Evaluation of methane emissions from the Spanish gas distribution system

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Gas Natural SDG

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1. Leakages in gas distribution networks
2. Objectives of the study for the Spanish case
3. Measurement of leak rates
4. Pressure variation method
5. Field tests and results
6. Conclusions
A fraction of the gas naturally distributed is released through leakages in the networks.

Consequences:
- Significant economic losses
- Release of methane:
  - Greenhouse gas, GWP=21 tonCO$_2$eq/tonCH$_4$
  - In Europe: ~80% of CH$_4$ emitted due to leakages

Issues:
- Reduce and quantify the leakages

Assessment of methane leakages:
- A few field results (BG, Ruhrgas)
- Emission factors:
  - Factors for different pressures, materials, ...
  - Calculation methods and emission factors are different for the diverse countries
Estimations of methane emissions

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Distribution</th>
<th>Service lines</th>
<th>SMR’s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nm³/m/y</td>
<td>Nm³/m/y</td>
<td>Nm³/Leakage/y</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPA-S</td>
<td>5</td>
<td>1</td>
<td>11.9</td>
</tr>
<tr>
<td>MPB-PE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA EIA 95/96 without p distinction (plastic and N-p.)</td>
<td>0.156 / 0.684</td>
<td>0.017 / 0.172</td>
<td>-</td>
</tr>
<tr>
<td>Steczko USA / Canada 2003</td>
<td></td>
<td></td>
<td>0.99 / 0.73 Nm³/m/y (network + service + EMR)</td>
</tr>
<tr>
<td>IGU (2000) medium and low</td>
<td>2</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Steczko. for not own data</td>
<td>2.89</td>
<td>0.385</td>
<td>-</td>
</tr>
<tr>
<td>Lott (EEUU). without p distinction</td>
<td>1.321</td>
<td>0.039</td>
<td>0.929 Nm³/Ser/y</td>
</tr>
<tr>
<td>Germany West / Est</td>
<td>0.165 / 1.648</td>
<td>0.034 / 0.247</td>
<td>0.55 / 5.49 Nm³/m/y</td>
</tr>
<tr>
<td>British Gas at 30 mbar (distribution + service lines)</td>
<td>-</td>
<td>0.38</td>
<td>-</td>
</tr>
<tr>
<td>Eurogas-Marcogaz (minimum / maximum)</td>
<td>0.233 / 0.339</td>
<td>0.064 / 0.300</td>
<td>20 / 90%</td>
</tr>
</tbody>
</table>

The ranges are too wide
Current procedure in Spain: PGM-087-E

<table>
<thead>
<tr>
<th>Distribution network (Nm³/m/y)</th>
<th>HPB</th>
<th>HPA</th>
<th>MPB</th>
<th>MPA</th>
<th>LP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>7.5</td>
<td>5</td>
<td>2.5</td>
<td>0.62</td>
<td>0.5</td>
</tr>
<tr>
<td>Ductile cast iron</td>
<td>-</td>
<td>-</td>
<td>6.5</td>
<td>1.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Grey cast iron</td>
<td>-</td>
<td>-</td>
<td>6.5</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.22</td>
<td>0.2</td>
</tr>
<tr>
<td>PVC</td>
<td>-</td>
<td>1</td>
<td>10</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Service lines (Nm³/leakage/y)</td>
<td>13.7</td>
<td>11.9</td>
<td>9.1</td>
<td>6</td>
<td>3.4</td>
</tr>
<tr>
<td>SMR’s (Nm³/SMR/y)</td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>
Revision of the Spanish procedure

- Large discrepancies with other methodologies. In particular:
  - Steel lines: emission factors are too high compared to others
  - PE – med. pressure B (MPB: 0.4-4 bar):
    » Emission factors too high?
    » Main source of emissions (after update of factor for steel)

- Project (2005):
  - Survey of methodologies in the world
  - Identification of critical emission factors
  - Field testing for selected parts of the network → PE-MPB
Measurement of leak rates

- Used in field tests to evaluate actual emissions in the gas network

- Two main groups,

<table>
<thead>
<tr>
<th>On whole sections:</th>
<th>On individual leaks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure decay method (BG)</td>
<td>Bagging method</td>
</tr>
<tr>
<td>+ <em>Reliable</em></td>
<td>+ <em>Service on</em></td>
</tr>
<tr>
<td>- <em>Service off</em></td>
<td>- <em>Only identified leaks</em></td>
</tr>
<tr>
<td>- <em>High cost and effort</em></td>
<td>- <em>Excavation required</em></td>
</tr>
<tr>
<td>Pressure variation method (RG)</td>
<td>Suction method (RG)</td>
</tr>
<tr>
<td>+ <em>Reliable</em></td>
<td>+ <em>Service on</em></td>
</tr>
<tr>
<td>+ <em>Low cost and effort</em></td>
<td>+ <em>No excavation required</em></td>
</tr>
<tr>
<td>+ <em>Service on</em></td>
<td>- <em>Only identified leaks</em></td>
</tr>
<tr>
<td>- <em>Only if consumers’ offtake</em>↓↓↓</td>
<td>- <em>Sources of error</em></td>
</tr>
</tbody>
</table>
Pressure Variation Method - **PVM**

