Airtightness Sessions – IEQ 2025 Conference

The IEQ 2025 conference, co-organised by ASHRAE and AIVC in Montreal, Canada, on 24-26 September, was also the 45th AIVC, 13th Tightvent and 11th venticool conference. The conference gathered experts worldwide to exchange the latest research, advances and practices on ventilation, indoor environmental quality, resilience and more. For the TightVent community, a key part of the programme was the dedicated focus on building airtightness, addressed in four sessions and workshops.
Below is an overview of the airtightness-focused sessions:

1. Workshop: Durability of the Building Airtightness
2. Paper session: Airtightness Applications, Repeatability, and Lessons Learned
3. Paper session: Tools for Envelope Leak Detection and Evaluation
4. Paper session: Airtightness of Building Components

Full details on the presentations and abstracts follow.

Workshop: Durability of the Building Airtightness

Chair: Valerie Leprince, PhD, Cerema, Lyon, France and Andres Litvak, PhD, Cerema, Bordeaux, France

Summary: Air leakages increasingly affect the energy performance of new buildings. Since the early 2000s, many countries have introduced regulations that emphasize airtightness, including mandatory standards, aligning with Europe's goal of achieving nearly zero energy buildings by 2030. However, building airtightness requirements are only effective if the levels remain durable over time. Studies reveal that these mandates often lead to last-minute sealing efforts, compromising durability.
The long-term durability of airtightness products and assemblies remains a complex issue, involving:

- Modeling the mechanical behavior and deformations of buildings and products,
- Laboratory-based accelerated aging tests,
- Field measurements for performance characterization.

1. **State of the Art of Knowledge on Building Airtightness Durability**

Valerie Leprince, *PhD, Cerema, Lyon, France*

2. **Understanding Early Airtightness Variations: Lessons from 11 Residential Case Studies**

Valerie Leprince, *PhD, Cerema, Lyon, France*

3. **From Site to Lab: Evaluating Implementation Conditions and Reproducing Them in Laboratory**

Andres Litvak, *PhD, Cerema, Bordeaux, France (presented by* ***Nolwenn Hurel,*** *Cerema France)*

4. **Experimental Measurement Results of the Impact of Surfaces Dust Built-up and Temperature on Building Airtightness Durability**

Andres Litvak, *PhD, Cerema, Bordeaux, France (presented by* ***Bassam Moujalled,*** *Cerema France)*

Figure 1: Valerie Leprince presenting during the 'Durability of the Building Airtightness' workshop at the 45th AIVC-ASHRAE IEQ-TightVent & venticool Conference in Montreal."

Paper Session: Airtightness Applications, Repeatability, and Lessons Learned

Chair: Cara Helen Lozinsky, P.Eng., Carleton University, Ottawa, ON, Canada

Summary: This session explored innovative approaches and practical challenges in evaluating residential and commercial building airtightness. Presenters introduced a predictive modeling tool using Generalized Linear Models (GLIM) to estimate airtightness across diverse construction scenarios. The session also examined the precision and uncertainty of fan pressurization testing, comparing methodologies and recommending best practices for reliable measurements. Finally, field-based lessons from guarded and unguarded tests in large buildings highlighted the complexities of whole-building assessments and the importance of consistent procedures.

1. **Application Of A Tool To Estimate The Level Of Airtightness Of Residential Buildings**

***Irene Poza-Casado**, Miguel Fernández-Temprano, Pilar Rodríguez-del-Tío and Alberto Meiss, Universidad de Valladolid, Valladolid, Spain*

Abstract: Estimating airtightness is challenging due to variability in influencing factors. Existing models face limitations such as lack of standardization, sensitivity to construction quality, insufficient representative data, and complexity that reduce their practical utility for designers. This work explores the application of a predictive approach from measured data using Generalized Linear Models (GLIM) that is applicable across diverse construction scenarios. The model incorporates 14 main variables and 6 interaction terms, which explains over 50% of the variability in airtightness (n50). A typical case study has been chosen in order to show the model's application, making it user-friendly. This example explores the criteria followed for each variable and building characteristics so that the model can be easily extrapolated to other contexts and applied to other cases.

