Pipeline Maintenance Best Practices

Lessons Learned from the Natural Gas STAR Program

SGA Environmental Round Table
Charlotte, North Carolina
June 25 - 27, 2008

epa.gov/gasstar
Pipeline Maintenance Agenda

❖ Methane Losses
  ❖ What are the sources of emissions?
  ❖ How much methane is emitted?

❖ Methane Recovery
  ❖ Hot Taps
  ❖ Pipeline Pumpdown
  ❖ Composite Wraps
  ❖ Additional Partner Reported Opportunities

❖ Discussion
2006 Transmission Sector Methane Emissions

Pipeline leaks can occur through internal and external corrosion, material defects, joint and fitting defects, and third party damage.

- **Station Fugitives**: 7 Bcf
- **Station Venting**: 8 Bcf
- **Centrifugal Compressors**: 8 Bcf
- **Gas Engine Exhaust**: 10 Bcf
- **Pneumatic Devices**: 11 Bcf
- **Reciprocating Compressors**: 39 Bcf
- **Other Sources**: 4 Bcf
- **Pipeline Leaks**: 7 Bcf


Natural Gas STAR reductions data shown as published in the inventory.
Older cast iron and unprotected steel pipelines contribute the majority of emission of pipeline related emissions.

- **Customer Meter Leaks**: 5 Bcf
- **Plastic Mains/Services**: 7 Bcf
- **Cast Iron Mains**: 8 Bcf
- **Protected Steel Mains/Services**: 4 Bcf
- **Regulator Stations**: 9 Bcf
- **Other Sources**: 2 Bcf
- **M&R Stations**: 14 Bcf
- **Unprotected Steel Mains/Services**: 12 Bcf

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Natural Gas STAR reductions data shown as published in the inventory.
What is the problem with current practices?

- Methane gas leaks are invisible, unregulated, and go unnoticed
- Methane vented in preparation for pipeline maintenance/new connections
- Smallest possible linear section of pipeline is blocked in and depressurized to the atmosphere
- “Hot work” may require purging pipeline with inert gas
- These practices result in methane emissions
  - Loss of Sales
  - Service disruption and customer inconvenience
  - Costs of evacuating the existing piping system
Hot Taps

Connecting Pipelines without Disruption

Certified Williamson Industries Technician performing a hot tap with a 760 Tapping Machine as part of a 12” Stopple application.

Source: Williamson Industries Inc.
What are Hot Taps?

- New branch connection while the pipeline remains in service
  - Attach a branch connection and valve to the main pipeline
  - Cut-out a section of the main pipeline wall through the valve to connect the branch to the main pipeline
- Current technology has improved reliability and reduced complications
- Hot tapping can be used to add connections to a wide range of pipelines
  - Transmission pipelines
  - Distribution mains

Schematic of Hot Tapping Machine

Source: IPSCO
Hot Tapping Procedure

- Connect fitting and permanent valve on the existing pipeline
- Install hot tapping machine on the valve
- Perform hot tap and extract coupon through the valve
- Close valve and remove hot tapping machine
- Connect branch line
Hot Tap Benefits

- Continuous system operation – shutdown and service interruptions are avoided
- No gas released to the atmosphere
- Avoided cutting, realignment and re-welding of pipeline sections
- Reduced planning and coordination costs
- Increased worker safety
- No gas outages for customers
Hot Tap Economics

- Determine physical conditions of existing line
- Calculate the cost of a shutdown interconnect
- Hot tap expenses
- Estimated annual hot tap costs
  - For hypothetical scenario
- Estimated annual hot tap savings
  - For hypothetical scenario
- Economic analysis of hot tap vs. shutdown
Determine physical conditions of existing line

- Maximum operating pressure (during hot tap)
- Type of pipe material
- Condition of parent pipeline (internal/external corrosion and wall thickness)
- Emergency valve location for isolation in case of accidents
- Working space evaluation (desired tap diameter, location of other welds, obstructions, etc.)
- Check if the line is looped
Calculate Cost of Shutdown Interconnect

