DIMP Approach to Assessment of Atmospheric Corrosion

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Company Overview

ESTABLISHED 1941

> Independent, not-for-profit established by the natural gas industry

> Providing natural gas research, development and technology deployment services to industry and government clients

> Performing contract research, program management, consulting, and training

> Wellhead to the burner tip including energy conversion technologies
Program Overview – Atmospheric Corrosion and Leak Survey

> **Background:** Study of atmospheric corrosion and leakage on indoor jurisdictional pipe prompted by change in the NYS service line definition to align with CFR 192

> Explore a practical approach to implementation, especially in challenging urban environments including the opportunity for extended inspection intervals as part of a distribution integrity management program

> **Phase 1** – White Paper Study, completed in 2014

> **Phase 2** – Field Inspections, statistical analysis, recommendations, commenced September 2015, will run through Q1 2017
Phase 1 Overview

> **Phase 1 - Sponsored by Operations Technology Development (OTD) on behalf of the New York OTD member companies (Con Edison, National Fuel, National Grid, NYSEG/RGE)**

> **Objective:** Independent technical review of risk considerations related to both atmospheric corrosion and leaks on indoor piping.

> **White Paper** submitted in formal comments to NYS proceedings
Components of the White Paper

> Atmospheric Corrosion
  – Theory
  – Outdoor vs. Indoor Characteristics
  – Peer-Reviewed Studies

> Operator Data – Atmospheric Corrosion

> Operator Data – Leak Surveys

> Risk-based Considerations

> Conclusions
Key Points

Atmospheric Corrosion Theory

> Atmospheric corrosion must have an electrolyte
  ─ Thin film, invisible electrolytes form on metal surface when critical humidity is reached
  ─ Moisture is the most important factor in atmospheric corrosion (rain, dew, condensation, high relative humidity)

> Dew or condensed moisture is more corrosive because of higher concentration of atmospheric contaminants
  ─ Corrosion rate increases in the presence of contaminants
  ─ Corrosion rate accelerates if condensate collects in pockets or surface crevices
  ─ Distance from contaminant source is important (industrial, coastal areas)
Coastal Area Example

Graph showing the loss in weight after 3 months of exposure versus distance from seashore.
Solid Matter (Particulates)

> Solid matter depositions can have a significant effect on atmospheric corrosion rates, particularly in the initial stages of corrosion.

> Impurities from emissions, like CO2 and CO, are adsorbed in the dust particles and create micro-corrosion cells

— Chart at bottom-right illustrates the effect of carbon particles on the initial corrosion rate of iron
Indoor vs. Outdoor Corrosion

> Characteristics of indoor corrosion may differ greatly from outdoors

> Different environmental conditions
  
  — Relative humidity and temperature
    > Minimal variation – variations often more important than absolute
    > Unconditioned basements have moderating effect of stable ground temperatures
  
  — Coarse and fine particulates are typically much lower due to air filtration systems and less direct exposure

Mean indoor corrosion rates can typically be 2-3 orders of magnitude (i.e. 100 – 1000 times lower) than for outdoors
Peer Reviewed Study (1973-1975)

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Location</th>
<th>Outdoor Environment</th>
<th>Indoor Environment Air Conditioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Los Angeles</td>
<td>Urban</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Chicago</td>
<td>Urban</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Manhattan, New York City</td>
<td>Urban</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Texas</td>
<td>Industrial/Rural</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Indiana</td>
<td>Industrial</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>South Carolina</td>
<td>Industrial</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>New Jersey</td>
<td>Industrial</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>New Jersey</td>
<td>Industrial</td>
<td>No</td>
</tr>
</tbody>
</table>
Peer Reviewed Study (1999)

<table>
<thead>
<tr>
<th>Exposure Time (months)</th>
<th>Outdoor</th>
<th>Sheltered</th>
<th>Ventilated Sheltered</th>
<th>Closed Space</th>
<th>Ratio Outdoor/Closed Space x 100 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>216.70</td>
<td>181.40</td>
<td>77.20</td>
<td>12.50</td>
<td>1,734</td>
</tr>
<tr>
<td>12</td>
<td>223.60</td>
<td>175.10</td>
<td>58.60</td>
<td>3.50</td>
<td>6,389</td>
</tr>
<tr>
<td>18</td>
<td>172.20</td>
<td>Lost to Wind</td>
<td>51.60</td>
<td>2.40</td>
<td>7,175</td>
</tr>
</tbody>
</table>

Indoor vs. Outdoor Corrosion Rate from 1999 Study

- **Outdoor**
- **Sheltered**
- **Ventilated Sheltered**
- **Closed Space**

<table>
<thead>
<tr>
<th>Corrosion Rate (g/m²·yr)</th>
<th>6</th>
<th>12</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor</strong></td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sheltered</strong></td>
<td></td>
<td>200</td>
<td></td>
</tr>
<tr>
<td><strong>Ventilated Sheltered</strong></td>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td><strong>Closed Space</strong></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
Practical Corrosion Rate Comparisons

Indoor, Outdoor, and Buried Corrosion Rate of Iron (mils/yr); upper 99% confidence level

- Atmospheric Indoor: 0.08 mils/yr
- Atmospheric Outdoor: 8.28 mils/yr
- Buried (Underground): 16.00 mils/yr
Practical Corrosion Rate Example

Time in years to 25% Wall Lost of a Standard Schedule 3/4-inch Diameter Iron Pipe with 0.113 inch Thick Wall (with upper 99% confidence level)

- Atmospheric Indoor Exposure: 348 years
- Atmospheric Outdoor Exposure: 3.4 years
- Buried (Underground): 1.8 years

Years For 25% Wall Loss of 3/4 Inch Iron Pipe
Key Findings from Literature Review

> **Relative humidity** and its interaction with pollutants are the main drivers for atmospheric corrosion.

