Methane Emissions Reduction Opportunities at Natural Gas Compressor Stations

Gazprom – EPA Technical Seminar on Methane Emission Mitigation

28 – 30 October, 2008
Methane Savings at Compressor Stations: Agenda

- Compressor Opportunities
  - Replacing wet seals with dry seals in centrifugal compressors
  - Scrubber dump valves
  - Reducing emissions when taking compressors offline
  - Economic rod packing replacement in reciprocating compressors

- Pneumatic Devices

- Discussion
Methane Savings at Compressor Stations: Economics

- All technologies and practices promoted by the Natural Gas STAR Program and Methane to Markets are proven based on successful field implementation by Partner companies.

- Costs and savings represented in the following presentation are based on company specific data collected from actual projects in the U.S. and other countries; data are presented in U.S. economics.

- One example estimates the economics for Russia using a range of natural gas prices and a factor to adjust for Russian capital and labor costs (slide 8 and 9) using data from the Oil and Gas Journal.
Compressor Methane Emissions
What is the problem?

- Methane emissions from the ~51,500 compressors in the U.S. natural gas industry account for 89 Billion cubic feet (Bcf) or 2,520,000 thousand cubic meters (Mcm) per year
- This represents 24% of all methane emissions from the U.S. natural gas industry
Methane Losses from Centrifugal Compressors

- Centrifugal compressor wet seals leak little gas at the seal face
  - The majority of methane emissions occur through seal oil degassing which is vented to the atmosphere
  - Seal oil degassing may vent 1.1 to 5.7 m³/minute to the atmosphere
  - One Natural Gas STAR Partner reported emissions as high as 2,124 m³/day
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
Reduce Emissions with Dry Seals

- Dry seal springs press stationary ring in seal housing against rotating ring when compressor is not rotating.
- At high rotation speed, gas is pumped between seal rings by grooves in rotating ring 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 205 atmospheres (atm)\(^1\) safely.

\(^1\) 205 atm = 3,000 pounds per square inch gauge (psig)
Methane Savings through Dry Seals

- Dry seals typically leak at a rate of only 0.8 to 5.1 m³/hour (0.01 to 0.09 m³/minute)
  - Significantly less than the 1.1 to 5.7 m³/minute emissions from wet seals
Example Economic Analysis: Adjusted Russian Cost Scenario

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hours/year

<table>
<thead>
<tr>
<th></th>
<th>United States Cost Scenario</th>
<th>Adjusted Russian Cost Scenario</th>
<th>High Russian Cost Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUB/Mcm</td>
<td>971</td>
<td>9,712</td>
<td>971</td>
</tr>
<tr>
<td>9,712 RUB/Mcm</td>
<td></td>
<td></td>
<td>9,712 RUB/Mcm</td>
</tr>
<tr>
<td>Internal Rate of Return (%)</td>
<td>43%</td>
<td>206%</td>
<td>38%</td>
</tr>
<tr>
<td>Net Present Value (RUB)</td>
<td>6,918,000</td>
<td>49,257,000</td>
<td>5,293,000</td>
</tr>
<tr>
<td>Payback Period (months)</td>
<td>24</td>
<td>6</td>
<td>26</td>
</tr>
</tbody>
</table>

- Economics are better for new installations
  - Vendors report that 90% of compressors sold to the natural gas industry are centrifugal with dry seals

2 Two times greater than the Adjusted Russian Cost Scenario
3 Net Present Value calculated at a 10% interest rate
**Detailed Calculations for the Adjusted Russian Cost Scenario**

- Compare costs and savings for a 6-inch shaft beam compressor
- Costs have been altered to reflect adjusted Russian cost scenario