Given: A pipeline company requires numerous shutdown or hot tap connections as follows --

| Pipeline diameter (D) = 4 inches | 4 | 8 | 10 | 18 |
| Pipeline pressure (P) = 350 psig | 350 | 100 | 1,000 | 200 |
| Isolated pipeline length (L), miles | 2 | 1 | 3 | 2 |
| Annual taps | 250 | 30 | 25 | 15 |

Volume of natural gas lost

\[ V_g = \frac{D^2 \times P \times \left[ \frac{L}{1,000} \right] \times 0.372}{1,000} = \]

\[ 4^2 \times 350 \times \left[ \frac{2 \times 5,280}{1,000} \right] \times 0.372 \]

\[ = 22 \text{ Mcf} \times \$7/\text{Mcf} = \$154 \]
Calculate Cost of Shutdown Interconnect (cont’d)

Volume of purge gas (assumed to be nitrogen)

\[ V_{\text{pgas}} = \frac{\left( \frac{D^2 \times L}{183} \right) \times 2.2}{1,000} = \frac{\left( \frac{4^2 \times 2 \times 5,280}{183} \right) \times 2.2}{1,000} = 2 \text{ Mscf} \]

- Given:
  - Cost of natural gas (\(C_g\)) = $7/Mscf
  - Cost of nitrogen (\(C_{\text{pgas}}\)) = $8/Mscf

Value of gas lost by shutdown interconnects (Including purge gas)

\[ \text{Cost} = C_g + C_{\text{pgas}} = V_g \times P_g + V_{\text{pgas}} \times P_{\text{pgas}} = (22 \times 7) + (2 \times 8) = $170 \text{ for each 4 inch pipeline shutdown interconnect} \]
Hot Tap Expenses

- Calculate the cost of a hot tap procedure
- Cost of the hot tap equipment purchase and O&M cost of hot tapping contract
- Purchase costs for small tapping machines vary from $17,287 to $30,122
- Most companies find it economical to contract out large jobs

<table>
<thead>
<tr>
<th>Connection Size</th>
<th>Capital Costs ($)</th>
<th>Contracting Service Cost ($)</th>
<th>Equipment O&amp;M Cost ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Taps (&lt;12”)</td>
<td>Machine¹ 17,287 – 30,122</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Taps (&gt;12”)</td>
<td>130,963 – 261,927²</td>
<td>2,619 – 11,944²</td>
<td>1,447 – 5,788</td>
</tr>
</tbody>
</table>

¹ Hot tap machines can last from 5 to 40 years. A company can perform as many as 400 small taps per year.
² Most companies will find it more economical to contract out large jobs, and would not therefore incur these costs.

Note: Cost information provided by Hot Tap manufacturers and contractors. Prices only provided for most economic options. Updated 2006
Estimated Annual Hot Tap Costs

- Given (annual program):
  - Equipment cost per small tap machine = $23,704
  - Operations and Maintenance (O&M) cost per machine = $3,979
  - Number of small hot tap machines = 2
  - Contract Services cost per large tap = $3,618
  - Number of contracted taps = 15 (all taps 12 inches and larger)

- Total equipment cost = $23,704 * 2 = $47,409
- Total O&M cost = $3,979 * 2 = $7,959
- Contract Service cost = $3,618 * 15 = $54,263
## Estimated Annual Hot Tap Savings

Evaluate the gas savings benefits of hot tapping

<table>
<thead>
<tr>
<th>Tap Scenario</th>
<th>Annual Tap Number</th>
<th>Natural Gas Savings</th>
<th>Nitrogen Purge Gas Savings</th>
<th>Total Gas Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Per tap Mscf</td>
<td>Annual Mscf</td>
<td>Per tap Mscf</td>
</tr>
<tr>
<td>Pipeline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4” pipeline, 350 psig, 2 mile line</td>
<td>250</td>
<td>22</td>
<td>5,500</td>
<td>2</td>
</tr>
<tr>
<td>8” pipeline, 100 psig, 1 mile line</td>
<td>30</td>
<td>13</td>
<td>390</td>
<td>4</td>
</tr>
<tr>
<td>10” pipeline, 1,000 psig, 3 mile line</td>
<td>25</td>
<td>589</td>
<td>14,725</td>
<td>19</td>
</tr>
<tr>
<td>18” pipeline, 200 psig, 2 mile line</td>
<td>15</td>
<td>255</td>
<td>3,825</td>
<td>41</td>
</tr>
<tr>
<td>Total Annual</td>
<td>320</td>
<td>24,440</td>
<td>1,710</td>
<td>184,760</td>
</tr>
</tbody>
</table>
Economic Analysis of Hot Tap vs. Shutdown