2. **How Precise is Airtightness Testing? Exploring Repeatability, Reproducibility, and Uncertainty Quantification**

***Martin Prignon, Dr.Ing.**[1], Ben Roberts[2], Liesje Van Gelder[3], Maarten De Strycker[3] and Jiri Novak[4], (1) Buildwise, Zaventem, Belgium, (2) Loughborough University, Loughborough, United Kingdom, (3) BCCA, Diegem, Belgium, (4) CTU Prague, Prague, Czech Republic*

Abstract: This study addresses two key challenges related to uncertainty assessment in fan pressurization measurements: (1) estimating the typical precision error (general approach), and (2) providing a rigorous framework for uncertainty calculation in individual tests (specific approach). The general approach is investigated through the analysis of multiple repeatability and reproducibility studies, including two new datasets reported by the authors. The specific approach is assessed by applying and comparing different uncertainty propagation frameworks on two

controlled datasets. For the general approach, results indicate a precision error of 1-2% for the measurement method itself, 2-3% when different experienced operators conduct the test without preparing the building, 4% when operators also prepare the building but with external verification, and up to 20% when no verification is performed, or with unexperienced operators. However, the limited availability of reproducibility data restricts the generalizability of these findings. For the specific approach, results show that all tested procedures perform similarly at 50 Pa (0.2 in.) in terms of both observed and estimated uncertainty. At 4 Pa (0.016 in.), all weighted procedures reduce the precision error compared to the unweighted ISO method. Based on these results, the authors recommend the WLOC procedure with newly proposed weights, as it is fully based on the GUM framework, supported by dedicated studies, and applicable even when equipment specifications are unknown or when only single-point measurements are available at each pressure station.

3. **Lessons Learned from Airtightness Testing**

***Yash Vyas, Student*[1]**, *Justin David Berquist, PhD (c), PEng, Associate[2], Russell Richman[1] and Michal Bartko[2], (1) Toronto Metropolitan University, Scarborough, ON, Canada, (2) National Research Council Canada, Ottawa, ON, Canada*

Abstract: Airtightness plays a vital role in the quantification of energy performance and indoor environmental quality. In large buildings, quantifying whole building airtightness has historically been a challenge to achieve due to various factors (i.e., implications of stack effect, inhomogeneity of building pressures). As a result, practitioners often attempt to extrapolate the whole building airtightness from data obtained through guarded or unguarded (compartmentalization) testing. This paper discusses the lessons learned from conducting whole building, unguarded, and guarded airtightness tests on three (3) buildings. Through the lessons learned in the field, this study aims to address the challenges associated with guarded airtightness testing, including airflow pathways, pressure balancing, and compartmental boundaries. The findings challenge the validity of the theoretical assumption that combining guarded test results equate to a reliable whole-building test. Additionally, this study highlights the importance of test planning, setup, and consistency throughout several tests as critical to derive consistent test results. This study will contribute to future airtightness field testing standards, research, and enable practitioners to refine methods for large building assessments.

Paper Session: Tools for Envelope Leak Detection and Evaluation

Chair: Marianne Touchie, PhD, Member, University of Toronto, Toronto, ON, Canada

Summary: This session explores innovative methods for detecting and mitigating air leakage in building envelopes, a critical factor in energy efficiency and indoor environmental quality. Presenters will share findings from laboratory and field tests using acoustic beamforming to locate complex leaks and introduce pressure inversion techniques with lock-in thermography to enhance thermal imaging sensitivity. Additionally, a novel aerosol sealing method for attics and crawlspaces will be discussed, demonstrating significant leakage reductions in occupied residences without disrupting occupants.

1. **Acoustic Leak Detection in Building Envelopes – Laboratory and Field Tests**

***Bjoern Schiricke*[1]**, *Markus Diel[1], Alexander Jahnke[2] and Michael Markus Ackermann[2], (1) German Aerospace Center, Cologne, Germany, (2) Society for the Advancement of Applied Computer Science, Berlin, Germany*

Abstract: Airtight building envelopes are essential for energy efficiency. Fast and reliable leak detection is crucial, especially when retrofitting large buildings. In previous research, feasibility studies in the field and small-scale laboratory tests have demonstrated the potential of the acoustic beamforming method as a tool for rapid and large-scale leak detection. To systematically investigate leaks and analyze the measurement system's behavior, an airtight test facility (ATLAS), as introduced in earlier studies, has been constructed. Building on foundational investigations from that research, this study presents findings from complex test specimens designed to simulate more realistic leakage scenarios. A sandwich system is used to model leaks with cavities (e.g. roof-wall transition) and a labyrinth system is used to simulate twisted leakages (e.g. window seals). The laboratory work is supplemented by an accompanying measurement campaign on a building in need of retrofit in order to ensure practical suitability. This investigation particularly focuses on the effects of the angle of incidence and the output signal from loudspeakers, using a leaky window as a case study. In the two measurement scenarios, leakages were located with success; notably, one leak featuring two consecutive cavities was detected by the measurement technology at the test facility. In addition, two real leakages were found at the analyzed window, whereby a newly developed evaluation algorithm was able to greatly improve simultaneous detectability. The findings indicate that acoustic beamforming is capable of

