Technical Standard L4

Measuring Air Permeability in Passivhaus & Low Energy Buildings Fan Pressurisation Method

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This document provides the technical standard to be followed for the air tightness testing of Passivhaus and other low energy buildings as required as part of a Passivhaus or low energy building design.

This testing described in this standard is fundamentally based on *ISO 9972:2015 Thermal performance of buildings – 'Determination of air permeability of buildings - Fan pressurization method'* though the guidance is provided by both the Passivhaus Trust and the Air Tightness Testing & Measurement Association.

This Technical Standard provides detailed guidance and clarification of the above standard to ensure consistency by testing companies. Guidance should always be taken from the Lead Consultant as methods described in this standard may have changed or have been updated since this standard was released.

Guidance for test procedures for the testing of buildings that are simple is provided within companion reference document ATTMA Technical Standard L1.

Guidance for test procedures for the testing of buildings that are non-simple is provided within companion reference document ATTMA Technical Standard L2.

Guidance for test procedures for the testing of buildings that are complex, high-rise or phased handover is provided within companion reference document ATTMA Technical Standard L3.

Guidance for test procedures for the testing of different types of buildings are indicated in the table below.

Building Type	Test Standard
Buildings - Single Fan	TSL1
Buildings - Multiple Fan	TSL2
Building Extensions	TSL2
Permanently Compartmentalised	TSL2 - All compartments simultaneously TSL3 - Compartments as zones
High Rise	TSL3
Phased Handover	TSL3
Student Accommodation	TSL1 - Whole building TSL2 - Whole building TSL3 - High rise, phased handover
Sheltered Housing	TSL1 - residential units, whole building TSL2 - communal areas, whole building
Apartments Over Retail	TSL1 - Apartments, retail TSL2 - Large retail
Shell and Core	TSL1 TSL2 TSL3
Low Energy Buildings	TSL4

Contents

Section 1 - Introduction

1.1 What is Air Leakage Testing?

Air leakage testing is the process of measuring the amount of conditioned (heated or cooled) air entering or exiting a building through uncontrolled infiltration.

1.2 How is Air Leakage Measured?

A calibrated fan is installed into the external envelope of the building and supplies air into, or extracts air out of, the property creating a controlled building pressure differential. The tester uses calibrated equipment and calculates an air flow into, or out of, the property. In simple terms, the amount of air going into, or out of the property when the building is subject to a pressure differential is the amount of 'air leakage'.

1.3 Presentation of Results

The result can be presented in several ways:

1. **Air Leakage**, known as 'Q_{pr}', is the amount of air entering or exiting the building at a given pressure.
    a. In most countries, Q_{50} is used to denote the air leakage at a building pressure differential of 50 Pa. Units are $m^3.h^{-1}$ @ 50 Pa.

2. **Air Changes per Hour**, known as 'N_{pr}', is the amount of air leakage divided by the internal volume of the building.
    a. In most countries, N_{50} is used to denote the air changes per hour at a building pressure differential of 50 Pa. Units are $m^3.h^{-1}.m^{-3}$ @ 50 Pa.

3. **Air Permeability**, known as 'AP_{pr}', is the amount of air leakage divided by the internal envelope area of the building.
    a. In most countries, AP_{50} is used to denote the air permeability at a building pressure differential of 50 Pa. Units are $m^3.h^{-1}.m^{-2}$ @ 50 Pa.

1.4 Who is Authorised to Test?

For a testing organisation to show compliance with this standard they shall carry out their testing in an equitable manner and must remain independent of companies involved in the construction of the buildings they test. They must also have suitable third party monitoring systems in place and this is demonstrated by either:

1. having an active registration with a nationally recognised Competent Persons Scheme (CPS) for building air leakage testing and are deemed qualified by the scheme to test buildings of this level.

    or

2. holding national accreditation specifically for building air leakage testing in line with ISO/IEC17025:2017, or later.

1.5 Air Tightness & Ventilation

A common myth is that very low air leakage can cause building sickness and poor air quality, however, it is inadequate ventilation that causes poor air quality. It is important to match the air tightness testing targets and result with adequate means of ventilation.

This standard does not give guidance on adequate ventilation levels. Guidance can be taken from the low energy building standards and due consideration should be given to local Building Regulations requirements.

The low air changes per hour results required for a low energy building (typically an N_{50} less than 0.6 for Passivhaus) require an assessment of the ventilation strategy to achieve adequate air changes and therefore adequate air quality.

1.6 Target Air Change Rates

Table 1 highlights the airtightness requirements for low energy building standards.

It shall be noted however that the below figures may not apply to all situations. In the case of doubt, advice shall be sought from the lead consultant.

Table 1 – Target Air Change Rate

Ventilation Strategy	Target Air Change Rate (N_{50})
Passivhaus Standard	≤0.6
EnerPHit Standard	≤1.0
PHI Low Energy Building	≤1.0
AECB CarbonLite Standard Level 1	≤5.0
AECB CarbonLite Standard Level 2	≤2.0
AECB CarbonLite Standard Level 3	≤1.5

1.7 Building Regulations Testing

This standard provides guidance on testing low air leakage buildings only. Guidance on testing for Building Regulations can be found in ATTMA TSL1 for simple buildings, ATTMA TSL2 for non-simple buildings and ATTMA TSL3 for complex buildings.

Section 2 – Pre-Test Requirements

Liaison shall be made with the client over the date and time of the test procedure. The client should be made fully aware of the nature of the test and the degree of disruption that it may cause to construction works and/or operation of the building, however minor these are.

The test can be affected by extremes of weather (wind speed, internal/external temperature differential). Weather forecasts should be checked prior to the proposed test date and if inclement weather is predicted, re-scheduling may be necessary.