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Implementation Costs(^2)</th>
<th>Gas Price: 971 RUB/Mcm</th>
<th>Gas Price: 9,712 RUB/Mcm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Seal (RUB)</td>
<td>Wet Seal (RUB)</td>
<td>Dry Seal (RUB)</td>
</tr>
<tr>
<td>Seal costs (2 dry @ 298,300 RUB/shaft-inch, w/testing)</td>
<td>3,579,000</td>
<td>3,579,000</td>
<td>3,579,000</td>
</tr>
<tr>
<td>Seal costs (2 wet @ 149,200 RUB/shaft-inch)</td>
<td>1,790,000</td>
<td>1,790,000</td>
<td>1,790,000</td>
</tr>
<tr>
<td>Other costs (engineering, equipment installation)</td>
<td>3,579,000</td>
<td>3,579,000</td>
<td>3,579,000</td>
</tr>
<tr>
<td>Total Implementation Costs</td>
<td>7,158,000</td>
<td>1,790,000</td>
<td>7,158,000</td>
</tr>
<tr>
<td>Annual O&amp;M</td>
<td>311,000</td>
<td>1,576,000</td>
<td>311,000</td>
</tr>
<tr>
<td><strong>Annual methane savings (8,000 hours/year)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 dry seals at a total of 10 m(^3)/hour</td>
<td>80,000</td>
<td>793,000</td>
<td></td>
</tr>
<tr>
<td>2 wet seals at total 170 m(^3)/hour</td>
<td>1,321,000</td>
<td>13,203,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total Costs Over 5-Year Period (RUB):</strong></td>
<td>9,108,000</td>
<td>16,268,000</td>
<td>12,672,000</td>
</tr>
<tr>
<td><strong>Total Dry Seal Savings Over 5 Years:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings (RUB)</td>
<td>7,161,000</td>
<td>63,007,000</td>
<td></td>
</tr>
<tr>
<td>Methane Emissions Reductions (Mcm) (at 1,278 Mcm/year)</td>
<td>6,389</td>
<td>6,389</td>
<td></td>
</tr>
</tbody>
</table>


\(^2\) Flowserve Corporation (updated costs and savings)
Industry Experience – PEMEX (Mexican Production Company)

- PEMEX had 46 compressors with wet seals at its PGPB production site
- Converted three to dry seals
  - Cost $444,000/compressor
  - Saves 580,500 m³/compressor/year
  - Saves $126,690/compressor/year in gas savings alone
- 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 a low pressure fuel gas boiler, capturing most 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

Source: TransCanada
Supersonic Gas Injector: TransCanada (Canadian Transmission Company)

- Developed for capturing very low pressure vent gases and re-injection into a high pressure gas stream without the use of rotating machinery

- Savings
  - 113,000 m³/year of gas savings from one compressor
  - Natural gas worth $28,000/year/unit @$7/Mcf
  - Zero operating cost

Source: TransCanada
Methane Savings at Compressor Stations: Agenda

- Compressor Opportunities
  - Replacing wet seals with dry seals in centrifugal compressors
  - Scrubber dump valves
  - Reducing emissions when taking compressors offline
  - Economic rod packing replacement in reciprocating compressors

- Pneumatic Devices

- Discussion
Scrubber Dump Valves, Unit Valves, Pressure Relief Valves

- Major sources of leakage identified from Research in mid 1990’s (GRI, EPA, PRCI) are the same in today.
  - Compressor seals, unit valves, scrubber dump valves and blow down valves.

- Most often missed savings opportunities occur from scrubber dump valves leaking through condensate tanks.
  - Easy access, low cost repair, huge savings potential.
Natural Gas Losses by Equipment Type

- Dump valves represent one of the largest sources of methane leaks at compressor stations

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Valves</td>
<td>$311,724</td>
</tr>
<tr>
<td>Blow Down Valves</td>
<td>$156,506</td>
</tr>
<tr>
<td>Standardized Components</td>
<td>$145,019</td>
</tr>
<tr>
<td>Rod Packing</td>
<td>$723,863</td>
</tr>
<tr>
<td>Pressure Relief Valves</td>
<td>$44,086</td>
</tr>
<tr>
<td>Dump Valves</td>
<td>$10,256,57</td>
</tr>
</tbody>
</table>

321 Leak Sources
1.6 Bcf
$7/Mcf

Data Source: Heath Consultants Inc. 2005 (U.S. measurements)
Scrubber Dump Valves

- Improper closing of dump valves in compressor scrubbers can lead to gas venting from tanks

- Causes
  - Seat repair/damage
  - Debris
  - Over flush

- Detection and measurement methods
  - Infrared Leak Detection
  - Sonic
  - Adiabatic expansion (ice)
  - Measurement charts
  - High volume sampler

Source: Northern Natural Gas
Northern Natural Gas Experience (U.S. Transmission Company): Dump Valves

- Separator Dump Valve Leak

Source: Northern Natural Gas

IR leak detection using FLIR GasFinIR®
Northern Natural Gas: Dump Valve Gas Losses

Natural Gas Loss

Cubic Meters/Day

0.8 mm
(1/32 inch)