detecting complex leaks in both laboratory and field settings. However, further experimentation is necessary to accurately classify measured noises and facilitate automated analysis.

2. **Pressure Inversion for Leakage Detection at Building Envelopes with Lock-In Thermography**

***Johannes Pernpeintner*[1]** *and Markus Diel[2], (1) Deutsches Zentrum für Luft- und Raumfahrt e.V., Cologne, Germany, (2) German Aerospace Center, Cologne, Germany*

Abstract: Infiltration through the building's envelope is a significant heat loss mechanism. Total leakage rates for buildings can be measured, for example, with the fan pressurization method (ISO 9972). Localization of leakages, however, is often a manual process where previous knowledge of weaknesses of the building is combined with fan pressurization and methods like smoke generators, anemometers, or infrared images. Lock-in thermography advances this by using a periodic cycle of pressurized/unpressurized interior combined with numerical analysis with Fourier transform. This paper presents laboratory measurements in which periodic inversion was used with cyclically pressurized/depressurized interior using Lock-In thermography. Goal of the inversion is to improve the temperature amplitude in Lock-In thermography. This increases sensitivity and decrease susceptibility to disturbances due to environmental changes of the method. Measurements were performed on a sample from MDF with Z-channels of diameters from 3 mm (0.12 in) to 8 mm (0.31 in) and channel lengths from 32 mm (1.3 in) to 512 mm (20.2 in). By application of pressure inversion the average temperature amplitude could be increased by +138%. Additionally, the temperature saturation – the reduction of amplitude with increasing number of measured periods – could be significantly reduced.

3. **Aerosol Sealing Occupied Residences from Exterior Spaces**

***David L Bohac, P.E., Life Member*[1]**, *Curtis Harrington, PE, Student[2], Frederick Nicholas Meyers, Associate[2], Timothy Levering[3], Mike Lyon[4] and Mike Lubliner, Life Member[5], (1)Center for Energy and Environment, Minneapolis, MN, (2)UC Davis, Davis, CA, (3)UC Davis, Western Cooling Efficiency Center, Davis, CA, (4)Aeroseal LLC, Miamisburg, OH, (5)Conservation And Renewable Energy Systems, Seattle, WA*

Abstract: Retrofit air sealing is typically manual with highly variable leakage reductions determined by the time allotted and the vigilance and experience of the contractor. Automated aerosol sealing has been deployed in residential construction to achieve tighter envelope assemblies. A new method has been developed that releases the sealant in attics and crawlspaces while the residence is depressurized. This method can be performed in occupied residences without disrupting occupants. Attic and crawlspace sealing of seven single-family homes provided more than a 35% leakage reduction for half the homes and sealing of 12 multifamily units results in a median reduction of 40%

Paper session: Airtightness of Building Components

Chair: Marco Simonetti, Department of Energy (DENERG), Italy

Summary: This session explores innovative approaches to improving airtightness and air distribution system performance in buildings, with a focus on energy efficiency, occupant comfort, and regulatory compliance. Presenters will examine the challenges of sealing elevator shafts in multi-unit residential buildings, highlighting their impact on airflow, safety, and energy loss. Studies address duct leakage characterization, proposing advanced methodologies that go beyond traditional classification systems by incorporating measured flow exponents and operating pressures. A new procedure for air system testing is introduced, enabling more accurate leakage modeling using existing equipment.