There may be occasions when the building needs to be tested in conditions that are less than ideal and under these circumstances this must be clearly identified in the test report. However, if tests need to be carried out during periods of 'fresh' (≥6 $m.s^{-1}$) wind speeds, the zero flow pressure differences could be outside the acceptable range for a valid test as stated Appendix B. In such circumstances the result may not be reflective of the actual performance of the building.

2.1 Building Volume Calculations

The calculation of building volumes is one of the most important parts of the test, as an incorrect volume calculation will result in an incorrect result, even if the test was carried out without any issues.

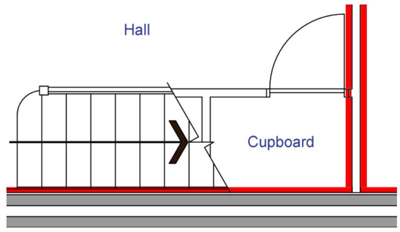
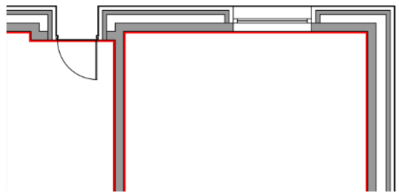
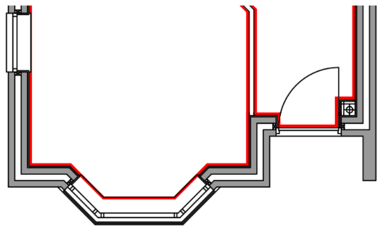
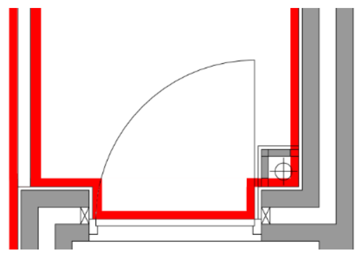
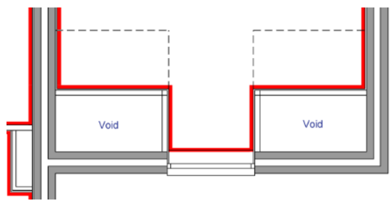
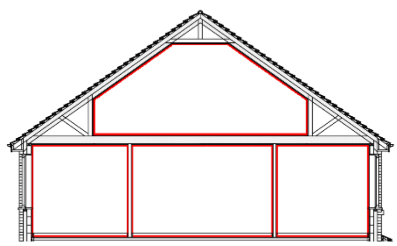
The building volume calculation is defined as the internal volume of the building minus any internal partitions, such as walls and floors, small window reveals and the volume between internal door reveals and small external door reveals, but inclusive of all other areas. The inclusion or exclusion of building elements contained within the volume of the building is defined in Table 2.

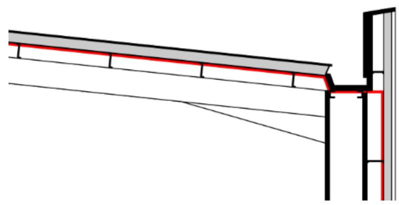
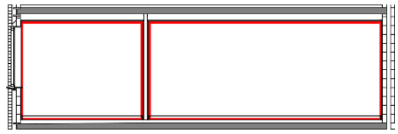
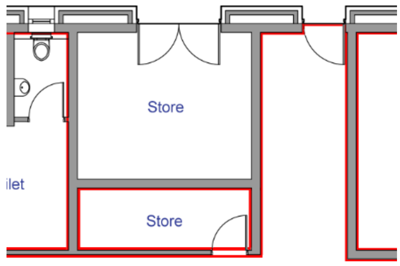
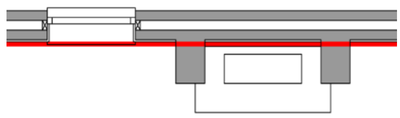
The volume of the building shall normally be measured along the line of the element bordering the internal volume (as defined within BS EN ISO 9972:2015). Areas are measured as flat, *i.e. no allowance is made for undulating profiles such as profiled cladding or textures to wall components.*

The extent of the building to be tested must be confirmed. This will reflect the extent of the 'conditioned space' within the building, *i.e. spaces that are intentionally heated or cooled.*

When testing at stages 1 or 2, as defined in Section 4.2, the building volume calculation must be representative of the finished building.

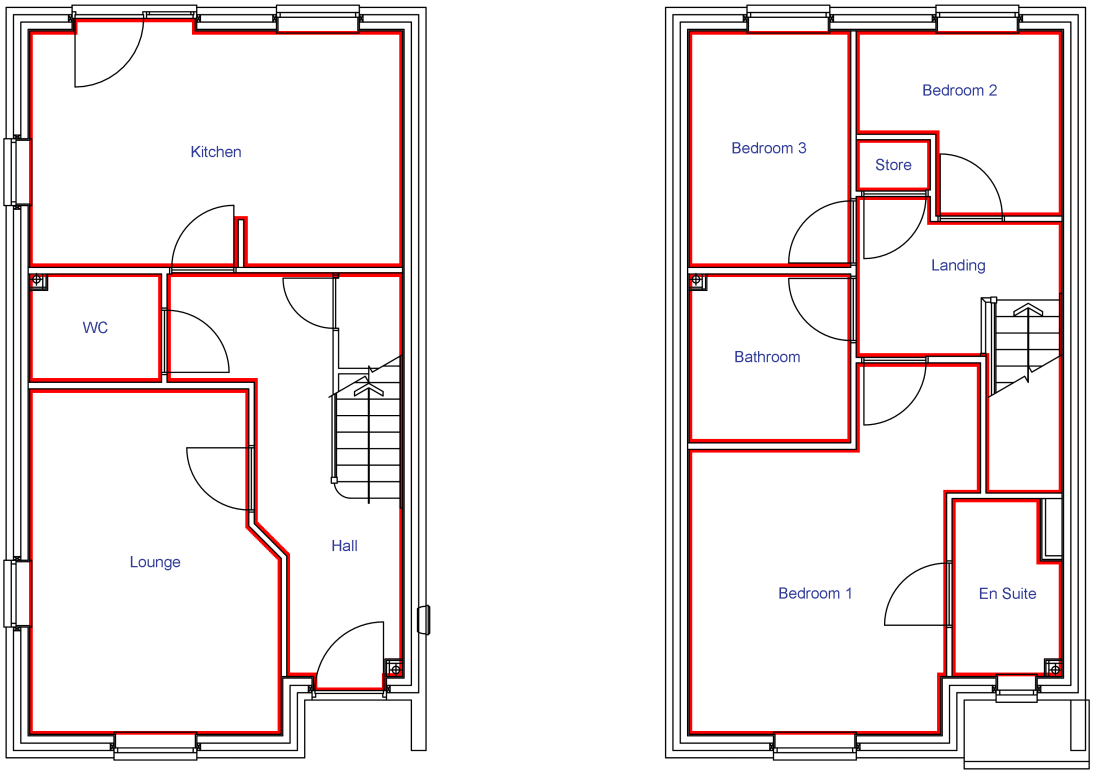
Table 2 – Air Volumes and Building Elements