1.6 mm
(1/16 inch)

3.2 mm
(1/8 inch)

6.4 mm
1/4 inch

- 21.4 atm (300 psi)
- 41.8 atm (600 psi)
Northern Natural Gas: Repaired Dump Valve

IR leak detection using FLIR GasFinIR®
Northern Natural Gas: Separator Dump Valve Data

- 435 dump valves: 3.7 m³/hour
- 41 @ one station
- Inspection
  - Daily rounds – feel & listen
  - Trim inspection & repair
- 435 dump valves: 0.3 m³/hour
- Volume from dumping operation – flash gas
- Purge volume
Methane Savings at Compressor Stations: Agenda

- Compressor Opportunities
  - Replacing wet seals with dry seals in centrifugal compressors
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- Pneumatic Devices

- Discussion
Compressors Offline: What is the Problem?

- Natural gas compressors cycled on- and off-line to match fluctuating gas demand
  - Peak and base load compressors

- Standard practice is to blow down (depressurize) off-line compressors
  - One reciprocating compressor blowdown vents 425 m$^3$ gas to atmosphere on average

- Isolation valves
  - Leak about 40 m$^3$/hour on average through open blowdown vents
Compressors Offline: Methane Recovery

- Principles of reducing emissions from offline compressors applicable to both reciprocating and centrifugal compressor
- Volume of losses vary for reciprocating and centrifugals
  - Blowdown volumes larger for reciprocating
  - Isolation valve leakage similar in magnitude
  - Compressor seal leakage similar in magnitude
- Following example show methane emissions savings from a reciprocating compressor
Basic Reciprocating Compressor Schematic

- Depressurized

- Blowdown Valve (Open)
- 40 m³/hour leak from isolation valves
- Inlet Gas
- Isolation Valve (Closed)
- Outlet Gas
Methane Recovery - Option 1

- Keep off-line compressors pressurized
  - Requires no facility modifications
  - Eliminates methane vents
  - Seal leak higher by 8.5 m³/hour
  - Reduces fugitive methane losses by 27 m³/hour (68%)
Methane Recovery - Option 2

- Route off-line compressor gas to fuel
  - Connect blowdown vent to fuel gas system
  - Off-line compressor equalizes to fuel gas pressure
  - (7.8 to 11.2 atm)
  - Eliminates methane vents
  - Seal leak higher by 3.5 m³/hour
  - Reduces fugitive methane losses by 36 m³/hour (91%)
Methane Recovery - Option 3

- Keep pressurized and install a static seal
  - Automatic controller activates rod packing seal on shutdown and removes seal on startup
  - Closed blowdown valve leaks
  - Eliminates leaks from off-line compressor seals
  - Reduces fugitive methane losses by 35 m³/hour (89%)
Compressors Offline: Calculate Methane Emissions

- Blowdown losses = (# blowdowns) x (425 m$^3$)$^1$
- Fugitive losses = (# offline hours) x (40 m$^3$/hour)$^1$

- Total losses = blowdown + fugitive savings

- Example for base load compressor:
  - 2 blowdowns/yr x 425 m$^3$
  - 1,752 offline hours x 40 m$^3$/hour = 70,900 m$^3$/year

$^1$EPA default values
Compressors Offline: Calculate Costs

- **Option 1:** Do not blow down
  - No capital costs
  - No O&M costs

- **Option 2:** Route to fuel gas system
  - Add pipes and valves connecting blowdown vent to fuel gas system
  - Upgrade costs range from $1,000 to $2,000 per compressor
Compressors Offline: Calculate Costs

- Option 3: Do not blow down and install static seal
  - Seals cost $675 per rod
  - Seal controller costs $1,500 per compressor
  - Less cost-effective in conjunction with Option 2
Compressors Offline: Is Recovery Profitable?

