Methane Savings from Compressors

Lessons Learned from Natural Gas STAR Program

Source Reduction Training

Interstate Oil and Gas Compact Commission

Charleston, West Virginia
February 27, 2008

epa.gov/gasstar

Compressors: Agenda

- Methane Losses from Reciprocating Compressors
- Methane Savings through Economic Rod Packing Replacement
- Is Rod Packing Replacement Profitable?
- Low Emission Packing
- Industry Experience
- Lessons Learned
- Discussion
**Methane Losses from Compressors**

- Compressors account for:
  - 13 Billion cubic feet (Bcf) of methane emissions in the production, gathering, and boosting sectors
  - 8 Bcf Meters and Pipeline Leaks
  - 8 Bcf Compressor Fugitives, Venting, and Engine Exhaust
  - 13 Bcf Dehydrators and Pumps
  - 8 Bcf Offshore Operations
  - 29 Bcf Dehydration and Pumps
  - 48 Bcf Pneumatic Devices


Natural Gas STAR reductions from gathering and boosting operations have been moved to the production sector.

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**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 transmission compressors and 15 cf/hour in production compressors
  - Worn packing has been reported to leak up to 15 times more gas than a newly installed packing

(Side View, Cut in Half)
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

Impediments to Proper Sealing

Ways packing case can leak
- Nose gasket (no crush)
- Packing to rod (surface finish)
- Packing to cup (lapped surface)
- Packing to packing (dirt/lube)
- Cup to cup (out of tolerance)

What makes packing leak?
- Dirt or foreign matter (trash)
- Worn rod (.0015”/per inch dia.)
- Insufficient/too much lubrication
- Packing cup out of tolerance (≤ 0.002”)
- Improper break-in on startup
- Liquids (dilutes oil)
- Incorrect packing installed (backward or wrong type/style)
Methane Losses from Rod Packing in Transmission Compressors

| Emission from Running Compressor | 99 cf/hour-packing |
| Emission from Idle/Pressurized Compressor | 145 cf/hour-packing |
| Leakage from Idle Compressor Packing Cup | 79 cf/hour-packing |
| Leakage from Idle Compressor Distance Piece | 34 cf/hour-packing |

**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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<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

Methane Losses from Compressors

- GRI/EPA\(^1\) reports an average leakage rate of 0.359 cf/hour per compressor rod packing annually in the production sector for throughputs of 0.13 to 250 million cubic feet per day (MMcf/day)
- GRI/EPA\(^1\) reports an average leakage rate of 169 cf/hour per compressor rod packing annually in the transmission sector for throughputs of 8.9 to 843 MMcf/day
- A production compressor vendor reported emissions of 15 scf/ hour per compressor rod packing

\(^1\) GRI/EPA : Volume 8, Equipment Leaks, 1996
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: $325 to $530
    (with cups and case) $1,010 to $1,640
  - Rods: $1,200 to $6,510
  - 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 \( i = \frac{i(1+i)^n}{(1+i)^n - 1} \)
- \( H \) = Hours of compressor operation per year
- \( GP \) = Gas price ($/thousand cubic feet)

Economic Replacement Threshold Example: Payback calculations for new rings and rod replacement

\[
CR = \$492 \text{ for rings } + \$1,725 \text{ for rod } = \$2,217 \\
H = 8,000 \text{ hours per year} \\
GP = \$7/Mcf
\]

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

DF @ \( i = 10\% \) and \( n = 2 \) years
\[
DF = \frac{0.1(1+0.1)^2}{(1+0.1)^2 - 1} = \frac{0.1(1.21)}{1.21-1} = \frac{0.121}{0.21} = 0.576
\]

One year payback
\[
ER = \frac{\$2,217 \times 1.1 \times 1,000}{(8,000 \times \$7)} = 44 \text{ scf per hour}
\]
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: $492 (6 cups)</td>
<td>Rings: $492 (6 cups)</td>
</tr>
<tr>
<td>Rod: $0</td>
<td>Rod: $1,725</td>
</tr>
<tr>
<td>Gas: $7/Mcf</td>
<td>Gas: $7/Mcf</td>
</tr>
<tr>
<td>Operating: 8,000 hours/year</td>
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</tr>
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</table>

<table>
<thead>
<tr>
<th>Leak Reduction Expected (cf/hour)</th>
<th>Payback (year)</th>
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<tbody>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
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<tr>
<td>4</td>
<td>3</td>
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<tr>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
</tr>
<tr>
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</table>

Based on 10% interest rate, Mcf = thousand cubic feet

Low Emission Packing

- Low emission packing (LEP) overcomes low pressure to prevent leakage

- The side load eliminates clearance and maintains positive seal on cup face

- LEP is a static seal, not a dynamic seal. No pressure is required to activate the packing

- This design works in existing packing case with limited to no modifications required
LEP Packing Configuration

Orientation in Cup

LEP: Low Emissions Packing
Orientation of P303 Rings
Reasons to Use LEP

- Upgrade is inexpensive
- Significant reduction of greenhouse gas are major benefit
- Refining, petrochemical and air separation plants have used this design for many years to minimize fugitive emissions
- With gas at $7/Mcf, packing case leakage should be identified and fixed.

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
Lessons Learned

- Development of a system to regularly measure and monitor leakage from piston rod packing cases
- Regularly monitor lubrication and cooling to help reduce wear on packing rings
- Establishment of baseline initial leakage rates (IL) for new rods and new packing rings by compressor type and size
- Establishment of a company wide emission threshold for each compressor to indicate economic compressor ring packing and piston rods replacement

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?