Directed Inspection and Maintenance and Infrared Leak Detection

Lessons Learned from the Natural Gas STAR Program

SGA Environmental Round Table
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epa.gov/gasstar
Directed Inspection and Maintenance and Infrared Leak Detection Agenda

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

- Methane Recovery
  - Directed Inspection and Maintenance (DI&M)
  - DI&M by Infrared Leak Detection

- Is Recovery Profitable?
- Partner Experience
- Discussion
Methane Losses – Natural Gas Transmission

- Fugitive emissions from gas transmission and storage facilities are estimated to be 58 billion cubic feet per year (Bcf/year)
- Estimated 26 million cubic feet per year (MMcf/year) per compressor station in fugitive emissions

Source: TransCanada
Methane Losses – Natural Gas Distribution

- Fugitive emissions from natural gas distribution systems are estimated to be 59 billion cubic feet per year (Bcf/year)
- Estimated 270 thousand cubic feet per year (Mcf/year) per surface facility in fugitive emissions

Source: ULC Robotics
What is the Problem?

- Methane gas leaks are invisible, unregulated, and go unnoticed

- Natural Gas STAR Partners find that valves, connectors, compressor seals, and open-ended lines (OELs) are major methane fugitive emission sources
  - Transmission and distribution fugitive methane emissions depend on operating practices, equipment age, and maintenance
Sources of Methane Emissions

- Compressor
- Drain Valve
- Dehydrator
- Contactor
- Energy Exchange Pump
- FTS
- Reboiler
- Pressure Relief Valve
- Pneumatic Controller
- Compressor Seal
- Packing Cup
Fugitive Emissions Study - Clearstone

- Clearstone studied 4 gas processing plants
  - Screened for all leaks
  - Measured larger leak rates
  - Analyzed data
- Principles are relevant to all sectors
  - Fugitive leaks from valves, connectors, compressor seals, and lines still a problem in transmission
  - Solution is the same

Source: Hy-bon Engineering
Clearstone - Distribution of Losses by Source Category

- Leaking Components: 53.1%
- Combustion Equipment: 9.9%
- Amine Vents: 0.5%
- Flare Systems: 24.4%
- Non-leaking Components: 0.1%
- NRU Vents: 0.3%
- Storage Tanks: 11.8%

Source: Clearstone Engineering, 2002
Clearstone - Distribution of Losses from Equipment Leaks by Type of Component

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

Source: Clearstone Engineering, 2002
## Clearstone - How Much Methane is Emitted?

<table>
<thead>
<tr>
<th>Component Type</th>
<th>% of Total Methane Emissions</th>
<th>% Leak Sources</th>
<th>Estimated Average Methane Emissions per Leaking Component (Mcf/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valves (Block &amp; Control)</td>
<td>26.0%</td>
<td>7.4%</td>
<td>66</td>
</tr>
<tr>
<td>Connectors</td>
<td>24.4%</td>
<td>1.2%</td>
<td>80</td>
</tr>
<tr>
<td>Compressor Seals</td>
<td>23.4%</td>
<td>81.1%</td>
<td>372</td>
</tr>
<tr>
<td>Open-ended Lines</td>
<td>11.1%</td>
<td>10.0%</td>
<td>186</td>
</tr>
<tr>
<td>Pressure Relief Valves</td>
<td>3.5%</td>
<td>2.9%</td>
<td>844</td>
</tr>
</tbody>
</table>


Mcf = Thousand cubic feet
# Clearstone - How Much Methane is Emitted?

## Summary of Natural Gas Losses from the Top Ten Leak Sources

<table>
<thead>
<tr>
<th>Plant Number</th>
<th>Gas Losses From Top 10 Leak Sources (Mcf/day)</th>
<th>Gas Losses From All Leak Sources (Mcf/day)</th>
<th>Contribution By Top 10 Leak Sources (%)</th>
<th>Contribution By Total Leak Sources (%)</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>892.8</td>
<td>53.5</td>
<td>1.85</td>
</tr>
</tbody>
</table>

1 – Excluding leakage into flare system  
2 – Approximately 10,000 components surveyed per plant
Distribution Emissions - EPA/GRI/PRCI Study

- Sixteen M&R facilities in the U.S. and Western Canada were selected for joint EPA and GRI (GTI) study of DI&M using high volume sampler

- Average gas lost from leaks at each site was estimated at 409 Mcf per year

- Final component count - 2,261
  - South East U.S. Plants - 171 components
  - North East U.S. Plants - 1,102 components
  - Midwest U.S. Plants - 859 components
  - Western Canada Plant - 129 components
## Distribution Emission Factors

