An Evaluation of the Accuracy and Utility of the Portascanner® AIRTIGHT in the Context of Airtightness Testing in the Built Environment

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Abstract

Energy and carbon dioxide emission reductions from buildings are central to many countries' net zero climate strategies. One factor that can have a significant impact on energy use and CO2 emissions attributable to buildings is the airtightness performance of the building fabric. Consequently, high levels of building airtightness are crucial if we are to obtain a low carbon built environment. This paper evaluates the performance of a novel ultrasonic technology, the Portascanner® AIRTIGHT, through comparative testing with existing methodologies, including Blower Door testing, Pulse testing, and thermography. The study found that the Portascanner® AIRTIGHT is an effective technology for airtightness testing and that the most comprehensive evaluation of airtightness is attained when multiple methods, including the Portascanner® AIRTIGHT, are used in conjunction with one another. Notably, the Portascanner® AIRTIGHT demonstrated a unique capability in identifying leaks that could be overlooked by other technologies, particularly in scenarios where thermography is limited due to unsuitable thermal conditions. Additionally, the study found that the Portascanner® AIRTIGHT's quantification of airflow and air permeability closely aligned with results from pressurisation tests, validating its effectiveness as an instrument for airtightness testing.

Figure 1: The Portascanner® AIRTIGHT 2.0, ultrasonic sensor and tablet

Introduction

Achieving high levels of airtightness is critical for a low carbon built environment. Traditional airtightness testing methods, such as blower door tests and low-pressure pulse tests, have been extensively adopted (*BSI*, 2015; *BTS*, 2018; *CIBSE*, 2021). While reliable, these methods can be disruptive, sensitive to environmental conditions, and do not localise leakage sources effectively without auxiliary tools such as smoke pencils or thermography.

Ultrasonic technologies have been explored for non-destructive leak detection, primarily in industrial settings (e.g., HVAC duct testing) rather than building envelopes. Some early devices, while potentially useful for qualitative leak detection, lack reliable quantification of airflow or leak severity. The Portascanner® AIRTIGHT addresses these shortcomings by combining directional ultrasonic detection with on-site quantification of leakage areas and inferred airflow rates, independent of pressure differentials.

The Portascanner® AIRTIGHT

The Portascanner® AIRTIGHT operates via an airborne ultrasonic transmitter (40kHz) and a directional receiver. The substantial mismatch between the acoustic impedance of air and solid materials ensures ultrasound is strongly reflected unless an air path (leak) exists (see Figure 2). By measuring the ultrasonic intensity transmitted through leaks relative to an open-air reference (Open Air Value, OAV), the system calculates leak area and predicts airflow.

Optimised test procedures involve:

- Positioning the transmitter facing the test area, ensuring adequate coverage.
- Conducting a saturation check to calibrate signal strength and avoid receiver saturation.
- Scanning the internal surface with the receiver to detect leaks.
- Marking leaks on a photograph of the test area, automatically saving the recorded data in an easy-to-visualise test report

Quantification requires measuring both leak signal (LV) and incident signal (OAV) at each site to calculate the signal fraction (SF), which correlates to leak size.

The expanded dynamic range of the 2nd generation of the Portacanner® AIRTIGHT allows for detection of both very small and large leaks without saturation, significantly improving performance over the first generation.

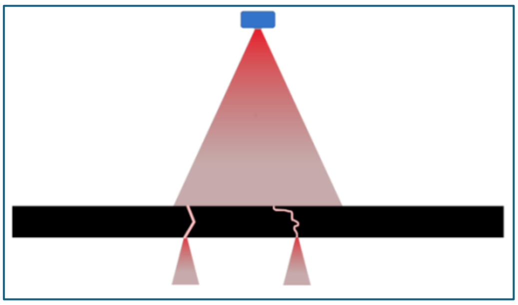

Figure 2: The basic principle used by the Portascanner® AIRTIGHT to detect air leaks

Test Method

As the Portascanner® AIRTIGHT is a novel device, there was previously a lack of empirical data confirming the accuracy of the device or how the device performed in relation to other commercially available airtightness testing technologies. Therefore, a series of comparative tests were devised to evaluate the performance of the device. These tests were undertaken within a controlled, partially controlled, and an uncontrolled (real-world) environment.

