</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*
Methane Savings Through Economic Rod Packing Replacement

Assess costs of replacements

- A set of rings: $675 to $1,100 (with cups and case) $2,100 to $3,400
- Rods: $2,500 to $13,500
- 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 (cf/hour) = \( CR \times DF \times \frac{1,000}{H \times GP} \)

Where:

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

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

- Measure initial leakage rate
  - i.e. leakage expected with new rings
- Periodically measure leakage increase

### Rings Only
- Rings: $1,620
- Rod: $0
- Gas: $7/Mcf
- Operating: 8,000 hours/year

<table>
<thead>
<tr>
<th>Leak Reduction Expected (cf/hour)</th>
<th>Payback (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

### Rod and Rings
- Rings: $1,620
- Rod: $9,450
- Gas: $7/Mcf
- Operating: 8,000 hours/year

<table>
<thead>
<tr>
<th>Leak Reduction Expected (cf/hour)</th>
<th>Payback (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>217</td>
<td>1</td>
</tr>
<tr>
<td>114</td>
<td>2</td>
</tr>
<tr>
<td>79</td>
<td>3</td>
</tr>
<tr>
<td>62</td>
<td>4</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
- Achieved reductions of 400 Mcf/day/compressor
- Saving 145 MMcf/year
- Payback in under 3 years

Source: Occidental
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
- Oil absorbs the gas on the inboard side
- Little gas leaks through the oil seal
- Seal oil degassing vents methane to the atmosphere

Source: PEMEX
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.
- Sealing at high rotation speed pump gas between the seal rings creating a high pressure barrier to leakage.
- Only a very small volume of gas escapes through the gap.
- Two seals are often used in tandem.
- Can operate for compressors up to 3,000 pounds per square inch gauge (psig) safely.

Source: PEMEX
Methane Savings through Dry Seals

- Dry seals typically leak 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

Source: PEMEX
# 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 @ $13,500/shaft-inch, with testing)</td>
<td>$162,000</td>
<td></td>
</tr>
<tr>
<td>Seal costs (2 wet @ $6,750/shaft-inch)</td>
<td></td>
<td>$81,000</td>
</tr>
<tr>
<td>Other costs (engineering, equipment installation)</td>
<td>$162,000</td>
<td>$0</td>
</tr>
<tr>
<td>Total implementation costs</td>
<td>$324,000</td>
<td>$81,000</td>
</tr>
<tr>
<td><strong>Annual Operating and Maintenance</strong></td>
<td>$14,100</td>
<td>$102,400</td>
</tr>
<tr>
<td><strong>Annual Methane Emissions</strong> (@ $7/Mcf; 8,000 hours/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 dry seals at a total of 6 cf/minute</td>
<td>$20,160</td>
<td></td>
</tr>
<tr>
<td>2 wet seals at a total of 100 cf/minute</td>
<td>$336,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total Costs Over 5-Year Period</strong></td>
<td>$495,300</td>
<td>$2,273,000</td>
</tr>
<tr>
<td><strong>Total Dry Seal Savings Over 5 Years</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings</td>
<td>$1,777,700</td>
<td></td>
</tr>
<tr>
<td>Methane Emissions Reductions (Mcf; at 45,120 Mcf/year)</td>
<td>225,600</td>
<td></td>
</tr>
</tbody>
</table>

¹ Flowserve Corporation (updated costs and savings)
Is Wet Seal Replacement Profitable?

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hours/year
  - Net present value = $1,337,769
    - Assuming a 10% discount over 5 years
  - Internal rate of return = 129%
  - Payback period = 10 months
    - Ranges from 3 to 11 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
Industry Experience – PEMEX

- PEMEX had 46 compressors with wet seals at its PGPB production site
- Converted all to dry seals
  - Cost $444,000/compressor
  - Saves 20,500 Mcf/compressor/year
  - Saves $126,690/compressor/year in gas
- 3.5 year payback from gas savings alone

Source: PEMEX
Finding More Opportunities

- Partners are identifying other technologies and practices to reduce emissions
  - BP-Indonesia degasses wet seal oil to fuel gas pressure, capturing emissions as fuel
    - Reduces expensive implementation costs of replacing with dry seals
  - TransCanada is researching the use of an ejector to recover dry seal leakage
    - Compressor discharge to suction
    - Application to TransCanada compressors would save 538 MMcf/year
    - Negligible operating costs
Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies and practices
- Actual costs and benefits
- Leased compressors
  - Control over rod packing type and maintenance?