![Graph showing gas flow in Nm³/h against gauge pressure in bar. The x-axis represents gauge pressure ranging from 0 to 3 bar, and the y-axis represents gas flow ranging from 0 to 1.8 Nm³/h. There is a shaded area indicating gas leakage and a notation for customers' offtake.]
PVM: Procedure and requirements

- **Procedure:**
  1. Measurement of $Q_{\text{gas}}$ @ different pressures
  2. Estimation of consumers’ offtake
  3. Estimation of leak rate @ operating pressure

- **Requirements:**
  - Consumers’ offtake: **Low** and **stable**
  - Critical instruments → flow rate meters:
    - **Span:** large enough to reach maximum flow rate (offtake+leak)
    - **Uncertainty:** low enough to resolve very low leak rates
Test unit:

- Two flowimeters (in parallel, selectable): a wide range of flow rates (0.04-100 m³/h), with good accuracy (down to 0.0012 m³/h)
- Auxiliary instruments: P, T
- Data recording: PC + ADC board
On-site installation

- Test unit inserted into district Metering and Regulating Stations
Test campaign

- Sections of PE-MPB (0.4-4 bar):
  - 34 sites (2-63 km)
  - Total=547.7 km

![Frequency chart showing the distribution of section lengths](chart.png)

![Map of Spain](map.png)
Data analysis (1)

1st Step: Results are validated only if:
- Flow rate < 100 m³/h
- Fluctuations < Mean value
- Flow rate and pressure variations are consistent
→ 21 valid results (out of 34 tests)
Data analysis (2)

2nd Step:
- Calculation of local emission factor:

\[
(\text{EF})_i = \frac{Q_{\text{leak}}}{L} \cdot \frac{24}{\text{hous}} \cdot \frac{365}{\text{day}} \cdot \frac{\text{days}}{\text{year}} (\text{Nm}^3 / \text{year} / \text{m})
\]

- Calculation of ensemble emission factor:

\[
\text{EF} = \frac{\sum_i Q_{\text{leak},i} \cdot 24}{\sum_i L_i \cdot \frac{365}{\text{day}} \cdot \frac{\text{days}}{\text{year}}} (\text{Nm}^3 / \text{year} / \text{m})
\]

3rd Step: Uncertainty analysis; Sources of error considered:
- Accuracy of Q, P, T sensors
- Fluctuations for constant pressure
- Consumers’ offtake: Uncertainty due to extrapolation
- Estimated leak rate: Uncertainty due to interpolation
- Variability among sites

Results are given in terms of: \(\text{EF} \pm U_i\), for a given confidence level
Emission factors

- Statistics of measured emission factors (21 tests):
  - $0.46 \pm 0.14 \text{ Nm}^3/\text{year/m}$ (confidence=80%)
  - 54% lower than factor currently used in Spain

Histogram

- Intervals of emission factors ($\text{Nm}^3/\text{year/m}$)
  - Frequency
  - % total
Emissions in Spain: New vs. Old method

- **Old procedure:**
  - 0.905 ton CH$_4$/km
  - HP-Steel: 0.49 ton CH$_4$/km
  - MPB-PE: 0.23 ton CH$_4$/km

- **New procedure:**
  - 0.478 ton CH$_4$/km
  - HP-Steel: 0.119 ton CH$_4$/km
  - MPB-PE: 0.113 ton CH$_4$/km
Test method:

- Procedures and equipment have been developed for the measurement of leak rates, based on the pressure variation method.
- In cases of low, stable consumption patterns, PVM offers the advantages of reliability and low cost and effort.

A field campaign has been accomplished in PE-MPB sections in the Spanish distribution network.

- 21 out of 34 sites yielded valid results.
- New results have been obtained, which are thought to be applicable to many countries having networks of similar characteristics.
A new procedure for the estimation of methane emissions in Spain has been developed and submitted to the Ministry of Environment:

- Emissions attributed to steel mains are significantly reduced (to levels similar to other countries)
- The emission factor for PE-MPB has been updated, according to the field tests
- As a result,
  - The total annual emission has been reduced in 53%
  - The relative contributions of the different types of lines is significantly modified

Gas Natural SDG is planning additional field tests on MP steel sections for this summer.