Two separate commercially available devices were used to undertake the airtightness measurements during the comparative tests. These devices comprised an Energy Conservatory Duct Blaster Blower Door with a DG1000 pressure/flow gauge (*The Energy Conservatory*, 2024a) and a Low Pressure Pulse 2.0 Test unit by Build Test Solutions (*BTS*, 2024). The typical uncertainty associated with the blower door tests is estimated to be between 3% and 10% for the air permeability and 10% for the Equivalent Leakage Area (EqLA) or the Effective Leakage Area (ELA), under calm conditions, according to BS EN ISO 9972:2015 (*BSI*, 2015). For the Pulse Test method, the uncertainty is estimated to be 5% (*BTS*, 2018). The uncertainty associated with the Portascanner® AIRTIGHT has been empirically characterised using an idealised cylindrical aperture model, demonstrating a measurement deviation within ±10%. The uncertainty in flowrate estimations is condition-dependent and is further discussed in subsequent sections of this paper.

All of the blower door and Pulse airtightness tests referred to within this paper were undertaken in accordance with CIBSE TM23 (*CIBSE*, 2021).

Test Results

Controlled Environment Testing

For the tests undertaken within the controlled environment, a pair of adjacent windowless rooms were repurposed (a former music recording studio). These rooms provided two distinct regions, separated by a wall with a large opening, which were isolated as much as is practical, from any external influences that are likely to affect the air leakage of the spaces.

The baseline airtightness of the room was measured using the blower door and Pulse Test unit. A series of known direct ‘leaks’ were then introduced into the opening between the rooms, ranging from 2 to 12mm in diameter, through a single layer of plywood. A double layer ply construction, separated by a 100mm cavity, was also used to mimic a series of convoluted indirect leakage paths. For the convoluted paths, tests were conducted with ingress and egress points that were equidistant with one another and of the same or differing size.

In order to be able to compare the results from the different devices, the estimated leakage area was used, as the Portascanner® AIRTIGHT is not able to measure the aggregate airtightness of an enclosure via a single measurement. The leakage area is a cumulative measure of all the individual holes and cracks, that when added together, are represented by a single aerodynamic equivalent hole. Two separate metrics are available to provide an estimate of the leakage area. These are termed the Equivalent Leakage Area (EqLA) or the Effective Leakage Area (ELA). The EqLA is defined as the area of a sharp-edged orifice that would leak the same amount of air as the building does at a pressure of 10Pa (*The Energy Conservatory*, 2024b). ELA, on the other hand, is defined as the area of a special nozzle-shaped hole that would leak the same amount of air as the building does at a pressure of 4 Pa (*The Energy Conservatory*, 2024b). Both the EqLA and the ELA metrics relate to the external envelope of the building. The Tectite Express 5.0 software used with the blower door provides an estimate of both the EqLA and ELA metric, whilst ELA is the only metric estimated by the Pulse Test method. Neither of these metrics are used as output from the Portascanner® AIRTIGHT, which provides a measurement of the internal leakage area, from which the air flowrate and air permeability are deduced under a user-specified pressure differential. The leakage area provided by the Portascanner® AIRTIGHT is representative of the equivalent cross-sectional area of an idealised, direct, cylindrical leak corresponding to the given airflow rate. Therefore, as 4Pa is considered representative of the naturally occurring pressure differentials that exist across the leaks that occur in a building envelope (*Modera et al.*, 1992), the ELA metric was used in this analysis.