### Average Emissions Factors for Equipment Leaks at Sixteen Metering and Regulating Facilities

<table>
<thead>
<tr>
<th>Component</th>
<th>Emissions Factor (Mcf/yr/component)</th>
<th>Total Number of Components Screened</th>
<th>Average Number Components per Site</th>
<th>% Contribution to Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball/Plug Valve</td>
<td>0.21</td>
<td>248</td>
<td>18</td>
<td>0.002%</td>
</tr>
<tr>
<td>Control Valve</td>
<td>0.46</td>
<td>17</td>
<td>1</td>
<td>0.33%</td>
</tr>
<tr>
<td>Flange</td>
<td>0.13</td>
<td>525</td>
<td>38</td>
<td>0.09%</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>0.79</td>
<td>146</td>
<td>10</td>
<td>0.6%</td>
</tr>
<tr>
<td>Pneumatic Vent</td>
<td>134.3</td>
<td>40</td>
<td>1</td>
<td>95.5%</td>
</tr>
<tr>
<td>Pressure Relief Valve</td>
<td>4.84</td>
<td>5</td>
<td>1</td>
<td>3.4%</td>
</tr>
<tr>
<td>Connectors</td>
<td>0.11</td>
<td>1,280</td>
<td>91</td>
<td>0.08%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>2,261</strong></td>
<td><strong>160</strong></td>
<td></td>
</tr>
</tbody>
</table>

Methane Recovery

- Fugitive losses can be dramatically reduced by implementing a directed inspection and maintenance program
  - Voluntary program to identify and fix leaks that are cost-effective to repair
  - Survey cost will pay out in the first year
  - Provides valuable data on leak sources with information on where to look “next time”
What is Directed Inspection and Maintenance?

- Directed Inspection and Maintenance (DI&M)
  - Cost-effective practice, by definition
  - Find and fix significant leaks
  - Choice of leak detection technologies
  - Strictly tailored to company’s needs

- DI&M is NOT the regulated volatile organic compound leak detection and repair (VOC LDAR) program

Source: TransCanada
How Do You Implement DI&M?

1. CONDUCT baseline survey
2. SCREEN and MEASURE leaks
3. FIX on the spot leaks
4. ESTIMATE repair cost, fix to a payback criteria
5. DEVELOP a plan for future DI&M
6. RECORD savings/REPORT to Natural Gas STAR
How Do You Implement DI&M?

- Screening - find the leaks
  - Soap bubble screening
  - Electronic screening (“sniffer”)
  - Toxic vapor analyzer (TVA)
  - Organic vapor analyzer (OVA)
  - Ultrasound leak detection
  - Acoustic leak detection
  - Infrared leak detection
How Do You Implement DI&M?

- Evaluate the leaks detected - measure results
  - High volume sampler
  - Toxic vapor analyzer (correlation factors)
  - Rotameters
  - Calibrated bagging

Leak Measurement Using High Volume Sampler
# How Do You Implement DI&M?

## 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 Detector</td>
<td>★</td>
<td>$$</td>
</tr>
<tr>
<td>Acoustic Detector/ Ultrasound Detector</td>
<td>★★</td>
<td>$$$</td>
</tr>
<tr>
<td>TVA (Flame Ionization Detector)</td>
<td>★</td>
<td>$$$</td>
</tr>
<tr>
<td>Calibrated Bagging</td>
<td>★</td>
<td>$</td>
</tr>
<tr>
<td>High Volume Sampler</td>
<td>★★★</td>
<td>$$$</td>
</tr>
<tr>
<td>Rotameter</td>
<td>★★</td>
<td>$</td>
</tr>
<tr>
<td>Infrared Leak Detection</td>
<td>★★★</td>
<td>$$$</td>
</tr>
</tbody>
</table>

Source: EPA’s Lessons Learned

* - Least effective at screening/measurement  
$ - Smallest capital cost  
*** - Most effective at screening/measurement  
$$ - Largest capital cost
Estimating Comprehensive Survey Cost

- Cost of complete screening survey using high volume sampler (processing plant)
  - Ranges $15,000 to $20,000 per medium size plant
  - Rule of Thumb: $1 per component for an average processing plant
  - Cost per component for compressor stations would be higher than $1

- 25 to 40% cost reduction for follow-up survey
  - Focus on higher probability leak sources (e.g. compressors)
DI&M by Infrared Leak Detection

- Real-time detection of methane leaks
  - Quicker identification & repair of leaks
  - Screen hundreds of components an hour
  - Screen inaccessible areas simply by viewing them

Source: Leak Surveys Inc.

