Methane Losses from Compressors

Lessons Learned from Natural Gas STAR

Technology Transfer Workshop

Northern Natural Gas Company, INGAA, CECO, Heath Consultants, TCEQ and EPA’s Natural Gas STAR Program

June 8, 2005
Compressors: Agenda

- Methane Emissions
- Reciprocating Compressors
- Centrifugal Compressors
- Directed Inspection and Maintenance (DI&M)
- Discussion Questions
Methane Losses from the Natural Gas Industry

Production: 148 Bcf
Transmission & Storage: 101 Bcf
Distribution: 68 Bcf
Processing: 36 Bcf
Oil Downstream: 2 Bcf

Emissions:
- Production: 148 Bcf
- Transmission & Storage: 101 Bcf
- Distribution: 68 Bcf
- Processing: 36 Bcf
- Oil Downstream: 2 Bcf

Reductions:
- Production: 1 Bcf
- Transmission & Storage: 24 Bcf


Reducing Emissions, Increasing Efficiency, Maximizing Profits
Compressor Emissions
What is the problem?

- Fugitive emissions from compressors in all sectors are responsible for approximately 86 Bcf/yr
- Over 45,000 compressors in the natural gas industry

THE NATURAL GAS INDUSTRY

Production: 32,000 Compressors
Processing: 5,000 Compressors
Transmission & Storage: 8,500 Compressors
Distribution: 0 Compressors

Reducing Emissions, Increasing Efficiency, Maximizing Profits
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/h)
  • Worn packing has been reported to leak up to 900 cf/h
Reciprocating Compressor Rod Packing

- A series of flexible rings fit around the shaft to prevent leakage
- Leakage still occurs through nose gasket, between packing cups, around the rings and between rings and shaft
## Methane Losses from Rod Packing

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission from Running Compressor</td>
<td>870</td>
<td>Mcf/year-packing</td>
</tr>
<tr>
<td>Emission from Idle/Pressurized Compressor</td>
<td>1270</td>
<td>Mcf/year-packing</td>
</tr>
<tr>
<td>Leakage from Packing Cup</td>
<td>690</td>
<td>Mcf/year-packing</td>
</tr>
<tr>
<td>Leakage from Distance Piece</td>
<td>300</td>
<td>Mcf/year-packing</td>
</tr>
</tbody>
</table>

### 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 (Mcf/yr)</td>
<td>612</td>
<td>554</td>
<td>1317</td>
<td>210</td>
</tr>
</tbody>
</table>

### Leakage from Rod Packing on Idle/Pressurized Compressors

<table>
<thead>
<tr>
<th>Packing Type</th>
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<th>Teflon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Rate (Mcf/yr)</td>
<td>614</td>
<td>N/A</td>
<td>1289</td>
<td>191</td>
</tr>
</tbody>
</table>

Source: Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations – PRCI/ GRI/ EPA
Methane Recovery Through Economic Rod Packing Replacement

★ Assess costs of replacements
- A set of rings: $500 to $800
  (with cups and case) $1500 to $2500
- Rods: $1800 to $3500

★ Determine economic replacement threshold
- Partners can determine economic threshold for all replacements

Economic Replacement Threshold (scfh) = \( \frac{CR \times DF \times 1,000}{(H \times GP)} \)

Where:
- CR = Cost of replacement ($)  
- DF = Discount factor (%)  
- H = Hours of compressor operation per year  
- GP = Gas price ($/Mcf)

\[ DF = \frac{i(1+i)^n}{(1+i)^n - 1} \]
Is Rod Packing Replacement Profitable?

- Periodically measure leakage increase

<table>
<thead>
<tr>
<th>Rings Only</th>
<th>Rod and Rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings: $1,200</td>
<td>Rings: $1,200</td>
</tr>
<tr>
<td>Rod: $0</td>
<td>Rod: $7,000</td>
</tr>
<tr>
<td>Gas: $3/Mcf</td>
<td>Gas: $3/Mcf</td>
</tr>
<tr>
<td>Operating: 8,000 hrs/yr</td>
<td>Operating: 8,000 hrs/yr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leak Reduction Expected (scfh)</th>
<th>Payback Period (yrs)</th>
<th>Leak Reduction Expected (scfh)</th>
<th>Payback Period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>1</td>
<td>376</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>2</td>
<td>197</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>137</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>108</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>90</td>
<td>5</td>
</tr>
</tbody>
</table>