### Costs and Savings

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Keep Pressurized</td>
<td>Keep Pressurized and Tie to Fuel Gas</td>
<td>Keep Pressurized and Install Static Seal</td>
</tr>
<tr>
<td><strong>Capital</strong></td>
<td>None</td>
<td>$1,700/compressor</td>
<td>$4,100/compressor</td>
</tr>
<tr>
<td><strong>Off-line Leakage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Baseload</strong></td>
<td>6,400 m$^3$/year</td>
<td>1,800 m$^3$/year</td>
<td>2,100 m$^3$/year</td>
</tr>
<tr>
<td></td>
<td>$1,600</td>
<td>$400</td>
<td>$500</td>
</tr>
<tr>
<td><strong>Peak Load</strong></td>
<td>51,000 m$^3$/year</td>
<td>14,100 m$^3$/year</td>
<td>17,000 m$^3$/year</td>
</tr>
<tr>
<td></td>
<td>$12,600</td>
<td>$3,500</td>
<td>$4,200</td>
</tr>
</tbody>
</table>

**Note:** Baseload scenario assumes compressor is off-line 500 hours/year; peak load scenario assumes compressor is off-line 4,000 hours/year. Gas cost is $7/Mcf.
Compressors Offline: Economic Analysis

- Peak load options more economical due to more blowdowns and offline time

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th></th>
<th>Option 2</th>
<th></th>
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<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Keep Pressurized</td>
<td></td>
<td>Keep Pressurized and Tie to Fuel Gas</td>
<td></td>
<td>Keep Pressurized and Install Static Seal</td>
<td></td>
</tr>
<tr>
<td>Base Net Gas Savings (m³/year)</td>
<td>14,700</td>
<td>124,600</td>
<td>+5,900</td>
<td>+38,100</td>
<td>+4,200</td>
<td>+34,000</td>
</tr>
<tr>
<td>Peak Net Gas Savings (m³/year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dollar Savings/year¹</td>
<td>$ 3,600</td>
<td>$ 30,800</td>
<td>$ 1,500</td>
<td>$ 9,400</td>
<td>$ 1,100</td>
<td>$ 8,400</td>
</tr>
<tr>
<td>Facilities Investment</td>
<td>0</td>
<td>0</td>
<td>$ 1,700</td>
<td>$ 1,700</td>
<td>$ 4,100</td>
<td></td>
</tr>
<tr>
<td>Payback</td>
<td>Immediate</td>
<td>Immediate</td>
<td>1 yr</td>
<td>2 months</td>
<td>4 yrs</td>
<td>6 months</td>
</tr>
<tr>
<td>IRR²</td>
<td>&gt;100%</td>
<td>&gt;100%</td>
<td>82%</td>
<td>560%</td>
<td>9%</td>
<td>207%</td>
</tr>
</tbody>
</table>

¹ Assuming value of gas is $7/Mcf
² 5 year life (not including annual O&M costs)
Compressors Offline: Lessons Learned

- Avoid depressuring whenever possible
  - Immediate benefits with no investment
- Educate field staff about benefits
- Identify compressor loads to conduct economic analysis
- Develop schedule for installing fuel gas routing systems
- Record savings at each compressor
Methane Savings at Compressor Stations: Agenda

- Compressor Opportunities
  - Replacing wet seals with dry seals in centrifugal compressors
  - Scrubber dump valves
  - Reducing emissions when taking compressors offline
  - Economic rod packing replacement in reciprocating compressors

- Pneumatic Devices

- Discussion
Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - Newly installed packing may leak 0.3 to 1.7 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
- Packing to rod
- Packing to cup
- Packing to packing
- Cup to cup

### What makes packing leak?
- Dirt or foreign matter (trash)
- Worn rod (.015 mm/ per cm dia.)
- Insufficient/too much lubrication
- Packing cup out of tolerance (≤ 0.05 mm)
- Improper break-in on startup
- Liquids (dilutes oil)
- Incorrect packing installed (backward or wrong type/style)
## Methane Losses from Rod Packing

| Source: Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations – PRCI/ GRI/ EPA PR-246-9526 |

### 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 (m³/year)</td>
<td>17,300</td>
<td>15,700</td>
<td>37,300</td>
<td>5,900</td>
</tr>
</tbody>
</table>

### Leakage from Rod Packing on Idle/Pressurized 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 (m³/year)</td>
<td>17,400</td>
<td>N/A</td>
<td>36,500</td>
<td>5,400</td>
</tr>
</tbody>
</table>

- Emission from Running Compressor: 24,600 m³/year-packing
- Emission from Idle/Pressurized Compressor: 36,000 m³/year-packing
- Leakage from Packing Cup: 19,500 m³/year-packing
- Leakage from Distance Piece: 8,500 m³/year-packing
Steps to Determine Economic Replacement

- Measure rod packing leakage
  - When new packing installed – after worn-in
  - Periodically afterwards
- Determine cost of packing replacement
- Determine economic replacement threshold
  - Partners can determine economic threshold for all replacements
  - This is a capital recovery economic calculation
- Replace packing when leak reduction expected will pay back cost

