Methane Savings from Compressors

Lessons Learned from the Natural Gas STAR Program

Shell Exploration & Production Company, Chevron Corporation, Offshore Operations Committee, and Gulf Coast Environmental Affairs Group

Offshore Technology Transfer Workshop
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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
      - Industry Experience – TransCanada
- Discussion
Methane Emissions from Natural Gas Production Sector (2005)

- Compressor seal fugitives make up 6% of total offshore emissions

![Pie chart showing emissions sources](image)

- Offshore Operations 34 Bcf
- Pneumatic Devices 57 Bcf*
- Dehydrators and Pumps 17 Bcf
- Well Venting and Flaring 9 Bcf
- Compressor Fugitives, Venting, and Engine Exhaust 14 Bcf
- Meters and Pipeline Leaks 9 Bcf
- Storage Tank Venting 6 Bcf
- Other Sources 10 Bcf

*Bcf = billion cubic feet


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

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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)
  - Worn packing has been reported to leak up to 900 cf/hour

![Diagram of reciprocating compressor](image)
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)
- Ring to rod (surface finish)
- Ring to cup (lapped surface)
- Ring to ring (dirt/lube)
- Cup to cup (out of tolerance/dirt)

**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

| Packing Type | Bronze | Bronze/Steel | Bronze/Teflon | Teflon |
| Leak Rate (cf/hour) | 70 | 63 | 150 | 24 |

Leakage from Rod Packing on Idle/Pressurized Compressors

| Packing Type | Bronze | Bronze/Steel | Bronze/Teflon | Teflon |
| Leak Rate (cf/hour) | 70 | N/A | 147 | 22 |

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 wear-in period
  - Periodically afterwards (e.g. six months)
- 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: $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

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 rate \( i \) = \[ DF = \frac{i(1+i)^n}{(1+i)^n - 1} \]  
- 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 = $1,620 for rings + $9,450 for rod
   = $11,070
H = 8,000 hours per year
GP = $7/Mcf

One year payback

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

\[
\text{DF} = \frac{0.1(1 + 0.1)^1}{(1 + 0.1)^1 - 1} = \frac{0.1(1.1)}{0.1} = 1.1
\]

\[
\text{DF} = \frac{0.1(1 + 0.1)^2}{(1 + 0.1)^2 - 1} = \frac{0.1(1.21)}{0.21} = 0.576
\]

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: $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>
</tr>
<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 (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>

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 million cubic feet per year (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 pumps 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>Implementation Costs</td>
<td>$162,000</td>
<td>$81,000</td>
</tr>
<tr>
<td>Seal costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 dry @ $13,500/shaft-inch, with testing</td>
<td>$162,000</td>
<td>$81,000</td>
</tr>
<tr>
<td>Seal costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 wet @ $6,750/shaft-inch</td>
<td>$162,000</td>
<td>$0</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>Annual Operating and Maintenance</td>
<td>$14,100</td>
<td>$102,400</td>
</tr>
<tr>
<td>Annual Methane Emissions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ $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>$336,000</td>
</tr>
<tr>
<td>2 wet seals at a total of 100 cf/minute</td>
<td>$324,000</td>
<td>$336,000</td>
</tr>
<tr>
<td>Total Costs Over 5-Year Period</td>
<td>$495,300</td>
<td>$2,273,000</td>
</tr>
<tr>
<td>Total Dry Seal Savings Over 5 Years</td>
<td>$1,777,700</td>
<td>$225,600</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 three 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
- Plans for future dry seal installations

Source: PEMEX
Finding More Opportunities

- Partners are identifying other technologies and practices to reduce emissions
  - BP-Indonesia degasses wet seal oil to low pressure fuel gas, capturing emissions as fuel
    - Reduces expensive implementation costs of replacing with dry seals
  - TransCanada has successfully conducted pilot studies on the use of an ejector to recover dry seal leakage

Industry Experience – TransCanada

- Two-stage supersonic ejector for capturing dry-gas seal vent gases
  - First stage - expansion of the motive gas
  - Second stage - recompression to a pressure equal to the fuel gas pressure
- Installed and commissioned successfully in one of TransCanada's compressor stations in Alberta
  - 3,960 Mcf/year savings (4 cfm/seal)
  - 100% recovery of vented gas
  - Zero operating cost
  - Payback in 1-2 years

Source: TransCanada
Discussion

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