Compare the options and determine the economics of five year hot tapping program (320 taps/yr)

<table>
<thead>
<tr>
<th>Economic Analysis of Hot Tap Versus Shutdown</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Year 0</strong></td>
</tr>
<tr>
<td>Capital Cost, $</td>
</tr>
<tr>
<td>Contract Service Cost, $</td>
</tr>
<tr>
<td>O&amp;M Cost, $</td>
</tr>
<tr>
<td>Total Cost, $</td>
</tr>
<tr>
<td>Natural Gas Savings, $</td>
</tr>
<tr>
<td>Inert Gas Savings, $</td>
</tr>
<tr>
<td>Net Benefit, $</td>
</tr>
<tr>
<td>Payback (months)</td>
</tr>
<tr>
<td>IRR</td>
</tr>
<tr>
<td>NPV(^1)</td>
</tr>
</tbody>
</table>

\(^1\) Net Present Value (NPV) based on 10% discount rate for 5 years
Methane Recovery by Pipeline Pumpdown

- Most applicable to large pipelines operating at high pressures
- Use In-Line compressors to “pull down” the pressure to minimum suction pressure
- Use portable compressor to “pull down” pressure even further
- Cost is justified by immediate payback in gas savings
- About 90% of gas usually vented is recoverable
Pipeline Pumpdown Technique

- **In-line Compressor**
  - Typically 2:1 compression ratio
  - By blocking upstream valve, the pressure in the pipeline is reduced to safe limits for maintenance

- **Portable Compressor**
  - Typically 5:1 compression ratio
  - Can be used in conjunction with in-line compressors to reduce pressure in pipeline section
  - Cost-justifiable only when multiple sections of pipeline are being serviced
  - Distribution mains generally do not contain a large enough volume of gas to justify the use of portable compressors
Sequence of Depressurization Events

1. Identify Pipeline Segment Needing Repair
   - Pipeline
   - Compressor Block Valve Open
   - Compressor Block Valve Open
   - Pipeline

2. Depressurize Segment by 50% Using In-line Pipeline Compressor
   - Pipeline
   - Compressor Block Valve Closed
   - Compressor Block Valve Open
   - Pipeline

3. Depressurize Segment Further to 90% Using Portable Compressor In Sequence With an In-line Compressor
   - Pipeline
   - Compressor Block Valve Closed
   - Compressor Block Valve Closed
   - Pipeline
   - Portable Compressor

Legend:
- Normal pipeline pressure
- Pipeline with pressure reduced to 50%
- Pipeline with pressure reduced to 90%
Economics of Pipeline Pumpdowns

- Calculate gas vented by depressurizing pipeline
- Calculate gas saved with in-line compressors
- Calculate gas saved with portable compressor
  - Consider cost of a portable compressor
- Calculate annual savings
Calculate Gas Vented by Depressurizing Pipeline

- Estimate the quantity and value of gas that in-line compressors can recover

**Given:**
- Pipeline isolated length \((L) = 10\) miles
- Pipeline interior diameter \((I) = 2.375\) feet
- Pipeline operating pressure \((P) = 600\) psig
- In-line compressor compression ratio \((R_i) = 2\)