The results of the baseline airtightness measurements are illustrated in Table 1. The results indicate that the air permeability of the test room was only slightly leakier than that of a new build UK dwelling (~4/5$m^3.h^{-1}.m^{-2}$ @ 50Pa), but much tighter than the mean of the existing UK housing stock (11.5$m^3.h^{-1}.m^{-2}$ @ 50Pa (*Stephen*, 2000)). There was also a significant difference in the air permeability and ELA derived from the blower door and Pulse Test results, with the Pulse Test results being much lower. The reasons for this are unknown but may be a consequence of using the conversion formula within CIBSE TM23 (*CIBSE*, 2021) to convert the Pulse Test at 4Pa to a reference pressure of 50Pa. This formula may not be appropriate for the test room, as it was derived from over 293,000 blower door tests undertaken at 50Pa that were provided by a range of testing organisations (*CIBSE*, 2021).

Table 1: Summary of the baseline airtightness measurement on the test room.

Test	**Depressurisation**	**Pressurisation**	**Mean Air Permeability**	**ELA**
	$m^3.h^{-1}.m^{-2}$ @ 50Pa	**$m^3.h^{-1}.m^{-2}$ @ 50Pa**	**$m^3.h^{-1}.m^{-2}$ @ 50Pa**	**mm^2 @ 4Pa**
Blower door	6.75	5.09	5.92	9820
Pulse	NA	3.09[1]	NA	5853

[1] This figure has been calculated based upon the conversion formula contained within CIBSE TM23 (*CIBSE*, 2021).

Following the baseline measurements, a series of comparative airtightness tests were then undertaken on the single layer of ply to simulate the effect of a direct air leakage path through an element of construction. The results are detailed in Table 2 and are illustrated in Figure 3 and were undertaken for a range of holes of known diameter.

As illustrated in Figure 3, the leakage area estimated using the blower door and Pulse Tests is considerably different to the true leakage area for the majority of the measurements and varies significantly across the different hole sizes, with no apparent pattern present. This is not surprising, given the size of the holes measured, and is likely to be a consequence of all the measurements being within the uncertainty of the baseline measurement for each device. For the Portascanner® AIRTIGHT, the estimated leakage areas are all within ±10% of the actual true leakage area and in the majority of cases are within the uncertainty of the measurement method. The results suggest that the Portascanner® AIRTIGHT is the only device of those compared that is capable of accurately quantifying the small direct air leakage areas introduced as part of this testing.

Table 2: Summary of leakage area measurements on the single layer of ply.

Hole diameter	True leakage area (mm^2)	Blower door ELA @ 4Pa (mm^2)[1]	Pulse Test ELA @ 4Pa (mm^2)[1]	Portascanner Test 1 ELA @ 4Pa (mm^2)	Portascanner Test 2 ELA @ 4Pa (mm^2)	Portascanner Test 3 ELA @ 4Pa (mm^2)	Portascanner average ELA @ 4Pa (mm^2)
2mm	3	-30.0	-421	3	3	3	3
4mm	13	1040	194	12	13	13	13
5mm	20	660	-364	19	18	20	20
6mm	28	1050	45	30	29	27	27
7mm	39	1080	-186	35	35	35	35
8mm	50	870	-220	54	51	48	48
10mm	79	980	-188	79	78	75	75
12mm	113	670	-190	121	117	123	123

[1]These figures are the difference between the reported figure and the baseline figure. Hence negative values reflect a leakage area that is less than the baseline measurement.