Element	
Stairs Include the volume of air displaced by the stairs (unless the stairs are of monolithic stone or concrete construction without any opening or cupboard beneath them).	
Stair opening in floor plate Include the air volume of the stair opening in the floor plate.	
Door and window reveals Exclude the volume of air in all internal doorways. Exclude the volume of air in external door reveals (unless reveal depth ≥ 13cm). Exclude the volume of air in window reveals (unless full height window with reveal depth ≥ 13cm).	
Bay windows Include the volume of air in bay windows when they have a floor area level with the storey floor level, before any furniture or fittings are installed, or there are steps to walk into them.	
Beams and columns Include the volume of air displaced by beams and columns (unless the cross-sectional area of an individual beam or column is greater than $0.1m^2$)	
Boxing Include the volume of air displaced by boxing (unless the cross-sectional area is greater than $0.1\ m^2$).	
Roof voids and dormer windows Exclude the volume of air in roof voids. Include the volume of air in dormer windows.	
Attic/loft space Include if a conditioned roof construction with openable loft hatch or if accessed by a door that is not weather resistant. Exclude if an unconditioned roof construction or not accessible via a loft hatch or a door.	

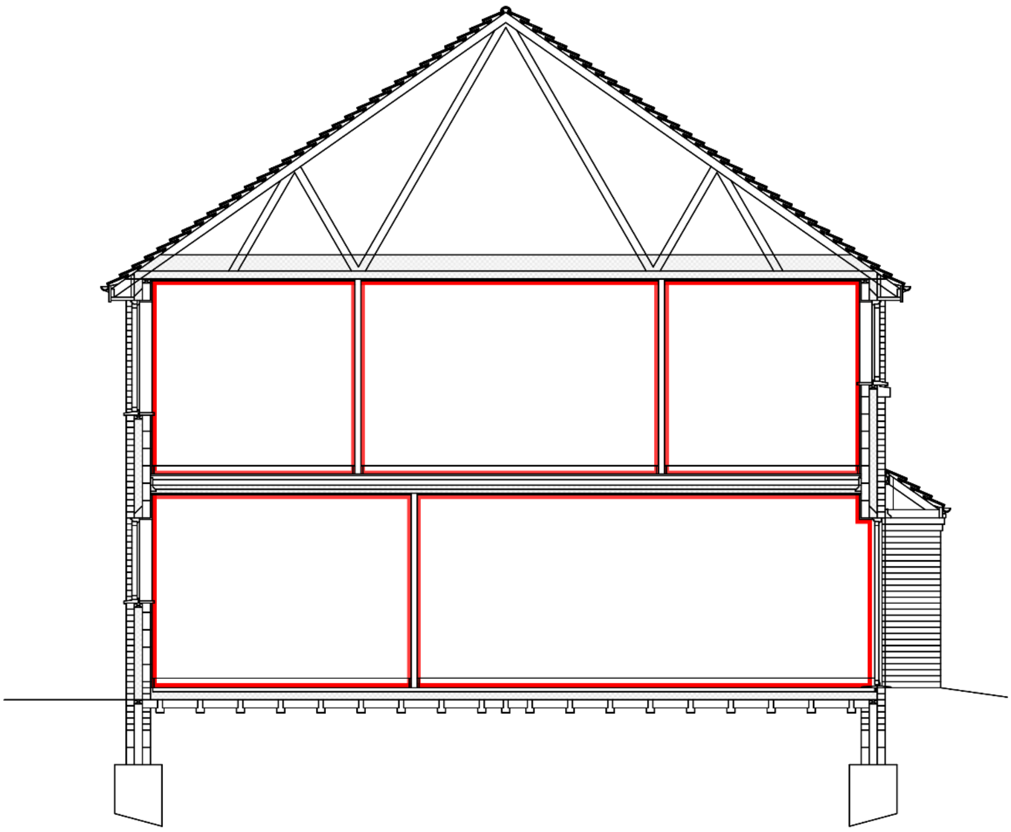
Parapets Exclude the volume of air in parapets.	
Suspended ceilings Exclude the volume of air above suspended ceilings or boxed in areas, even if the ceiling is perforated.	
Ductwork and flues Include the volume of air displaced by the ductwork and flues (unless the duct or flue is room sealed and the cross-sectional area is greater than $0.1m^2$)	
Cupboards and storage areas Include the volume of air displaced by all wall mounted cupboards and shelving units. For walk in wardrobes and storage rooms measure internal volumes as per a room. Exclude the volume of external stores.	
Storage cylinders, header tanks and building services Include the volume of air displaced by all hot water storage cylinders, header tanks and building services (unless the total air volume displaced by an individual item is greater than 1% of the net internal air volume).	
Skirting boards, architrave etc. Include the volume of air displaced by skirting board, architrave etc.	
Fireplaces Exclude the volume of air in fireplaces.	