**Gas vented in depressurizing pipeline**

\[
M = L \times (5,280 \text{ ft/mile}) \times (\pi \times I^2/4) \times (P/14.65 \text{ psig}) \times (1/1,000 \text{ Mcf/1,000cf})
\]

\[
M = (10 \times 5,280) \times (\pi \times 2.375^2/4) \times (600+14.65)/14.65 \times (1/1,000)
\]

\[
M = 9,814 \text{ Mcf}
\]
Calculate Gas Saved using In-line Compressors

- Amount of gas recoverable per action using an in-line compressor
  \[ Ni = M - \frac{M}{R_i} = 9,814 - \frac{9,814}{2} = 4,907 \text{ scf} \]

- Value of gas recovered per action using an in-line compressor
  \[ Vi = Ni \times \$7/Mscf = 4,907 \times \$7 = \$34,349 \]

- Annual value of gas recovered assuming 4 actions per month
  \[ = \$34,349 \times 4 \times 12 = \$1,648,752 \]
Calculate Gas Saved using Portable Compressors

Given:

- Portable compression ratio (Rp) = 8
- Rate of compressor = 416 Mscf / hour

Gas available for recovery

\[ M - Ni = 9,814 - 4,907 = 4,907 \text{ Mscf} \]

Gas saved using a portable compressor

\[ Np = Ni - (Ni / Rp) = 4,907 - (4,907 / 8) = 4,294 \text{ Mscf} \]

Value of gas recovered using portable compressor\(^1\)

\[ Vg = Np * $7/ \text{Mscf} = 4,294 * 7 = $ 30,056 * 4 * 12 = $ 1,442,688 \]

\(^1\) Because cost of operating portable compressor is high, assume portable compressor is used for 4 pipeline pumpdowns per month.
Consider Costs of a Portable Compressor

- Estimate the costs associated with using a portable compressor
  - Fuel costs (mostly natural gas) ($V_{cf}$) $\sim$ 7,000 – 8,400 Btu per brake horse power per hour
  - Maintenance costs ($V_{cm}$) $\sim$ $5 - $12 per horsepower per month
  - Labor costs ($V_{cl}$)
  - Taxes and administrative costs ($V_{ct}$)
  - Installation costs ($V_{ci}$)
  - Freight costs ($V_{cs}$)
# Portable Compressor Costs – Capital Costs

<table>
<thead>
<tr>
<th>Portable Compressor Purchase and Lease Cost Range*</th>
<th>1,000 PSIG – High Flow</th>
<th>600 PSIG – Medium Flow</th>
<th>300 PSIG – Low Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase</td>
<td>$3 - $6 million</td>
<td>$1.0 - $1.6 million</td>
<td>$518,131 - $777,197</td>
</tr>
<tr>
<td>Lease</td>
<td>$77,000 - $194,000 per month</td>
<td>$31,000 - $46,000 per month</td>
<td>$15,000 - $23,000 per month</td>
</tr>
</tbody>
</table>

*Based on assumptions that purchase cost does not include cost of freight or installation and that lease cost is 3 percent of purchase cost
Cost of a Portable Compressor – Operating and Maintenance Costs

- Fuel used by compressor per 10 mile isolated length, per month
  \[= 69 \text{ Mscf}\]

- Fuel costs assuming one 10-mile isolated lengths, per month
  \[= 7/\text{Mscf} \times 69 \text{ Mscf}\]
  \[= $483 \text{ per month}\]

- Total cost of using the portable compressor during a 12 month period
  \[= \text{fuel costs} + \text{lease and maintenance costs} + \text{freight costs}\]
  \[= 12 \times ($483 + $31,000) + $19,000\]
  \[= $396,796\]
Calculate Annual Savings

Gross value of gas recoverable during a 12-month period, **In-line Compressor**

\[ V_g \times 1 \times 12 = 34,349 \times 4 \times 12 = $1,648,752 \]

Gross value of gas recoverable during a 12-month period, **Portable Compressor**

\[ V_g = N_p \times \$7/\text{Mscf} = 4,294 \times 7 \]
\[ = $30,056 \times 4 \times 12 \]
\[ = $1,442,688 \]

**Net Savings** associated with using both In-line and Portable Compressor

\[ = $1,648,752 + (\$1,442,688 - \$396,796) \]
\[ = $2,677,256 \]
Composite Wrap

Permanent On-Line Pipeline Repair Technology

Source: Armor Plate
What is Composite Wrap?