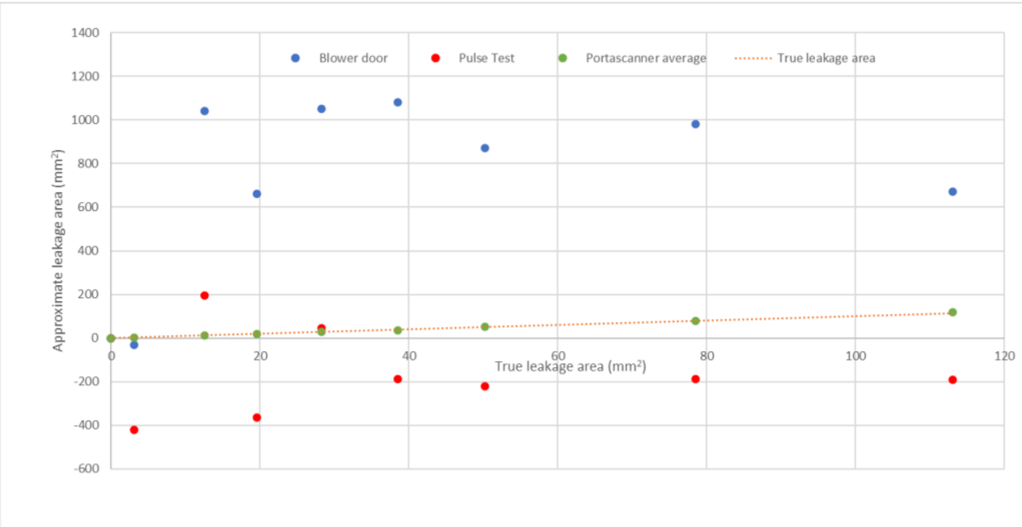

Figure 3: Summary of single layer ply leakage area measurements.

To simulate the effect of indirect convoluted air leakage paths, the tests were repeated on a double layer ply construction which had a 12mm and 22mm hole drilled on the external face and a series of known holes (2, 4, 5, 6, 7, 8, 10 & 12 mm in diameter) drilled on the internal face. The results of the measurements are detailed in Table 3 and illustrated in Figures 4 & 5.

Table 3: Summary of the convoluted ELA measurements on the double layer of ply.

Hole diameter	Blower door ELA @ 4Pa (mm^2)[1]	Pulse Test ELA @ 4Pa (mm^2)[1]	Portascanner ELA @ 4Pa (mm^2)
12 + 2mm	-220	-28	0.001

12 + 4mm	-430	-620	0.0264
12 + 5mm	-640	-622	0.0349
12 + 6mm	-200	-817	0.0487
12 + 7mm	-600	-8	0.0703
12 + 8mm	-380	-356	0.076
12 + 10mm	-330	-680	0.11
12 + 12mm	-250	-651	0.165
22 + 2mm	-110	-584	0.004
22 + 4mm	-430	-108	0.0388
22 + 5mm	-550	-401	0.0572
22 + 6mm	-670	-515	0.0651
22 + 7mm	-450	-648	0.0667
22 + 8mm	-210	-44	0.092
22 + 10mm	-410	-225	0.119
22 + 12mm	-490	-916	0.173

[1]These figures are the difference between the reported figure and the baseline figure. Hence negative values reflect a leakage area that is less than the baseline measurement.