2.1.1 Example Building Volume Calculation

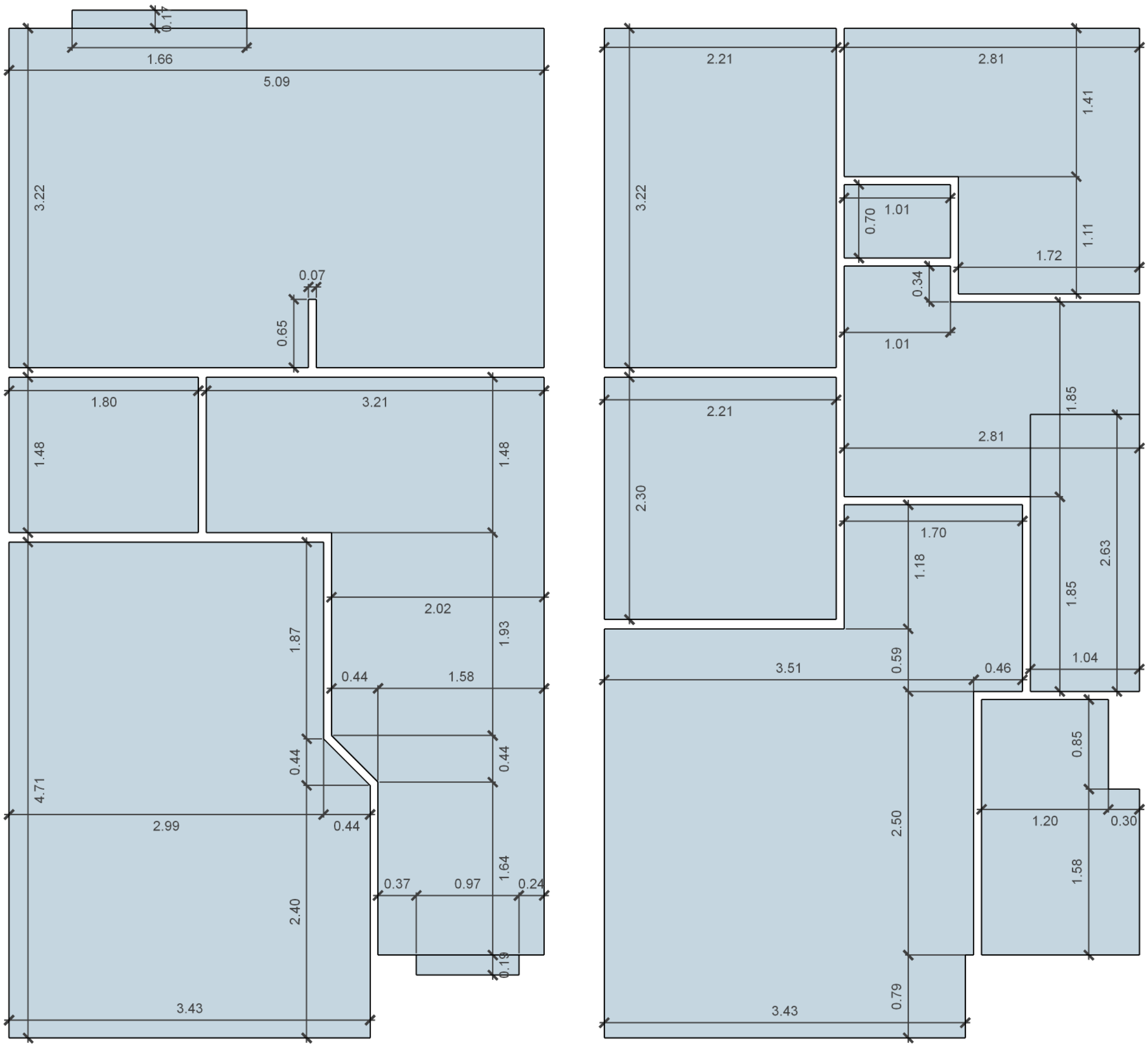
Floor Plans



Section

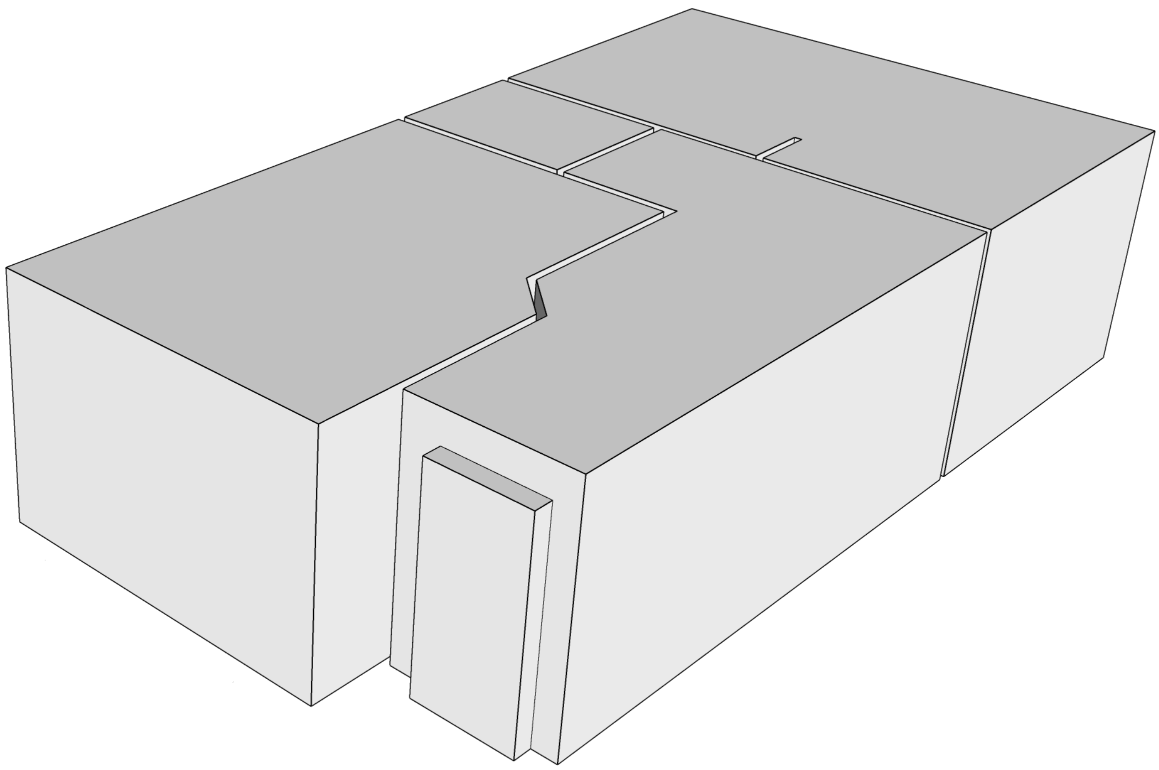


Floor Areas

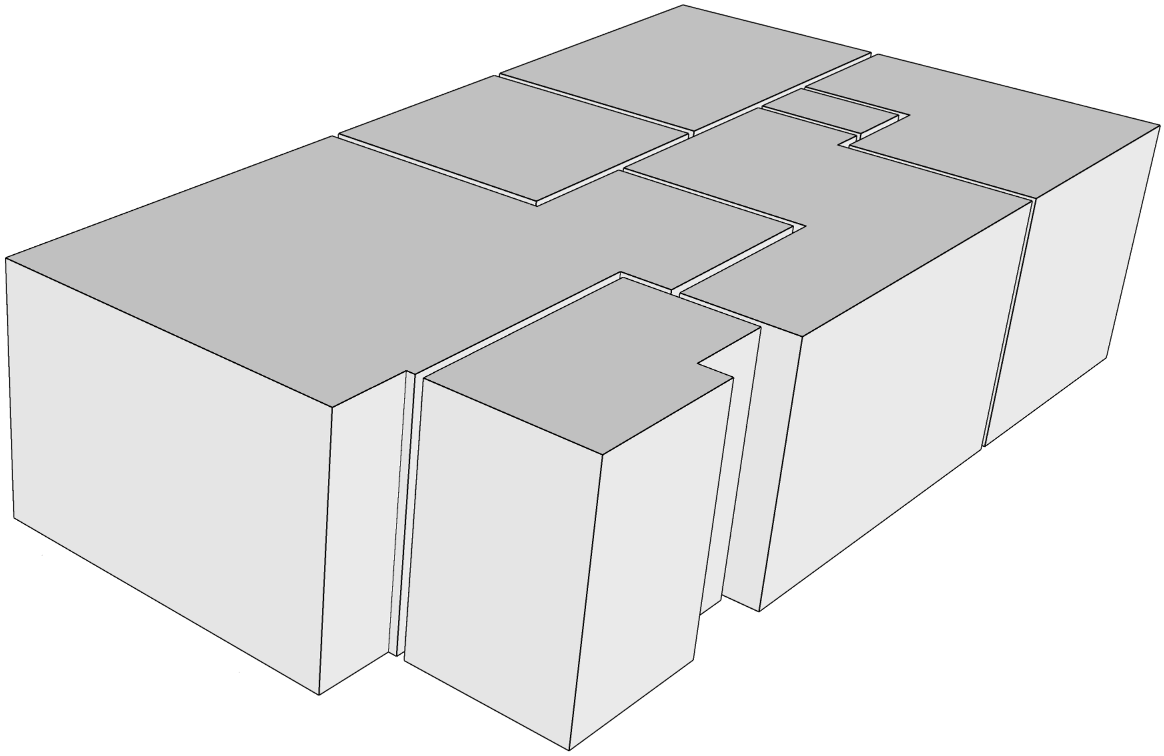

0.17
1.66
5.09
3.22
0.07
0.65
1.80
3.21
1.48
1.48
2.02
1.87
1.93
0.44
1.58
0.44
0.44
4.71
2.99
0.44
0.37
0.97
1.64
0.24
2.40
0.19
3.43
2.21
2.81
3.22
1.41
1.01
0.70
1.11
1.72
0.34
1.01
2.21
1.85
2.81
2.30
1.70
1.18
2.63
1.85
3.51
0.59
0.46
1.04
0.85
1.20
0.30
2.50
1.58
3.43
0.79

