Large Pipeline Leakage Model

Edgar Johnson | Chartered Professional Engineer (Engineers Australia); Professional Engineer (Engineering Council of South Africa)
Outline

• Purpose & derivation of a *Pipeline Leakage Model*

• Pressure- leakage relationship

• Components of leakage

• Leak frequency relationship

• Large single transmission pipelines

• Statistics of the existing pipelines

• Derivation of *Leakage Model* coefficients

• Results & Conclusions
Purpose

• To develop an *irrigation pipeline water loss model* for potentially determining applicable pipeline loss rates in DEPI’s *Technical Manual for the Quantification of Water Savings*.

• The model must also be capable of determining the additional water losses that may be *offset against water savings* which would otherwise be claimed for completely decommissioning the open channel, if pipelines are used for their replacement.

• Development of a model to accommodate the client’s *current unique pipeline conditions* with respect to operations and assets.
Derivation Pipeline Water Loss Model- Overview

- Theoretical pressure-flow relationship
- Initial (new) pipeline leakage relationship
- Technical minimum leakage during the life of the pipeline
- Allowance for growth in leakage due pipeline deterioration
- Calibration of Model Coefficients with data from:
  - Literature on leakage in large pipelines
  - Literature on leakage in pipe networks
  - Asset and O&M records for existing pipelines
**Relationship between Pressure and Leakage**

Leakage is a function of pressure \((P^{N_1})\).
Components of leakage

Unavoidable Real Losses

- **Background leakage**
  Un-reported and un-detectable using traditional acoustic equipment.

- **Un-reported leakage**
  Often does not surface but is detectable using traditional acoustic equipment.

- **Reported leakage**
  Often surfaces and is reported by the public or utility workers.
**Conceptual** Pressure: Leak Frequency Relationship  
(Lambert & Thornton, 2012)
Leak Frequency versus Pressure

- Distribution networks 1 m increase in pressure = an increase of 1.4 leaks per 100km pipe
- Transmission pipes 1 m increase in pressure = an increase of 1.5 leaks per 100km pipe (Hamilton & Krywyj, 2012)
- Transmission pipes with $\leq$ 55 leaks per 100km per year could be caused by factors other than pressure
Large Single Transmission Pipelines (Hamilton & Krywyj, 2012)

- **Weep** has a small volumetric loss < 0.27 m$^3$/hr (0.007 ML/d)
- **Leak** has a medium loss between 0.27 m$^3$/hr and 11 m$^3$/hr (0.26 ML/d)
- **Burst** has a large loss between 11 m$^3$/hr and 27 m$^3$/hr (0.65 ML/d)
- **‘Extreme’ failure** has a large loss > 27 m$^3$/hr (0.65 ML/d)

Noting that the volume of water lost is dependent on the leakage flow rate, the number of occurrences as well as the time it takes to find and repair the leak.

<table>
<thead>
<tr>
<th>Likelihood (i.e. of occurring)</th>
<th>Consequences (i.e. leak water loss impact)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Major</td>
</tr>
<tr>
<td>Likely</td>
<td>Leak</td>
</tr>
<tr>
<td>Possible</td>
<td></td>
</tr>
<tr>
<td>Unlikely</td>
<td></td>
</tr>
</tbody>
</table>
Examples of Existing Pipeline Data

75% pipes 300 to 700 mm dia.

Ave. 4.6 connections per km

International benchmark 0.92 leaks per km
Pipeline Leakage Model

Pipeline leakage = initial pipe life leakage + leakage from pipes + leakage from connections + growth in leakage

- Initial pipe life leakage relates to leakage that was undetectable during construction acceptance testing and persists for the life of the pipeline. (includes consideration of pipe diameter)
- Technical minimum leakage from pipes and connections (URL) that current technology cannot detect. (excludes consideration of pipe diameter)
- Growth in leakage (e.g. 4.3 m$^3$/h expected to grow at 0.07% per annum)

\[ \text{Pipeline leakage} = \left[ P_i \times (2.377 \times C \times d_i \times L_p \times (H)^{0.5}) \right] + \left[ P_g \times (C_1 \times L_p) \times (H/50)^{N_1} \right] + \left[ P_g \times C_2 \times 3.759 \times L_p^{-0.288} \times (H/50)^{N_1} \right] + \left[ P_g \times C_3 \times L_C \times (H/50)^{N_1} \right] \]
Logic Diagram for Derivation of Leakage Model Coefficients

Coefficient Derivation from:
- Pipe networks (literature)
- Pipe material leak characteristics
- Current operating pressures

Derivation of Control Coefficient from:
- Current operating pressure
- Estimated leak flow rate
- KPIs for maintenance activities
- Historic leak frequencies

Comparison of the two Coefficients

Equal
Adopt Coefficient for model
Within Range

Not Equal
Adjust leak flow rate to within range until Coefficients are equal

Outside Range
Change Operating Pressures

NOTE: Iteration process applicable for leakage model when operating pressures that leaks occurred and leak flow rates are the two unknowns
**Results & Conclusions**

<table>
<thead>
<tr>
<th>Pipeline Loss Indicator (m)</th>
<th>GMID Pipelines</th>
<th>GMW Pipelines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flexible</td>
<td>Rigid</td>
</tr>
<tr>
<td>Average Age (yrs)</td>
<td>12 yrs</td>
<td>34 yrs</td>
</tr>
<tr>
<td>Average size (mm dia. ID)</td>
<td>525</td>
<td>525</td>
</tr>
<tr>
<td>Average Operating pressure (m)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Lost in ML/yr/km of pipeline</td>
<td>0.004605</td>
<td>0.034804</td>
</tr>
</tbody>
</table>

- Pipeline leakage losses are lower than those reported in literature
- Leakage should be reported in losses per km and not % of deliveries
- Outputs are dependant upon the accuracy of the asset and operational data
Acknowledgements

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