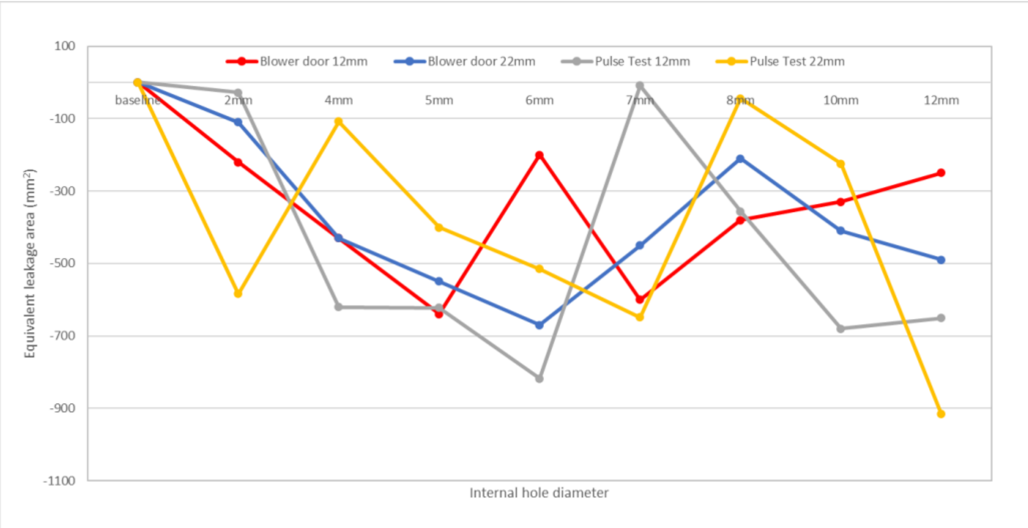

Figure 4: Double layer ply convoluted blower door and Pulse Test leakage area measurements.

Figure 4 illustrates that the leakage area estimated using the blower door and Pulse Test unit for both convoluted sets of measurements (12mm and 22mm) not only varied considerably but was also less than the baseline measurement for each test, resulting in a negative value. This contrasts with the fact that the external leakage area should have remained constant for each test condition (either 12mm or 22mm). However, closer analysis of the results reveals that most of the measurements are within the uncertainty associated with the test method. For the Portascanner® AIRTIGHT, as it measures the internal leakage area, as opposed to the external leakage area, as would be expected, very similar estimated leakage areas were obtained for the 12mm and 22mm hole and the estimated leakage area increased as the true size of the internal hole increased (see Figure 5). However, it is also clear that the leakage areas estimated for all of the convoluted measurements was significantly lower than the true leakage area, even when the uncertainty associated with the measurement is considered. These results suggest that none of the test methods employed were able to accurately measure the very small differences in leakage area that were created by the convoluted indirect leakage paths. For the blower and door and Pulse Test units, this is due to the uncertainty associated with the test method. However, for the

Portascanner® AIRTIGHT, while the cross-sectional leakage areas were significantly smaller than either of the drilled holes, the instrument was able to successfully rank the leakage areas in order of size. This has not been possible to achieve using the two other measurement devices and is likely to have important implications in terms of air leakage identification.

Following the quantitative measurements, a series of qualitative leakage detection measurements were undertaken to determine if the known leaks could be identified by each device. These measurements were only undertaken using the Portascanner® AIRTIGHT and the blower door, as it is not possible to undertake these measurements using the Pulse Test unit. For the blower door tests, the room was depressurised to ~60Pa and a smoke pencil used to identify leakage areas. No additional equipment was needed to identify the leakage areas using the Portascanner® AIRTIGHT. The results revealed that all the leaks, both direct and convoluted, were detectable using both the blower door and the Portascanner® AIRTIGHT.

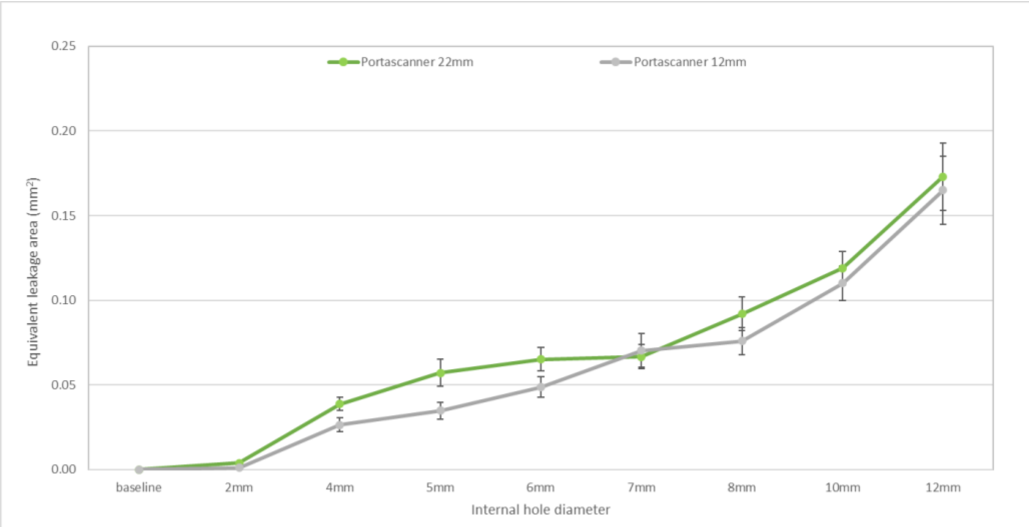

Figure 5: Double layer ply convoluted Portascanner® AIRTIGHT leakage area measurements.