Cross Sectional View of Ground Floor

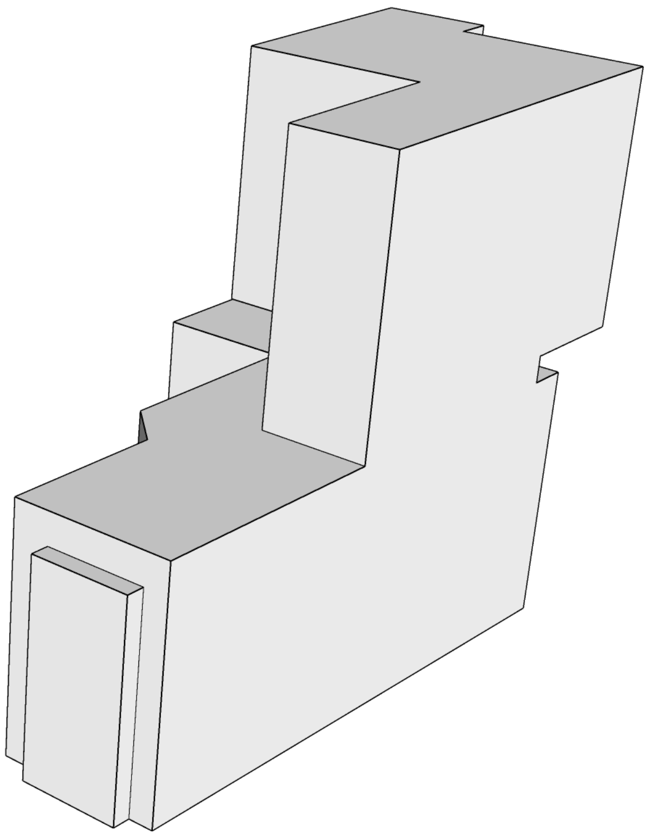
Ground Floor Volumes



First Floor Volume



Hall and Landing Volume Joined by the Volume of the Floor Plate



Volume Calculation

Ground Floor	
Rooms - Floor Areas	
Kitchen	= (5.09 x 3.22) – ((0.07 x 0.65) = 16.39 – 0.05 = 16.34 m²
WC	= 1.8 x 1.48 = 2.66 m²
Hallway	= (3.21 x 1.48) + (2.02 x 1.93) + ((0.44 x 0.44) / 2) + (1.58 x (0.44 + 1.64)) = 4.75 + 3.9 + 0.1 + 3.29 = 12.04 m²
Lounge	= (2.99 x (1.87 + 0.44)) + ((0.44 x 0.44) / 2) + (3.43 x 2.4) = 6.91 + 0.1 + 8.23 = 15.24 m²
Total Floor Area	**= 16.34 + 2.66 + 12.04 + 15.24 = 46.28 m²**
Volume	**= 46.28 x 2.4 = 111.07 m³**
External Door and Window Reveals with a Depth ≥ 13cm - Floor Areas	
Kitchen	= 0.17 x 1.66 = 0.28 m²
Hall	= 0.19 x 0.97 = 0.18 m²
Total Floor Area	**= 0.28 + 0.18 = 0.46 m²**
Volume	**= 0.46 x 2.09 = 0.96 m³**
First Floor	
Rooms – Floor Areas	
Bathroom	= 2.21 x 2.3 = 5.08 m²
Bedroom 1	= (3.43 x 0.79) + (3.51 x 2.5) + ((3.51 + 0.46) x 0.59) + (1.7 x 1.18) = 2.71 + 8.78 + 2.34 + 2.01 = 15.84 m²
Bedroom 2	= (2.81 x 1.41) + (1.72 x 1.11) = 3.96 + 1.91 = 5.87 m²
Bedroom 3	= 2.21 x 3.22 = 7.12 m²
Landing	= (1.04 x 1.85) + (2.81 x 1.85) + (1.01 x 0.34) = 1.92 + 5.2 + 0.34 = 7.46 m²
Store	= 1.01 x 0.7 = 0.71 m²
En Suite	= (1.2 x 0.85) + ((1.2 + 0.3) x 1.58) = 1.02 + 2.37 = 3.39 m²
Total Floor Area	**= 5.08 + 15.84 + 5.87 + 7.12 + 7.46 + 0.71 + 3.39 = 45.47 m²**
Volume	**= 45.47 x 2.4 = 109.13 m³**
Floor Plate	
Floor Plate	= 2.63 x 1.04 = 2.74 m²
Volume	**= 2.74 x 0.255 = 0.7m³**
Volume Total	**= 111.07 + 0.96 + 109.13 + 0.7 = 221.86 m³**

2.2 Envelope Area Calculations

Where an Air Permeability result is also required, please refer to ATTMA TSL1 for simple buildings, ATTMA TSL2 for non-simple buildings and ATTMA TSL3 for complex buildings.

2.3 Confirmation of Calculations

The building volume can be calculated from dimensioned drawings, if the building volume is calculated using dimensioned drawings it is essential to verify the calculation on-site, using 2 or more 'reference check points' to confirm the dimensions are accurate. The drawings used for the measurement must reflect the dimensions of the completed building.

An evaluation of the building or test area volume must be made prior to the test being undertaken. The necessary fan flow required to undertake the test shall be calculated from this figure.

The calculated building volume will be referred to in subsequent data analysis and test reports and/or Lodgement Certificates and must be sent to the Low Energy Building Certifier.

Section 3 - Test Set Up Methods

3.1 Fan System Selection

The fan system will generally consist of one unit located within an external opening to the building envelope, or area under test. Adequate fan capacity must be available to undertake the test which will be established from the target specification, and the building volume calculation.

The fan pressurisation system and associated equipment utilised must be calibrated in accordance with national standards, must be within accepted calibration periods and must be used within calibrated ranges (see Appendix C).

Care shall be taken when choosing a measurement system such that the system is relatively unaffected by irregular air entry conditions (wind velocities and local obstructions) and that there is stability in the measurement system. The proximity of local obstructions can cause inaccuracies. The proximity of multiple fan pressurisation systems can also cause inaccuracies.

3.2 Fan Flow Rate

The fan flow rate must be more than that required to pressurise or depressurise the building to greater than +/-55 Pa and less than that required to pressurise or depressurise the building to lower than +/-45 Pa.

For buildings smaller than 300m^3 in volume, a 'low flow fan' shall be exclusively used, as traditional larger fans have high inaccuracies and can unintentionally be used outside of their calibrated ranges at low flow pressures.