> **Variation** in humidity and temperature are dramatically lower indoors.

> **Pollutant levels** are dramatically lower indoors.

> Both factors combined result in lower corrosion rates for indoor vs. outdoor assets.

> Mean indoor corrosion rates are reported at 2-3 orders of magnitude (100 – 1000 times) lower than outdoor rates.

> Extended inspection intervals are warranted for indoor environments.
Investigation of Utility Records

(a) New England work records

(b) New York City work records
Investigation of Utility Records

(a) New England work records

(b) New York City work records
Key Findings

> The number of indoor locations with pitting corrosion were very small.
  
  ─ An average of 1% of the atmospheric corrosion inspections in NE and LI had pitting corrosion which required repair or referred for further action.
  
  ─ The ratio was much lower (0.18%) in NYC.

> The remaining portion of the indoor corrosion inspection records (99%) had either no visible corrosion or surface rust.

> Pipe age, bare vs. coated steel, relative humidity & variations in RH were significant parameters affecting indoor pipe corrosion condition.
Investigation of Utility Leak Records

> 2014 survey by NY LDCs

> Indoor leak survey performed randomly during 1,050 routine inspections and repairs by the utilities.

> Results:

- 90% of surveyed sites had no leak indications
- 5% had leak indications; remaining 5% had no leak indication data
- Most indications were minor soap-bubble leaks (4.1% out of the 5%)
- Significant leaks were about 0.1% of the total repair records
Investigation of Utility Leak Records

Figure 38. Results of indoor leak survey

(a) Inspection Reason

(f) Leak Location
Risk-Based Considerations

> Each utility has its own macro and micro environments based on geographic location and concentration of urban, industrial, rural and coastal operations. Therefore, these considerations should be adjusted and applied accordingly.

> Relative humidity is the largest driver for indoor corrosion rates; this could be a category for inspection class
  - Air conditioned space, basement, etc.
  - Consistent relative humidity of greater than 70-80% could be a consideration

> Pollutants (including coastal areas) – areas with high pollution levels could be considered more corrosive
Risk-Based Considerations (continued)

> Age – older piping systems had more occurrences of pitting

> Point of entry – moderate increase in corrosion present at point of building entry vs. indoor space

> System knowledge – each operator knows their service environment and should include secondary or tertiary considerations as appropriate

> Indoor atmospheric corrosion rates are up to three orders of magnitude lower than outdoor corrosion rates. This should be taken into consideration when balancing needs for both outdoor and indoor atmospheric corrosion surveys as part of DIM programs.
Phase 2 Overview

> Sponsored by the Northeast Gas Association on behalf of members in NY (and possibly NJ)

> Detailed investigation and statistical study of indoor atmospheric corrosion levels and system leakage to develop recommendations for risk-based inspection intervals for indoor piping systems.

> Timeline:
  − Program and statistical design: Q4 2015
  − Site investigations and data collection: 2016
  − Summary report with findings and recommendations: Q1 2017
Phase 2

Study Design

> Environmental Categories – based on atmospheric corrosion drivers/findings from phase 1
  - Relative humidity extremes and variability
  - Temperature variations
  - Pollution levels (including coastal regions)
  - Age of piping system
  - Wall penetration

> “Room Sets”

> Bayesian Statistics – allows probability level calculation with confidence levels

> Random sampling coupled with “Opportunistic Inspections”
Phase 2

Data Collection

> Standardized inspection protocols to allow aggregation of data across the state

> Atmospheric corrosion

  – Visual inspection with 4 corrosion levels/categories based on visual comparators (NACE, SSPC, and/or ISO)
  – May measure pits/wall loss of highest corrosion level

> Leak survey

  – Developing a fit-for-purpose leak survey inspection protocol
  – CGI or equivalent worn during atmospheric corrosion inspection; device alarm at 0.10% gas in air determines a leak
  – Subsequent leak investigation with CGI will determine leak severity category
Phase 2

Data Analysis

> Data from all utility inspections will be statistically analyzed at both the Company level and in aggregate

> Excel based calculator will be used with stop criteria based on the desired confidence level (95.0, 97.5, 98.5 percent)

> Calculation of probable corrosion and leak severity levels for each category of piping will be used to determine baseline inspection intervals.

> Consequence of failure will be used to adjust (shorten) recommended inspection intervals based on an elevated level of risk.

  — Similar approach to the use of a Factor of Safety
DIMP Approach

> Based on the findings through the region and within their own operating territory, sponsor utilities may elect to develop a risk-based DIMP inspection plan for both atmospheric corrosion and leak inspections for indoor jurisdictional pipe.
Tackling Important Energy Challenges and Creating Value for Customers in the Global Marketplace

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