- Non-leaking pipeline defects can only be fixed in one of three ways, per Department of Transportation (DOT) regulations:
  - Cut out damaged segment and replace with new pipes
  - Install a full-encirclement steel split sleeve over the damaged area
  - Install a composite sleeve over the damaged area

- Composite Wrap Advantages:
  - Can be performed without taking pipeline out of service
  - Repair is quick and less costly than replacement or sleeve options
  - Eliminates venting associated with replacement
Composite Wrap. What is it?

1) A high-strength glass fiber composite or laminate
2) An adhesive or resin bonding system
3) A high-compressive-strength load transfer filler compound
4) Replaces lost hoop strength

Source: Clock Spring® Company L. P.
Composite Wrap Installation

- After excavation and pipe preparation
  - External defects filled with filler
  - Composite wrap wound around pipe with adhesive or laminating agents
  - Typically 2” of wrap must extend beyond damage
  - Excavation site refilled after mandated curing time

- Reducing pressure improves quality of repair
Economics of Composite Wrap

- Calculate associated costs
  - State assumptions
  - Calculate labor cost
  - Calculate equipment cost
  - Calculate indirect costs
- Calculate Natural Gas Savings
- Compare options
Calculate Associated Costs: Assumptions

Given:

Need to repair a 6” non-leaking defect on a 24” pipeline, operating at 350 psig; assume 16 hours to complete the project\(^1\). Assume cost of engineering management is 25% cost of field labor.

\[ C_{\text{lab}} = \text{cost of labor} \]

*Hourly rate of field labor category*

- Operator = $46/hr
- Pipeliner = $42/hr
- Apprentice = $28/hr

\[ C_{\text{eq}} = \text{cost of equipment} \]

*Cost of individual equipment*

- Composite Wrap Kit = $1,087/kit
- Backhoe = $45/hr
- Sandblasting equipment = $12/hr
- Pipeline coatings (5% composite kit) = $54

\(^1\)Partner supplied information. Updated to 2006 costs.
Labor Costs

Given:
\( C_{\text{indirect}} \) = indirect costs such as field inspection crew, permits, etc.
(assume 50% of total equipment and labor cost)

Calculate cost of labor
\( C_{\text{labor}} \) = Engineering management cost + Field labor cost
Field labor cost = hourly rate \( \times \) time-length of project
\[ = (\$\ 46 + \$\ 42 + \$\ 28) \times 16 \]
\[ = $1,856 \]
Engineering Management cost = 0.25 \( \times \) $1,856 = $464

\[ C_{\text{labor}} = $464 + $1,856 = $2,320 \]
Equipment and Indirect Costs

- Calculate cost of equipment
  - \( C_{\text{equip}} = \text{Cost of consumable materials (composite wrap kit and coatings)} + \text{Cost of renting/using equipment on site} \)
  - \( = $1,087 + $54 + ($45 \times 16) + ($12 \times 16) \)
  - \( = $2,053 \)

- Calculate indirect costs
  - \( C_{\text{indirect}} = \text{Cost of permits, inspection services, right-of-way, etc.} \)
  - \( = 0.5 \times (C_{\text{labor}} + C_{\text{equip}}) = 0.5 \times ($2,320 + $2,053) \)
  - \( = $2,186 \)

- Calculate total cost of repair
  - \( \text{Total Cost of Repair} = C_{\text{labor}} + C_{\text{equip}} + C_{\text{indirect}} \)
  - \( = $2,320 + $2,053 + $2,186 \)
  - \( = $6,559 \)
Calculate Natural Gas Savings