1. **Mind the Gaps: Improving Airtightness Elevator Shafts in Multi-Unit Residential Buildings**

***John Nguyen Hoang, Student Member*[1]** *and Marianne F. Touchie[2], (1) University of Toronto, Oakville, ON, Canada, (2) University of Toronto, Toronto, ON, Canada*

Abstract: As cities expand vertically, high-rise multi-unit residential buildings (MURBs) are becoming more popular forms of urban housing. Elevators are an essential part of vertical living but are also detrimental to building performance when it comes to uncontrolled airflow. Unlike stairway doors, which can be weather-stripped using conventional solutions, the mechanical nature of elevator doors makes standard air-tightening methods impractical. However, ensuring airtight elevator shafts in MURBs is essential for energy efficiency, occupant comfort, and safety. The goal of this paper is to demonstrate the impact of elevator shaft airtightness on building performance and provide potential solutions. Elevator shaft airtightness is crucial to energy efficiency and comfort in MURBs as these shafts can act as vertical conduits for smoke, fire, and conditioned air. Typical values for elevator shaft airtightness are presented, then these are compared with existing airtightness requirements, focusing on regulations related to smoke

and fire safety, to highlight the importance of compliance with established standards. Existing solutions to improve elevator doors include vestibules which are widely used in commercial buildings but less so in residential buildings and cannot be implemented on all floor plate configurations due to the space requirement. Adopting different solutions such as fire curtains, high-speed roll-ups, and bi-fold doors could offer improvements without encroaching on the current common area floor space. This paper emphasizes the need for improved elevator shaft airtightness in MURBs and illustrates how improving elevator shaft airtightness can enhance energy efficiency, occupant comfort, and safety. Further research efforts should focus on investigating the feasibility of applying some of these alternative solutions to improve elevator door airtightness.

2. Using Measured Exponents and Fractional Leakage Flow to Characterize Air Leakage in Ducts

*Federico Pedranzini[1] and **Mark P Modera, Fellow Life Member**[2], (1)Politecnico di Milano, Milano, Italy, (2) University of California in Davis, Davis, CA*

Abstract: The issue of leakage in air distribution systems is one of the most underappreciated efficiency improvement opportunities, even though potential improvements are significant. One of the main reasons for this lack of awareness lies in the current ineffective practices for determining and addressing the energy consequences due to poor tightness. The airtightness of ducts is generally only evaluated based on classifications (e.g. leakage class or seal class), which are in turn used to estimate duct leakage flows during normal operation using an assumed operating pressure, and a fixed flow exponent of 0.65. This paper presents technical arguments for why it is worthwhile to characterize duct leakage with measured flow exponents and operating pressures, or with direct measurements of leakage flows during normal operation. The focus is non-residential buildings, for which there are large variations in duct pressures during normal operation, between different duct sections, and between testing/classification values and normal-operation values. Experimental evidence is presented to show that the current methodology is not suitable for describing the real behavior of ductwork. Two alternative methodologies are described, both related to expressing leakage in percentage terms with respect to the nominal flow rate. The difference between the two indexes is that the first one utilizes the estimated leakage at working pressure, the other indicates the maximum pressure at which the system can work in order not to exceed a predetermined percentage leakage value.

3. Proposal for a Procedure for the Characterization of Air Systems Based on an Extended Model

***Federico Pedranzini**[1], Valerie Leprince, PhD[2], Mark P Modera, Fellow Life Member[3], Nolwenn Hurel[4] and Francesco Romano[1], (1) Politecnico di Milano, Milano, Italy, (2) Cerema, Lyon, France, (3) University of California in Davis, Davis, CA, (4) Cerema, L'Isle d'Abeau, France*

Abstract: Duct air leakage tests -DALT- carried out on air systems today are carried out according to the procedures prescribed by specific International Standards. All these Standards, without exception, refer to a model that estimates leakage as a function of a leakage coefficient (f) multiplied by the leakage area value (A) and the static overpressure value elevated to an exponent n assumed constant and equal to 0.65. This model is a simplified form of a more general model that also requires determining the leakage exponent n. Within certain limits, the simplified model fulfills the classification requirements but does not prove reliable for the analysis of leaks under operating conditions and, thus, for verifying the increase in energy consumption. For such purpose, the application of the full model appears to be necessary; this requires the identification of a different test procedure capable of obtaining the information needed to determine not only the f- value but also the n - value. The paper is focused on the proposal of a procedure useful for the characterization of the full model as well as a methodology for calculating the f and n parameters borrowed from that currently applied for the characterization of air leakages in buildings. Finally, the paper proposes a method to transfer the results obtained by the new procedure back to the information useful for classification, thus allowing the old procedure to be fully replaced without losing the applicability of the existing standards. The methodology was applied to a real system and the values were identified. The procedure presented was developed with the aim of being able to carry out the measurements using the same DALT instruments used to date without requiring replacement.