Reducing Methane Emissions from Compressors: Economic Rod Packing Replacement

IAPG & US EPA Technology Transfer Workshop

November 5, 2008
Buenos Aires, Argentina
U.S. Processing Sector Methane Emissions

Centrifugal Compressors 15%
Gas engine exhaust 20%
Reciprocating compressors 47%
Dephrators Plant and pumps
Blowdowns 6%
Fugitives 6%
Other sources 3%

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

- It is estimated that methane emissions from compressors in the natural gas industry account for about one fourth of all methane emissions from the natural gas industry.
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 1.70 m$^3$/hour
  - Worn packing has been reported to leak up to 25.5 m$^3$/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
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 (0,0015 mm/mm Ø)
- Insufficient/too much lubrication
- Packing cup out of tolerance (≤ 0,051mm)
- Improper break-in on startup
- Liquids (dilutes oil)
- Incorrect packing installed (backward or wrong type/style)
Methane Losses from Rod Packing

<table>
<thead>
<tr>
<th>Emission from Running Compressor</th>
<th>2.80 m³/hour-packing</th>
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</thead>
<tbody>
<tr>
<td>Emission from Idle/Pressurized Compressor</td>
<td>4.11 m³/hour-packing</td>
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<tr>
<td>Leakage from Idle Compressor Packing Cup</td>
<td>2.24 m³/hour-packing</td>
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<tr>
<td>Leakage from Idle Compressor Distance Piece</td>
<td>0.96 m³/hour-packing</td>
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<table>
<thead>
<tr>
<th>Leakage from Rod Packing on Running Compressors</th>
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<tbody>
<tr>
<td>Packing Type</td>
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<tr>
<td>Leak Rate (m³/hour)</td>
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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 (US$)
  - 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 (m³/hour) = \( \frac{CR \times A/P \times 1,000}{(H \times GP)} \)

Where:
- \( CR = \) Cost of replacement (US$)
- \( A/P = \) Capital recovery factor at interest \( i \) and \( n \) years recovery period
- \( H = \) Hours of compressor operation per year
- \( GP = \) Gas price (US$/thousand cubic meter)
Economic Replacement Threshold

- Example: Payback calculations for new rings and rod replacement

CR = $1.620 for rings + $9.450 for rod
CR = $11.070

H = 8,000 hours per year

GP = $70,63/Mm³ (US$ 2/mcf)

A/P @ i = 10%, n = 1 year = 1,1
A/P @ i = 10%, n = 2 years = 0,576

Two year payback:

\[
ER = \frac{11.070 \times 0.576 \times 1.000}{(8.000 \times $70.63)}
\]

= 11.28 stdm³ / 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>
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<tbody>
<tr>
<td>Rings:</td>
<td>Rings:</td>
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<tr>
<td>Rod:</td>
<td>Rod:</td>
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<tr>
<td>Gas:</td>
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<td>$1.620</td>
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<td>$70,63/Mm³</td>
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<td>8,000 hours/year</td>
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<tr>
<th>Leak Reduction Expected (m³/hour)</th>
<th>IRR (%)</th>
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<th>IRR (%)</th>
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<tr>
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<tr>
<td>1,13</td>
<td>28</td>
<td>5,66</td>
<td>14</td>
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Industry Experience – Northern Natural Gas

- Monitored emission at two locations
  - Unit A leakage as high as 0.301 liters/min (640 cf/hour)
  - Unit B leakage as high as 105 liters/min (220 cf/hour)
- Installed Low Emission Packing (LEP)
  - After 3 months, leak rate showed zero leakage increase
Northern Natural Gas - Leakage Rates

- Unit A
- Unit B

Leak Rate (liters/min)

640 cf/hour

60 cf/hour
Case Study: Partner Packing Leakage Economic Replacement Point

- Approximate packing replacement cost is US$3,000 per compressor rod (parts/labor)
- Assuming gas at US$70.63/Mm³ ($2/Mcf):
  - 50 liters/minute =
  - 50 x 60 minutes/hour = 3,000 liters/hr
  - 3,000 x 24/1,000 = 72 m³/day
  - 72 x 365 days = 26,280 m³/year
  - 26,280/1,000 x $70.63/Mm³ = $1,900 per year leakage
  - This replacement pays back in <2 years
Industry Experience – Natural Gas Star Partner

A physical leak measurement study was performed to quantify current gas losses and determine leak reduction potential for a 4 cylinder natural gas compressor.

- Actual leak rate: 76.3 m³/h (668 Mm³/year)
- Methane content of leakage flow: 78%
- Potential methane savings: 59.5 m³/h (522 Mm³/year)
- Implementation cost (rods and packing): US$ 56,000¹
- Savings (@ US$ 70,63/Mm³): US$ 37,000/year
- Payback: 19 months

¹: Price considering US$ 7,500 per rod and US$ 2,500 per set of packing for each of the four cylinders with installation cost of US$4,000 per cylinder
Emissions from reciprocating compressors

Anticipated emissions:

- Typical gas compression station: 3 x 3-stage 1.100 hp, 60 kg/cm² compressors
- Typical emissions:
  50 Mm³/year / compressor for total of 150 Mm³ of gas emitted per station
- Emissions affected by:
  - Rod / packing material and construction
  - Maintenance frequency
  - Rotation speed

Mitigation Option:
Optimize frequency for replacing worn rod / packing rings
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 US$ 70,63/Mm3 (US$2/Mcf), many packing case leakage LEP applications are cost-effective.
Discussion

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