Given:
- **D** = inside diameter of pipeline (inches)
- **L** = length of pipeline between shut-off valves (feet)
- **P** = Pipeline pressure
- **$P_{\text{natural gas}}$** = Current natural gas market price ($7/Mcf$)
- **$V_{\text{natural gas}}$** = Volume of natural gas emissions

\[
V_{\text{natural gas}} = \frac{D^2 \times P \times (L/1000) \times 0.372}{1000}
\]

\[
= \frac{24^2 \times 350 \times (52,800/1,000) \times 0.372}{1000}
\]

\[
= 3,960 \text{ Mcf}
\]

Value of natural gas = \( V_{\text{natural gas}} \times P_{\text{natural gas}} \)

\[
= 3,960 \times 7/\text{Mcf}
\]

\[
= 27,720
\]
## Comparison of Options – Pipeline Replacement vs. Composite Wrap

Given: 24” diameter operated at 350 psig, with 10 miles between shut-off valves

<table>
<thead>
<tr>
<th></th>
<th>6” Defect</th>
<th>234” Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Composite Wrap Repair</td>
<td>Pipeline Replacement</td>
</tr>
<tr>
<td>Natural Gas Lost</td>
<td>0</td>
<td>3,960</td>
</tr>
<tr>
<td>Purge Gas (Mcf)</td>
<td>0</td>
<td>199</td>
</tr>
<tr>
<td>Number of Composite Wrap Kits</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cost of Natural Gas Lost</td>
<td>$0</td>
<td>$27,720</td>
</tr>
<tr>
<td>Cost of Purge Gas</td>
<td>$0</td>
<td>$1,592</td>
</tr>
<tr>
<td>Labor</td>
<td>$1,720</td>
<td>$4,350</td>
</tr>
<tr>
<td>Equipment and Materials</td>
<td>$1,142</td>
<td>$3,520</td>
</tr>
<tr>
<td>Indirect Costs</td>
<td>$1,886</td>
<td>$3,148</td>
</tr>
<tr>
<td><strong>Total Cost of Repair</strong></td>
<td><strong>$4,748</strong></td>
<td><strong>$40,330</strong></td>
</tr>
<tr>
<td><strong>Most Economical Option</strong></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Composite Wrap Lesson Learned

- Proven permanent repair for external defects
- Temporary repair for internal faults
- In-service pipeline repair methodology
- Ideal for urgent and quick repair
- Avoid service disruptions
- Cost-effective

- Trained but not skilled crafts persons required
- Specialized welding and lifting equipment not required
- Minimizes access concerns
- No delays awaiting metal sleeve
- Cathodic protection remains functional
Additional Partner Reported Opportunities

- Install excess flow valves
- Insert gas main flexible liners
- Cast iron joint sealing robot (CISBOT)

Source: ConEd
Install Excess Flow Valves

**What is the Problem?**
- Gas line breaks from ground movement or third party damage can release gas to the atmosphere

**Partner Solution**
- Installing excess flow valves that shut off gas flow in response to the high-pressure differential

**Methane Savings**
- Based on 1 valve activation a year on a 50 psig, ½ inch service line

**Applicability**
- All gas service lines

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**Methane Savings**
- 15 Mcf/yr

**Project Economics**
- Project Cost: > $10,000
- Annual O&M Costs: < $100
- Payback: > 10 yr
Insert Gas Main Flexible Liners

What is the Problem?
- Cast iron and unprotected steel piping have the highest leakage factors

Partner Solution
- Using flexible plastic inserts where replacement is unfeasible reduces losses

Methane Savings
- Based on retrofitting 1 mile of cast iron main and 1 mile of unprotected steel service lines

Applicability
- Cast iron and unprotected steel pipelines

Methane Savings
225 Mcf/yr

Project Economics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Project Cost</td>
<td>$1,000 - $10,000</td>
</tr>
<tr>
<td>Annual O&amp;M Costs</td>
<td>&lt; $100</td>
</tr>
<tr>
<td>Payback</td>
<td>&lt; 1 yr</td>
</tr>
</tbody>
</table>
Cast Iron Joint Sealing Robot (CISBOT)

- Robotic system inserted into live 15- to 31-cm diameter cast iron distribution lines to seal leaking joints with an anaerobic sealant.
- No service disruption and minimal excavation.

Source: ConEdison
Discussion

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