Based on 10% interest rate
Mcf = thousand cubic feet, scfh = standard cubic feet per hour

Reducing Emissions, Increasing Efficiency, Maximizing Profits
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/m) to the atmosphere
  - A Natural Gas STAR partner reported wet seal emissions of 75 Mcf/day (52 cf/m)
Centrifugal Compressor Wet Seals

★ High pressure seal oil is circulates between rings around the compressor shaft
★ Gas absorbs in the oil on the inboard side
★ Little gas leaks through the oil seal
★ Seal oil degassing vents methane to the atmosphere
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.
- At high rotation speed, gas is pumped between the seal rings creating a high pressure barrier to leakage.
- Only a very small amount of gas escapes through the gap.
- 2 seals are often used in tandem.
- Can operate for compressors up to 3,000 psig safely.
Methane Recovery with Dry Seals

★ Dry seals typically leak at a rate of only 0.5 to 3 cf/m

◆ Significantly less than the 40 to 200 cf/m emissions from wet seals

★ These savings translate to approximately $49,000 to $279,000 in annual gas value
Aside from gas savings and reduced emissions, dry seals also:

- **Lower operating cost**
  - Dry seals do not require seal oil make-up
- **Reduced power consumption**
  - Wet seals require 50 to 100 kiloWatt per hour (kW/hr) for ancillary equipment while dry seals need only 5 kW/hr
- **Improve reliability**
  - More compressor downtime is due to wet seals with more ancillary components
- **Eliminate seal oil leakage into the pipelines**
  - Dry seals lower drag in pipelines (and horsepower to overcome)
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></td>
<td></td>
</tr>
<tr>
<td>Seal costs (2 dry @ $10,000/shaft-inch, w/testing)</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>Seal costs (2 wet @ $5,000/shaft-inch)</td>
<td></td>
<td>60,000</td>
</tr>
<tr>
<td>Other costs (engineering, equipment installation)</td>
<td>120,000</td>
<td>0</td>
</tr>
<tr>
<td>Total Implementation Costs</td>
<td>240,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Annual O&amp;M</td>
<td>10,000</td>
<td>73,000</td>
</tr>
<tr>
<td>Annual methane emissions(^\d) (@ $3.00/Mcf; 8,000 hrs/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 dry seals at a total of 6 scfm</td>
<td>8,640</td>
<td></td>
</tr>
<tr>
<td>2 wet seals at total 100 scfm</td>
<td></td>
<td>144,000</td>
</tr>
<tr>
<td>Total Costs Over 5-Year Period ($)</td>
<td>333,200</td>
<td>1,145,000</td>
</tr>
<tr>
<td>Total Dry Seal Savings Over 5 Years:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings ($)</td>
<td>811,800</td>
<td></td>
</tr>
<tr>
<td>Methane Emissions Reductions (Mcf) (at 45,120 Mcf/yr)</td>
<td></td>
<td>225,600</td>
</tr>
</tbody>
</table>

Flowserve Corporation

Reducing Emissions, Increasing Efficiency, Maximizing Profits
Is Wet Seal Replacement Profitable?

★ Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hr/yr
  ❖ Net Present Value = $531,940
    ▪ Assuming a 10% discount over 5 years
  ❖ Internal Rate of Return = 86%
  ❖ Payback Period = 14 months
    ▪ Ranges from 8 to 24 months based on wet seal leakage rates between 40 and 200 cf/m
★ Economics are better for new installations
  ❖ Vendors report that 90% of compressors sold to the natural gas industry are centrifugal with dry seals
Directed Inspection and Maintenance at Compressor Stations

★ What is the problem?
  ◆ Gas leaks are *invisible, unregulated* and *go unnoticed*

★ STAR Partners find that valves, connectors, compressor seals and open-ended lines (OELs) are major sources
  ◆ About 40 Bcf methane emitted per year from OELs
  ◆ About 10 Bcf methane emitted per year from compressor seals

★ Facility fugitive methane emissions depend on operating practices, equipment age and maintenance
Natural Gas Losses by Equipment Type

- Pressure Relief Valves: 3.5%
- Orifice Meters: 0.1%
- Other Flow Meters: 0.2%
- Open-Ended Lines: 11.1%
- Control Valves: 4.0%
- Compressor Seals: 23.4%
- Crankcase Vents: 4.2%
- Pump Seals: 1.9%
- Pressure Regulators: 0.4%
- Valves: 26.0%
- Blowdowns: 0.8%
- Connectors: 24.4%

Clearstone Engineering, 2002
# How Much Methane is Emitted?