3.3 Installation Location

From information available, and through liaison with the client, the location for the installation of the fan pressurisation system should be established prior to the test date when testing large buildings (buildings with a building volume greater than 850 m^3). Several issues must be considered:

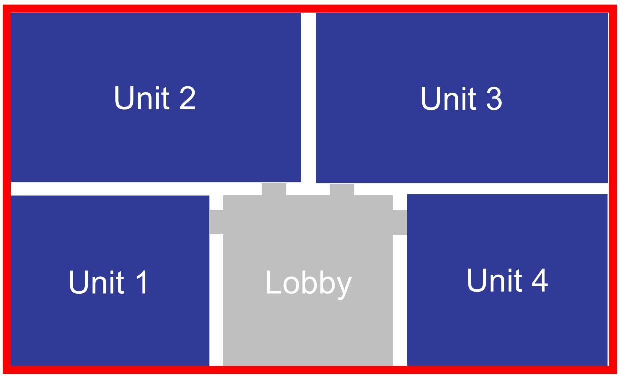
1. Access for fan pressurisation system to be delivered and installed.
2. Air flow restrictions in front of and around fans. A clear opening is preferred.
3. Any electrical power supplies which may be necessary.
4. Local restrictions, *e.g. noise, working hours etc.*
5. Acceptable route for the air to flow from the fans to achieve a uniform pressure throughout the building.

3.3.1 Multi-Unit Buildings

When multiple units are contained within the same thermal envelope, and built to a low energy standard, then the building is typically tested in its entirety.

If the communal and circulation areas are within the thermal envelope, and have a connection to all units, then the doors to all units and all the internal doors within each unit must be opened. The fan pressurisation system can then be installed in the main entrance door, or another suitable opening, and the building tested in its entirety as shown below.

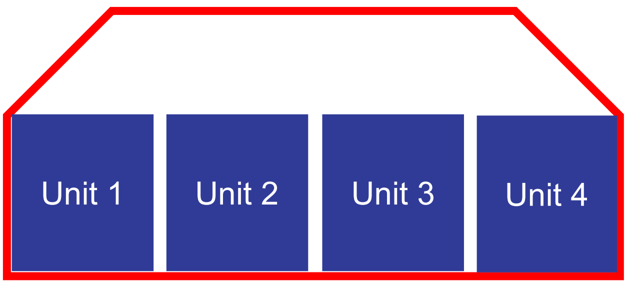
Communal and Circulation Areas Within the Thermal Envelope



When it is not possible to achieve a uniform building pressure differential through a single installation location refer to the guidance in ATTMA TSL2.

When there are no communal or circulation areas within the thermal envelope that connects all the units, or these areas are outside of the thermal envelope, the tester should test all units simultaneously. When this is not possible all units should be co-pressure tested to determine a result for the building. This includes units that are directly to the side as shown below or above or below such as in a block of flats.

No Communal or Circulation Areas Within the Thermal Envelope

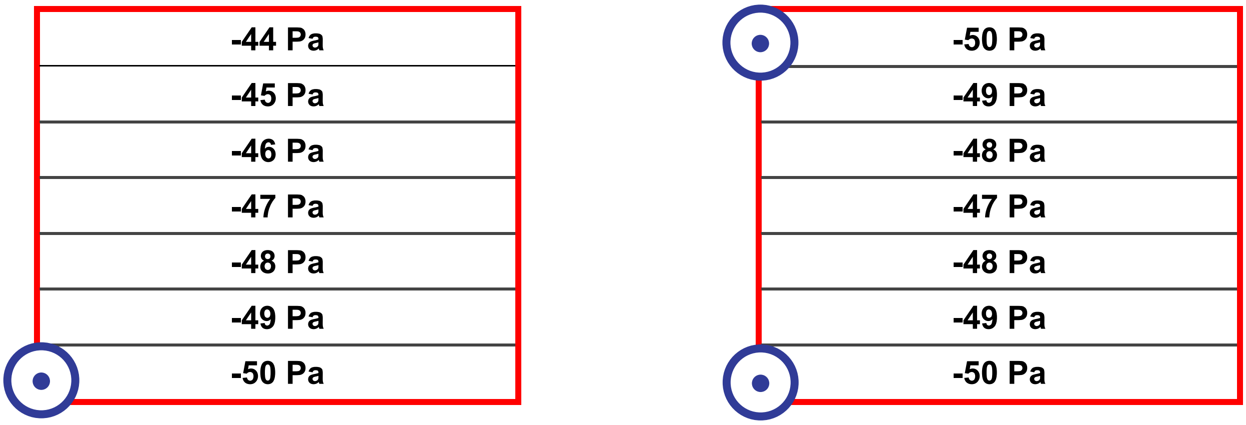


This method of testing is complex and additional guidance on testing buildings with multiple compartments can be found in ATTMA TSL2 and TSL3.

3.4 Buildings with Multiple Storeys

It can sometimes be difficult to achieve a uniform building pressure across buildings with multiple storeys, due to a loss of pressure through stairwells, and it may be necessary to change the test set up to remedy this.

The preferred method to achieve a uniform building pressure is to employ fan pressurisation systems at different locations within the building.



When it is not possible, due to the design of the building, to set up the equipment in different locations, then the following may be used to allow a greater flow of air to multiple storey:

1. Make use of light wells.
2. Make use of atria.
3. Make use of lift shafts providing suitable safety precautions are employed.
4. Make use of riser shafts if they have been sealed at the bottom floor and top floor roof level and not sealed horizontally at intermediate floors.

Where the guidance in this section cannot be implemented and the building has 10 or more storeys refer to the guidance in ATTMA TSL3 for high rise buildings.

3.5 Building Preparation

Prior to the test being undertaken, the building must be prepared to allow effective pressurisation and depressurisation results to be obtained.

