Uncertainty of effective leakage areas
determination through reductive sealing
technique

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Air infiltration

Effective Leakage Areas

The area of a single orifice that would produce the same leakage as the group of leakages it represents at a reference pressure difference

- Typical form of expressing air leakage characteristics
  - building components
  - whole envelopes

\[
E_{LA} = \frac{10q}{3.6} \sqrt{\frac{\rho_0}{2}} \frac{\Delta p}{C_D} \\
E'_{LA} = \frac{10}{3.6} C_{ew}(\frac{T_0}{T})^{1-n} \left(\frac{\rho_0}{2}\right)^{0.5} \Delta p^{n-0.5}
\]
Effective Leakage Areas

- Available extensively in ASHRAE and AIVC documentation
- repeated measurements
- compilation of laboratory and in situ experiments

**Results using ordinary least squares regression in the airflow**

No propagation of uncertainty in incremental sealing

Reductive sealing

Offsetting results from blower door tests to attain the performance of individualized elements or groups

French database has 46 subcategories of leaks
Reductive sealing

Most frequent
- windows
- doors
- shutters

Most impactful
- lighting components
- junction between floor and wall
- electrical board
- junction between window and wall
- trapdoors to attics

*Leakage type assessment often qualitative – smoke tracer/thermography*

*Background leakage after initial assessment usually ranges from 45% to 75%*

Regression models

![Diagram of regression model](image)

1. pressure measuring device
2. temperature measuring device
3. air-flow measuring device
4. air-moving equipment
5. fan

![Graph showing Flow vs. Induced Pressure](image)
Regression models

**OLS** – Ordinary least squares

**WLOC** – Weighted Line of Organic Correlation

<table>
<thead>
<tr>
<th>OLS</th>
<th>OLS uncertainty</th>
<th>WLOC uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>q readings: distance to regression values</td>
<td>q readings: fan accuracy</td>
<td>q readings: sensors accuracy and resolution</td>
</tr>
<tr>
<td></td>
<td>t readings: sensors accuracy and resolution</td>
<td>Δp and Δp0 readings: manometer accuracy and resolution</td>
</tr>
</tbody>
</table>

Uncertainty propagation

- Uncertainty propagation to the ELA

\[
u(ELA) = \left( 2.155C_{\text{ref}} \Delta p^{n-86 \text{C}_{\text{ref}}} \left( \frac{T_c}{T} \right) \ln \left( \frac{\Delta p}{T_c} \right) u(n) \right)^2 + \left( 2.155C_{\text{ref}} \Delta p^{n-86 \text{C}_{\text{ref}}} \left( \frac{T_c}{T} \right) \ln \left( \frac{\Delta p}{T_c} \right) u(\ln(C_{\text{ref}})) \right)^2 + \left( 2.155C_{\text{ref}} \Delta p^{n-86 \text{C}_{\text{ref}}} \left( \frac{T_c}{T} \right) \ln \left( \frac{\Delta p}{T_c} \right) r(n, \ln(C_{\text{ref}})) \right)^2
\]

- Offset of uncertainties between sealing steps

\[
ELA_{\text{offset}} = ELA_{i-1} - ELA_i
\]

\[
u(ELA_{\text{offset}}) = \sqrt{u(ELA_{i-1})^2 + u(ELA_i)^2}
\]
Smoke tracer provides info for:

- Identification of predominant leaks
- Sealing step sequence

Exterior finishings can be a challenge
**Application and best practices**

- 12 sealing steps
- 11 leakage path types

- default mode (DEF)
- mechanical ventilation (MEV)
- heating and air conditioning elements (HAC)
- electrical appliances (ELE)
- lighting (LIG)
- plumbing (PLU)
- wall/wall joints (WWJ)
- wall/floor joints (WFJ)
- wall/roof joints (WRJ)
- wall/openings joints (WOJ)
- openings (OPE)
- entrance door (ENT)

**Application and best practices**

- Significant dispersion of air flow rates between leakage paths
- WLOC provides higher calculated uncertainties in the airflow rates
- No leakage path type exceeded 18% of the total air change rate
- On average, 2.6 and 1.7 times greater than OLS and OLSu

### Average effective leakage area uncertainty

<table>
<thead>
<tr>
<th>Pressure difference</th>
<th>OLS (%)</th>
<th>OLSu (%)</th>
<th>WLOC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9.9</td>
<td>18.8</td>
<td>27.5</td>
</tr>
</tbody>
</table>

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Application and best practices

Normalized ranges of ELAs

Ranges only provide \((y - u(y); y + u(y))\)

Less impacting air leakage types should be assessed first

Minimize uncertainty accumulation effect in earlier steps

Measure similar types of air leakage paths in a consecutive order

If adjoining is needed for subsequent data treatment

WLOC should be preferred since it considers the greatest number of error sources

Even though a greater variability will result from its application
Application and best practices

Effective Leakage Areas are used primarily for input in airflow models

Risk assessment on health-related issues:
- minimum air renovations
- comfort concerns

Energy relevant aspects:
- ranges of heating and cooling loads

Support decision on intervention scenarios by:
- Cost
- Invasiveness
- Labour
- Time

With truer uncertainties → Most adequate leakage paths for intervention

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