Partially Controlled Environment Testing

The purpose of this testing was to compare the performance of the devices when undertaking leakage identification on a real building within a semi-controlled environment, thus limiting the impact of external conditions on the tests. Therefore, the tests were undertaken on the eHome 2, which is located within the Energy House 2.0 at the University of Salford. This house is located within an environmental chamber, enabling the local external environmental conditions surrounding the building to be controlled. Tests were undertaken using the blower door and Portascanner® AIRTIGHT. To identify areas of air leakage during the blower door test, thermography was used. Therefore, a pressure differential of ~50Pa was maintained across the house, with the internal temperature inside the house being set to 20°C and the chamber temperature set at 6°C. In addition, to avoid introducing any potential bias, both sets of measurements were undertaken blind.

Although the temperature of the emerging air observed via thermography can provide information on the leakage paths identified; with cooler emerging air indicating a more severe or more direct leakage path, it is not possible to measure what proportion of the overall air leakage a particular leakage path is responsible for or to rank the leakage paths quantitatively in order of severity. In addition, when undertaking thermographic leakage detection at a pressure differential of -50Pa, it is important to note that it will pull outward opening windows and doors more tightly closed on their seals and will have the opposite effect on inward opening windows and doors. These are a limitation of using thermography for leakage detection. Nevertheless, thermography under depressurisation was used to identify the main air leakage paths within eHome 2. The most significant direct leakage paths observed were at the access hatches in the master bedroom, through and around window trickle ventilators and at the patio door. Significant indirect air leakage was also observed around penetrations through the 1st floor ceilings and where air movement from the external environment entered various voids within the house rather than directly into the habitable space. The most notable was into the voids behind the dry lining at the 1st floor ceiling perimeter, on the external wall adjacent to the stairs, at the ground floor perimeter into the space behind the heated skirting and into the intermediate floor void above the patio doors.

The results obtained from the Portascanner® AIRTIGHT indicated that, in general, the building had a low air permeability of ~3 $m^3/(h.m^2)$ @ 50Pa, a figure that was calculated automatically by summing the total flowrates of all leaks detected. The most significant leaks were identified in the trickle ventilators above windows and at parts of the two externals doors. This is in agreement with the thermographic results, with the following exceptions. The main entrance door, identified as a structure with significant leaks by the Portascanner® AIRTIGHT was not tested with thermographic cameras due to its being used to affix the fan pressurisation equipment. Additionally, there were some leaks that were impractical to investigate ultrasonically, specifically those that related to airflow through the first-floor ceiling into the roof space and minor leaks at the ground floor perimeter into the wall cavity. Figure 6 shows the results of both tests on the patio door, with leak hotspots matching between tests and with the added flowrate information provided by the Portascanner® AIRTIGHT.


Site: eHome 2

Room: Kitchen

Structure: Back Door

Date: 2024-05-23

Leak Details

Leak Number	Cross-Sectional Area (mm²)	Air Flow Rate (m³/h)
1	0.39	0.004
2	1.13	0.02
3	6.16	0.223
4	12.43	0.591
Total	**20.11**	**0.839**

Figure 6: Excerpt from the Portascanner® AIRTIGHT 2.0 automated report at Salford Energy House 2.0, alongside the corresponding thermographic results.