## Summary of Natural Gas Losses from the Top Ten Leakers

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>Gas Losses From Top 10 Leakers (Mcf/d)</th>
<th>Gas Losses From All Equipment Leakers (Mcf/d)</th>
<th>Contribution By Top 10 Leakers (%)</th>
<th>Percent of Plant Components that Leak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43.8</td>
<td>122.5</td>
<td>35.7</td>
<td>1.78</td>
</tr>
<tr>
<td>2</td>
<td>133.4</td>
<td>206.5</td>
<td>64.6</td>
<td>2.32</td>
</tr>
<tr>
<td>3</td>
<td>224.1</td>
<td>352.5</td>
<td>63.6</td>
<td>1.66</td>
</tr>
<tr>
<td>4</td>
<td>76.5</td>
<td>211.3</td>
<td>36.2</td>
<td>1.75</td>
</tr>
<tr>
<td>Combined</td>
<td>477.8</td>
<td>892.84</td>
<td>53.5</td>
<td>1.85</td>
</tr>
</tbody>
</table>

*Excluding leakage into flare system*
How Can These Losses Be Reduced?

★ Implementing a Directed Inspection and Maintenance (DI&M) Program

Clearstone Engineering, 2002
What is a DI&M Program?

- Voluntary program to identify and fix leaks that are cost-effective to repair
- Outside of mandatory LDAR
- Survey cost will pay out in the first year
- Provides valuable data on leakers
### Summary of Screening and Measurement Techniques

<table>
<thead>
<tr>
<th>Instrument/Technique</th>
<th>Effectiveness</th>
<th>Approximate Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soap Solution</td>
<td>** *</td>
<td>$</td>
</tr>
<tr>
<td>Electronic Gas Detectors</td>
<td>*</td>
<td>$$</td>
</tr>
<tr>
<td>Acoustic Detection/ Ultrasound Detection</td>
<td>** *</td>
<td>$$$</td>
</tr>
<tr>
<td>TVA (FID)</td>
<td>*</td>
<td>$$$</td>
</tr>
<tr>
<td>Bagging</td>
<td>*</td>
<td>$$$</td>
</tr>
<tr>
<td>High Volume Sampler</td>
<td>** * *</td>
<td>$$</td>
</tr>
<tr>
<td>Rotameter</td>
<td>** *</td>
<td>$</td>
</tr>
<tr>
<td>Infrared Detection</td>
<td>** * *</td>
<td>$$$</td>
</tr>
</tbody>
</table>
## Repair the Cost Effective Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Value of Lost Gas ($1)</th>
<th>Estimated Repair Cost ($)</th>
<th>Payback (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug Valve: Valve Body</td>
<td>12,641</td>
<td>200</td>
<td>0.2</td>
</tr>
<tr>
<td>Union: Fuel Gas Line</td>
<td>12,155</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>Threaded Connection</td>
<td>10,446</td>
<td>10</td>
<td>0.0</td>
</tr>
<tr>
<td>Distance Piece: Rod Packing</td>
<td>7,649</td>
<td>2,000</td>
<td>3.1</td>
</tr>
<tr>
<td>Open-Ended Line</td>
<td>6,959</td>
<td>60</td>
<td>0.1</td>
</tr>
<tr>
<td>Compressor Seals</td>
<td>5,783</td>
<td>2,000</td>
<td>4.2</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>4,729</td>
<td>60</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Hydrocarbon Processing, May 2002

$1^\text{Based on $3/Mcf gas price}$
How Much Gas Can Be Saved?

- Natural Gas STAR Lessons Learned study for DI&M at compressor stations estimates
  - Potential Average Gas Savings ~ 29,000 Mcf/yr/compressor station
  - Value of gas saved ~ $87,000 / compressor station (at gas price of $3/Mcf)
  - Average initial implementation cost ~ $26,000 / compressor station
Discussion Questions

☆ To what extent are you implementing these opportunities?
☆ Can you suggest other opportunities?
☆ How could these opportunities be improved upon or altered for use in your operation?
☆ What are the barriers (technological, economic, lack of information, regulatory, focus, manpower, etc.) that are preventing you from implementing these practices?