Source: Heath Consultants
Infrared Methane Leak Detection

- Video recording of fugitive leaks detected by various infrared devices
Is Recovery Profitable? – Compressor Stations

<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>29,498</td>
<td>200</td>
<td>0.1</td>
</tr>
<tr>
<td>Union: Fuel Gas Line</td>
<td>28,364</td>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>Threaded Connection</td>
<td>24,374</td>
<td>10</td>
<td>0.0</td>
</tr>
<tr>
<td>Distance Piece: Rod Packing</td>
<td>17,850</td>
<td>2,000</td>
<td>1.4</td>
</tr>
<tr>
<td>Open-Ended Line</td>
<td>16,240</td>
<td>60</td>
<td>0.1</td>
</tr>
<tr>
<td>Compressor Seals</td>
<td>13,496</td>
<td>2,000</td>
<td>1.8</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>11,032</td>
<td>60</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Source: Hydrocarbon Processing, May 2002
\(^1\) – Based on $7/Mcf gas price
### Is Recovery Profitable? – Surface Facilities

#### Example of Repair Costs and Net Savings for Selected Equipment Components

<table>
<thead>
<tr>
<th>Component Description</th>
<th>Type of Repair</th>
<th>Repair Cost¹</th>
<th>Total Number of Components Fixed at Two Sites</th>
<th>Total Gas Savings (Mcf/year)</th>
<th>Estimated Net Savings² ($/yr)</th>
<th>Repair Payback Period (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Valve</td>
<td>Re-grease</td>
<td>$18</td>
<td>5</td>
<td>60</td>
<td>$330</td>
<td>3</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>Replace valve stem packing</td>
<td>$4</td>
<td>5</td>
<td>67</td>
<td>$449</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>Replace valve stem packing</td>
<td>$4</td>
<td>1</td>
<td>92</td>
<td>$640</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Connector</td>
<td>Tighten threaded fittings</td>
<td>$4</td>
<td>4</td>
<td>11</td>
<td>$61</td>
<td>3</td>
</tr>
<tr>
<td>Sr. Daniel Orifice Meter</td>
<td>Tighten fittings</td>
<td>$44</td>
<td>1</td>
<td>68</td>
<td>$432</td>
<td>2</td>
</tr>
<tr>
<td>Flange³</td>
<td>Tighten (estimated)</td>
<td>$54</td>
<td>5</td>
<td>99</td>
<td>$423</td>
<td>5</td>
</tr>
</tbody>
</table>

1 – Average repair costs include labor and materials, 2006 dollars  
2 – Assumes gas price of $7/Mcf  
3 – Repair cost not reported in original study.  
DI&M - Lessons Learned

- A successful, cost-effective DI&M program requires measurement of the leaks
- A high volume sampler is an effective tool for quantifying leaks and identifying cost-effective repairs
- Open-ended lines, compressor seals, blowdown valves, engine-starters, and pressure relief valves represent <3% of components but >60% of methane emissions
- The business of leak detection has changed dramatically with new technology

Source: Chevron
Partner Experience - Northern Natural Gas

- Screened 659 rod packings with IR camera to identify leaks
- High volume sampler, Rotameter, and Mueller utilized to measure leaks
- Leak rates varied from default (newly installed) to 3,155 Mcf/yr
- Regular monitoring and correction keeps rod packing emissions low
- Annual savings of 71MMcf in 2006 by replacing compressor rod packing

Source: Northern Natural Gas
DI&M - Aerial Leak Surveys

- Aerial leak surveys with infrared leak detection devices can aid in leak identification over large sections of pipelines.
- Aerial surveys can be conducted in helicopters or fixed wing aircrafts using both active and passive IR detection devices.

Source: LaSen Inc.
Partner Experience - Northern Natural Gas

- 1,183 miles of pipeline surveyed using ITT ANGEL Service (Airborne Natural Gas Emission Lidar) with
- Data collection time: 13.4 hours
- Differential Absorption LIDAR (DIAL) laser technology provides accurate leak detection and measurement
- Color digital geospatial video of rights-of-way and surrounding areas
- Datasets show complete pipeline leak survey coverage
- Leaks found and verified in 27 locations

Source: Northern Natural Gas
Partner Experience - Northern Natural Gas

Facility leak detection by DIAL, Kansas

Source: Northern Natural Gas
Partner Experience - Northern Natural Gas

Underground leak detected by DIAL, Kansas

Source: Northern Natural Gas
Discussion

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