Reciprocating Compressor Rod Packing

Lessons Learned from the Natural Gas STAR Program

Chevron Corporation,
New Mexico Oil and Gas Association,
Texas Oil and Gas Association

Technology Transfer Workshop
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epa.gov/gasstar
Industry Emissions: Production, Gathering, and Boosting


Note: Natural Gas STAR reductions from gathering and boosting operations are reflected in the production sector.
2006 Processing Sector Methane Emissions

- Reciprocating Compressors: 16 Bcf
- Centrifugal Compressors: 5 Bcf
- Blowdowns: 2 Bcf
- Gas Engine Exhaust: 7 Bcf
- Plant Fugitives: 2 Bcf
- Dehydrators and Pumps: <1 Bcf
- Other Sources: 1 Bcf


Note: Natural Gas STAR reductions from gathering and boosting operations are reflected in the production sector.
Compressor Methane Emissions
What is the problem?

- Methane emissions from the ~51,500 compressors in the natural gas industry account for 89 Bcf/year or about 24% of all methane emissions from the natural gas industry.

### THE NATURAL GAS INDUSTRY

- **Production**: 38,500 Compressors
- **Processing**: 5,000 Compressors
- **Transmission & Storage**: 8,000 Compressors
- **Distribution**: 0 Compressors
Methane Savings from Compressors: Agenda

- Reciprocating Compressors
  - Methane Losses
  - Methane Savings
  - Industry Experience

- Discussion
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)
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 ($\leq 0.002”$)
- Improper break-in on startup
- Liquids (dilutes oil)
- Incorrect packing installed (backward or wrong type/style)
# Methane Losses from Rod Packing

## 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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<tr>
<th>Packing Type</th>
<th>Bronze</th>
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<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>
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</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: $135 to $1,080
  (with cups and case) $1,350 to $2,500
- 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 \( i = \)
- **H** = Hours of compressor operation per year
- **GP** = Gas price ($/thousand cubic feet)

\[ DF = \frac{i(1+i)^n}{(1+i)^n - 1} \]
Economic Replacement Threshold

Example: Payback calculations for new rings and rod replacement

CR = $1,620 for rings + $9,450 for rod
    = $11,070
H  = 8,000 hours per year
GP = $7/Mcf

DF @ i = 10% and n = 1 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% 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

\[
ER = \frac{\$11,070 \times 1.1 \times 1,000}{(8,000 \times \$7)} = 217 \text{ scf per hour}
\]
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

Based on 10% interest rate

Mcf = thousand cubic feet

<table>
<thead>
<tr>
<th>Rings Only</th>
<th>Rod and Rings</th>
</tr>
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<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>
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<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>
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<tbody>
<tr>
<td>55</td>
<td>7</td>
<td>376</td>
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<td>29</td>
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<td>20</td>
<td>18</td>
<td>137</td>
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<tr>
<td>16</td>
<td>22</td>
<td>108</td>
<td>22</td>
</tr>
</tbody>
</table>

Based on 10% interest rate

Mcf = thousand cubic feet
Industry Experience – Northern Natural Gas

- Monitored emission at two locations
  - Unit A leakage as high as 301 liters/min (640 cf/hour)
  - Unit B leakage as high as 105 liters/min (220 cf/hour)
- Installed Low Emission Packing (LEP)
  - Testing is still in progress
  - After 3 months, leak rate shows zero leakage increase
Industry Experience – Occidental

- Occidental upgraded compressor rod packing at its Elk Hills facility in southern California
- Achieved reductions of 400 Mcf/day/compressor
- Savings 145 MMcf/yr
- Payback in under 3 years

Source: Occidental
Northern Natural Gas - Leakage Rates

Leak Rate (liters/min)


640 cf/hour

60 cf/hour

Unit A

Unit B
Northern Natural Gas Packing Leakage
Economic Replacement Point

- Approximate packing replacement cost is $3,000 per compressor rod (parts/labor)
- Assuming gas at $7/Mcf:
  1 cubic foot/minute = 28.3 liters/minute
  - 50 liters/minute/28.316 = 1.8 scf/minute
  - 1.8 x 60 minutes/hour = 108 scf/hr
  - 108 x 24/1000 = 2.6 Mcf/day
  - 2.6 x 365 days = 950 Mcf/year
  - 950 x $7/Mcf = $6,650 per year leakage
- This replacement pays back in <6 months
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.
Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies and practices
- Actual costs and benefits