Economic Replacement Threshold (m³/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 meters)

\[ DF = \frac{i(1+i)^n}{(1+i)^n - 1} \]
Low Emission Packing

- 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
Industry Experience – Northern Natural Gas (U.S. Transmission Company)

- Monitored emission at two locations
  - Unit A leakage as high as 301 liters/minute (18 m$^3$/hour)
  - Unit B leakage as high as 105 liters/minute (6 m$^3$/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

- **Northern Natural Gas - Leakage Rates**

- **Graph showing leakage rates from 1997 to 2005.**
  - **Unit A**
  - **Unit B**
  - Leakage rates:
    - 1.7 m³/hour
    - 18 m³/hour

- **Graph legend:**
  - **Green** for Unit A
  - **Yellow** for Unit B

- **Years:** 1997 to 2005

- **Note:** Methane to Markets

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Northern Natural Gas Packing Leakage
Economic Replacement Point

- Approximate packing replacement cost is $3,000 per compressor rod (parts/labor)

- Assuming gas at $7 per thousand cubic feet (Mcf) or $250/Mcm:
  - 50 liters/minute/1000 = 0.05 m³/minute
  - 0.05 x 60 minutes/hour = 3 m³/hour
  - 3 x 24 = 72 m³/day
  - 72 x 365 days/1000 = 26.3 Mcm/year
  - 26.3 x $250/Mcm = $6,600 per year leakage
  - This replacement pays back in <6 months
Reciprocating Compressor Lessons Learned

- A threshold exists when it is economic to replace rod packing in reciprocating compressors
- This threshold is often surpassed before replacement occurs
- Sharing these thresholds company-wide is an easy way for operators to determine when replacement is economic
- You must periodically measure emissions
- Economic replacement of rod packing reduces methane emissions, saves money
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- **Compressor Opportunities**
  - Replacing wet seals with dry seals in centrifugal compressors
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- **Pneumatic Devices**

- **Discussion**
Methane Losses from Pneumatic Devices

- Pneumatic devices are used to actuate process controls on equipment throughout the natural gas industry.

SOV = Shut-off Valve (Unit Isolation)
LC = Level Control (Separator, Contactor, Glycol Regenerator)
TC = Temperature Control (Regenerator Fuel Gas)
FC = Flow Control (Glycol Circulation, Compressor Bypass)
PC = Pressure Control (Flash Tank Pressure, Compressor Suction/Discharge)
How Gas Pneumatic Devices Work

Regulator

Gas
7.8+ atm$^1$

Regulated Gas Supply
2.4 atm$^1$

Process Measurement

Liquid Level Pressure Temperature Flow

Weak Pneumatic Signal (1.2 to 2 atm)$^1$

Pneumatic Controller

Strong Pneumatic Signal

Valve Actuator

Weak Signal Bleed (Continuous)

Strong Signal Vent (Intermittent)

Process Flow

Control Valve

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1 atmosphere (atm) = 0 pounds per square inch gauge (psig) and 14.7 pounds per square inch atmospheric (psia)

1 atm = 1.013 bar and 101.3 kilopascals (kPa)
Pneumatic Devices: Methane Emissions

- As part of normal operations, pneumatic devices release natural gas to atmosphere

- High-bleed devices are defined as those that bleed in excess of 4 m$^3$ per day
  - Aggregates to more than 1,460 m$^3$/year
  - Typical high-bleed pneumatic devices bleed an average of 3,965 m$^3$/year

- Actual bleed rate is largely dependent on device’s design and maintenance
Methane Recovery from Pneumatic Devices

- **Option 1:** Replace high-bleed devices with low-bleed devices
  - Replace at end of device’s economic life
  - Typical cost range from $700 to $3000 per device
- **Option 2:** Retrofit controller with bleed reduction kits
  - Retrofit kit costs approximately $675
  - Payback time approximately 6 months
- **Option 3:** Maintenance aimed at reducing losses
  - Field survey of controllers
  - Re-evaluate the need for pneumatic positioners
  - Cost is low

Field experience shows that up to 80% of all high-bleed devices can be replaced or retrofitted with low-bleed equipment.
Five Steps for Reducing Methane Emissions from Pneumatic Devices

1. LOCATE and INVENTORY high-bleed devices
2. ESTABLISH the technical feasibility and costs of alternatives
3. ESTIMATE the savings
4. EVALUATE economics of alternatives
5. DEVELOP an implementation plan
Suggested Analysis for Replacement