Uncontrolled (Real-World) Environment Testing
This testing was undertaken to compare the performance of the devices on a number of real buildings exposed to the natural environment. The tests were undertaken on a range of existing dwellings, which were approximately 10 years old, all of which were located on the same development and of differing form (semi-detached, terraced and apartment). The results obtained from the Portascanner® AIRTIGHT device were only compared with some recent results that had been undertaking using a blower door, where thermography had been used to identify the main leakage areas. As with the partially controlled testing, the Portascanner® AIRTIGHT measurements were undertaken blind.

The most significant direct leakage paths observed using the blower door were around the window and door frames at the jamb, head, sill and reveal junctions and at junctions between the window and door frame elements. Significant indirect air leakage was also observed beneath some of the kitchen units, around the cooker hood (with an air leakage path detected from the cooker hood to the external MVHR inlet/extract), around unsealed service penetrations in the 1st floor ceiling (semi-detached and terraced dwellings) and at the bathroom window/external wall junction next to the stairwell (apartments). The most notable was at the junction between the internal vertical timber panels on the external walls and at the interface between these panels and the plastered wall, floor and ceiling. This was particularly noticeable on those panels located on the South-façade of the dwellings.

Site: Lilac House 10
Room: Hallway
Structure: Front door

Leak Number	Cross-Sectional Area (mm²)	Air Flow Rate (m³/h)
1	4.26	0.08
2	2.59	0.04
3	9.48	0.25
4	7.53	0.18
5	16.66	0.55
6	2.64	0.04
TOTAL	**43.16**	**1.14**

Figure 7: Excerpt from the Portacanner® AIRTIGHT 1.0 automated report at a real dwelling.

Similarly, the tests conducted with the Portascanner® AIRTIGHT identified the seal external doors and frame to be the most significant sources of direct air leakage. In particular, extended portions of the front door frames in several dwellings were found to have considerable leakage, with predicted flow rates exceeding 1 m^3/h (see Figure 7). Less significant leakage was also identified around many of the window frames, predominantly near the corners and occasionally extending further into the frame, with a much smaller contribution to total leakage. A small amount of ultrasound was detected through external timber panels outside the bathroom window next to the stairwell, in agreement with the blower door testing, though the predicted flow rate was negligible. In general, however, indirect leakage was much more challenging to detect, due to the long leak paths, with ingress/egress points separated by cavities in the internal structure. Overall, despite some difficulty with convoluted, indirect leak paths, the Portascanner® AIRTIGHT was successfully able to identify various direct leak paths as identified via thermography, and the severity of leaks was determined also in good agreement with thermographic testing.

Conclusion

During controlled testing, the Portascanner® AIRTIGHT was capable of detecting and quantifying simple leaks with high accuracy (within ±10%) including leaks that were not picked up by blower door tests and low-pressure pulse tests. It also detected convoluted leaks, accurately ranked their severity, and provided realistic airflow results in partially controlled tests, though equivalent cross-sectional areas were consistently smaller the more complex the leak. During uncontrolled testing, the instrument was capable of identifying a number of air leaks, including some that were not obvious using other methods. Some leaks were impractical to find using ultrasound without additional support e.g. through the use of a drone-mounted source. In general, the results obtained using the Portascanner® AIRTIGHT were in agreement with those recorded using traditional methods, suggesting that it can be used to enhance airtightness by identifying and ranking leaks for rapid remediation prior to, during, or after a pressurisation test. Its ability to function non-disruptively and without being affected by environment conditions lends itself to situations where other technologies may struggle, for example, in highly airtight or highly leaky environments, or in environments without a clear temperature differential.

The Portascanner® AIRTIGHT represents a significant advance in airtightness testing technology. By combining rapid, non-invasive leak detection with quantifiable airflow measurement, it addresses key limitations of traditional methods. Its integration into construction workflows, both during and after build, has the potential to improve build quality, reduce remedial costs, and enhance the energy and acoustic performance of the built environment. Widespread adoption could support more consistent achievement of net-zero building targets.

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