Methane Savings from Compressors

Lessons Learned from the Natural Gas STAR Program

Producers Technology Transfer Workshop

ConocoPhillips Petroleum Company,
New Mexico Environment Department,
New Mexico Oil & Gas Association

Farmington, New Mexico
May 11, 2010

epa.gov/gasstar

U.S. Production Sector Methane Emissions (2007)

Note: Bcf = billion cubic feet

- Compressors: 12 Bcf
- Storage Tank Venting: 27 Bcf
- Other Sources: 5 Bcf
- Offshore Operations: 29 Bcf
- Pneumatic Devices: 79 Bcf
- Dehydrators and Pumps: 3 Bcf
- Meters and Pipeline Leaks: 8 Bcf
- Well Venting and Flaring: 86 Bcf

Compressor Methane Emissions
What is the problem?

- Methane emissions from the ~46,700 compressors in the natural gas industry account for 121 Bcf/year or about 31% of all methane emissions from the natural gas industry.

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 11-12 cubic feet per hour (cf/hour)
  - Where packing rings are properly aligned and fitted
  - 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
**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)

Source: Newfield

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**Methane Losses from Rod Packing**

| Source: PRCI / GRI / EPA. Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations

- 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

**Breakdown of Leakage from Rod Packing**

<table>
<thead>
<tr>
<th>Leakage from Rod Packing on Running Compressors</th>
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</thead>
<tbody>
<tr>
<td>Packing Type</td>
</tr>
<tr>
<td>Leak Rate (cf/hour)</td>
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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) = \( CR \times DF \times \frac{1,000}{(H \times GP)} \)

Where:

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

\( DF = \frac{i(1 + i)^n}{(1 + i)^n - 1} \)

Example: Payback calculations for new rings and rod replacement

CR = $492 for rings + $1,725 for rod
CR = $2,217
H = 8,000 hours per year
GP = $4/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

\[
ER = \frac{2,217 \times 1.1 \times 1,000}{(8,000 \times 4)} = 76 \text{ scf per hour}
\]
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>Leak Reduction Expected (scf/hour)</th>
<th>Payback (months)</th>
<th>Rings Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>6</td>
<td>Rings: $492 (6 cups)</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>Rod: $0</td>
</tr>
<tr>
<td>12</td>
<td>18</td>
<td>Gas: $4/Mcf</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>Operating: 8,000 hours/year</td>
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<th>Leak Reduction Expected (scf/hour)</th>
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<td>149</td>
<td>6</td>
<td>Rings: $492 (6 cups)</td>
</tr>
<tr>
<td>76</td>
<td>12</td>
<td>Rod: $1,725</td>
</tr>
<tr>
<td>52</td>
<td>18</td>
<td>Gas: $4/Mcf</td>
</tr>
<tr>
<td>40</td>
<td>24</td>
<td>Operating: 8,000 hours/year</td>
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</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
Northern Natural Gas - Leakage Rates

Leak Rate (liters/min)

0 50 100 150 200 250 300 350


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