- Replacing high-bleed controllers at end of economic life
  - Determine incremental cost of low-bleed device over high-bleed equivalent
  - Determine gas saved with low-bleed device using manufacturer specifications
  - Compare savings and cost

- Early replacement of high-bleed controllers
  - Compare gas savings of low-bleed device with full cost of replacement

<table>
<thead>
<tr>
<th>Implementation^a</th>
<th>Replace at End of Life</th>
<th>Early Replacements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Level Control</td>
</tr>
<tr>
<td>Cost ($)</td>
<td>150 to 250^b</td>
<td>513</td>
</tr>
<tr>
<td>Annual Gas Savings (m³)</td>
<td>1,400 to 5,660</td>
<td>4,700</td>
</tr>
<tr>
<td>Annual Gas Savings (Mcf)</td>
<td>50 to 200</td>
<td>166</td>
</tr>
<tr>
<td>Annual Value of Saved Gas ($)^c</td>
<td>350 to 1,400</td>
<td>1,165</td>
</tr>
<tr>
<td>IRR (%)</td>
<td>138 to 933</td>
<td>226</td>
</tr>
<tr>
<td>Payback (months)</td>
<td>2 to 9</td>
<td>6</td>
</tr>
</tbody>
</table>

^a All data based on Partners’ experiences and represented in U.S. economics
^b Range of incremental costs of low-bleed over high bleed equipment
^c Gas price is assumed to be $7/Mcf
Suggested Analysis for Retrofit

- Retrofit of low-bleed kit
  - Compare savings of low-bleed device with cost of conversion kit
  - Retrofitting reduces emissions by average of 90%

<table>
<thead>
<tr>
<th>Implementation Costs(^b)</th>
<th>Retrofit(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleed rate reduction (m(^3)/device/year)</td>
<td>6,200</td>
</tr>
<tr>
<td>Bleed rate reduction (Mcf/device/year)</td>
<td>219</td>
</tr>
<tr>
<td>Value of gas saved ($/year)(^c)</td>
<td>$1,533</td>
</tr>
<tr>
<td>Payback (months)</td>
<td>6</td>
</tr>
<tr>
<td>Internal Rate of Return</td>
<td>226%</td>
</tr>
</tbody>
</table>

\(^a\) On high-bleed controllers
\(^b\) All data based on Partners’ experiences and represented in U.S. economics.
\(^c\) Gas price is assumed to be $7/Mcf
Suggested Analysis for Maintenance

- For maintenance aimed at reducing gas losses
  - Measure gas loss before and after procedure
  - Compare savings with labor (and parts) required for activity

<table>
<thead>
<tr>
<th></th>
<th>Reduce supply pressure</th>
<th>Repair &amp; retune</th>
<th>Change settings</th>
<th>Remove valve positioners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Cost ($)(^a)</td>
<td>207</td>
<td>31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gas savings (m³/year)</td>
<td>4,960</td>
<td>1,250</td>
<td>2,500</td>
<td>4,470</td>
</tr>
<tr>
<td>Gas savings (Mcf/year)</td>
<td>175</td>
<td>44</td>
<td>88</td>
<td>158</td>
</tr>
<tr>
<td>Value of gas saved ($/year)(^b)</td>
<td>1,225</td>
<td>308</td>
<td>616</td>
<td>1,106</td>
</tr>
<tr>
<td>Payback (months)</td>
<td>3</td>
<td>2</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>IRR</td>
<td>592%</td>
<td>994%</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

\(^a\) All data based on Partners’ experiences and represented in U.S. economics
\(^b\) Gas price is assumed to be $7/Mcf
Industry Experience: Marathon Oil (U.S. Production Company)

- Marathon surveyed 158 pneumatic devices at 50 production sites
- Half of the controllers were low-bleed
- High-bleed devices included
  - 35 of 67 level controllers
  - 5 of 76 pressure controllers
  - 1 of 15 temperature controllers
Marathon Oil: Industry Experience

- Marathon measured gas losses total 145 thousand m³/year
- Level controllers account for 86% of losses
  - Losses averaged 0.2 m³/hour/device
  - Losses ranged up to 1.4 m³/hour/device (11.9 thousand m³/year)
- Concluded that excessive losses can be heard or felt
Methane Savings at Compressor Stations: Discussion

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