The client should be advised and asked to ensure that all external doors and windows remain closed for the duration of the test.

Heating and ventilation systems are to be switched off from source before the test is conducted.

3.5.1 Test Methods

The methods of building preparation are identified in BS EN ISO 9972:2015, as:

Method 1. Building in use, natural ventilation openings are closed and whole building ventilation systems or air conditioning systems are sealed.

Method 2. Building envelope, all intentional ventilation openings are sealed.

Method 3. A test for a specific purpose, the treatment of intentional openings is adapted for compliance with an air tightness specification.

The method of building preparation for low energy buildings is Method 1 which may mean that the building needs to be prepared differently and tested again for compliance with national requirements.

3.5.2 Temporary Sealing

Table 3 highlights how the openings within a building are to be prepared for a test for Method 1.

Table 3 – Openings in the building

Opening	Status
Ventilation opening for natural ventilation	Closed
Openings for whole building mechanical ventilation or air conditioning (continual use)	Temporarily Sealed
Openings for mechanical ventilation or air conditioning (intermittent use)	Closed
Windows, doors, trapdoors and loft hatches in the envelope	Closed
Openings not intended for ventilation	Closed

Where an openings must be closed but closure is not possible the opening shall be left as found and not temporarily sealed.

It is the responsibility of the tester to ensure that the temporary seals are in accordance with the method of building preparation before commencement of a test.

The application of the temporary seals shall be agreed between the tester and the client before the test takes place.

Temporary seals may be applied internally or externally, but not both. Temporary seals must only be applied to the ventilation terminals or grilles and not the adjacent walls or ceilings.

Temporary seals employed during the test, including the method of closure, must be checked and recorded for inclusion in the test report.

3.5.3 Temporary Sealing - Deviations

Temporary sealing may be applied to broken or missing components in stage 1 or 2 tests as defined in Section 4.2. Care must be taken to not apply a better seal to broken or missing components than is envisioned by the finished component at stage 3. A stage 3 test may not be undertaken if there are still broken or missing components in the building.

Section 4 – Site Test Procedure

4.1 Test Direction

For Passivhaus and low energy buildings, both a pressurisation and depressurisation acceptance test must be undertaken. The result is the average of both tests.

4.2 Guidance

It can be advantageous to test a minimum of 3 times during the construction of a low energy building:

Stage 1	once the initial air barrier sealing works are completed
Stage 2	once the secondary fix works are completed
Stage 3	at completion

Checklists that provide guidance on the readiness of buildings for stage 1 and 2 tests can be found in Appendix F.

4.3 Test Procedure Detail

The procedure for undertaking a test is included within this section and detail on the technical validity of a test can be found in Appendix B.

4.3.1 Installation of Test Equipment

The fan pressurisation system may hinder the exit point(s) from the building. Whilst it is safe for the test to be undertaken with people remaining inside the building, it is often easier for the site operatives/staff to vacate the building for the period of the test.

The fan pressurisation system must be set up in a location that will not hinder airflow from or to the fan. For example, it is often required to set the fan pressurisation system up at the rear of a building to avoid the air flow being directed against a wall. The preferred set up location is in a window as this represents a smaller area in the envelope of the building.

There should also be an adequate air supply to the fan pressurisation system, for example if the equipment is located within a door to a garage, the external garage door should be open.

It is acceptable to temporarily seal around the fan pressurisation system should the window or door frame hinder a reasonable seal being achieved.

4.3.2 Approved Software

It is mandatory that the latest version of the approved software is used to achieve the correct result. Software can either be proprietary software, typically from equipment manufacturers, or a spreadsheet type software which has been created by the testing company.

All software should be verified against Appendix E to ensure compliance.

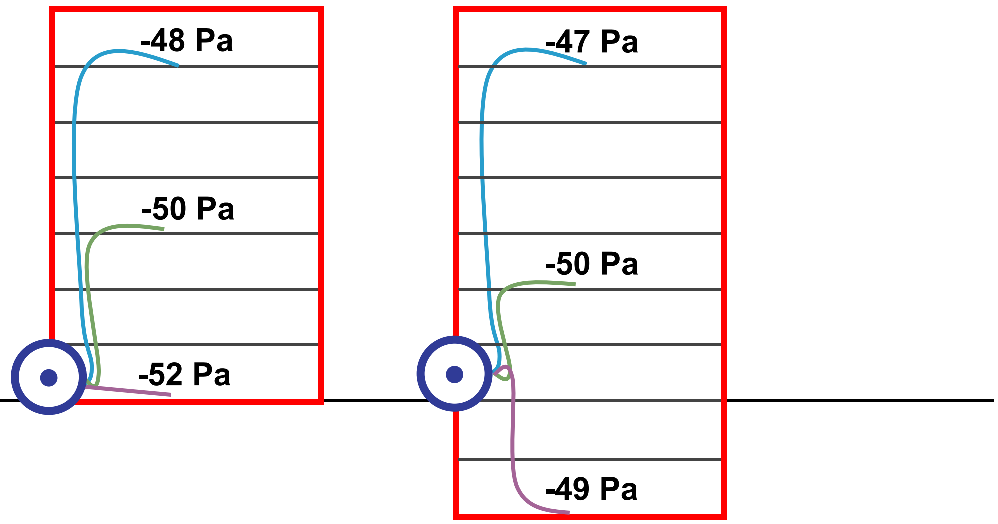
Coefficients and exponents from the latest fan calibration relative to the date of the test must be used.

4.3.3 Internal Pressure Tube

The indoor pressure is measured at the approximate geometric centre of the building or part thereof being tested. Measurements are obtained through small bore tubing (no greater than 6mm internal diameter). The internal pressure tube must be located away from corridors or doorways where air movement (dynamic pressure) is likely to affect the readings obtained.

Pressure tubes shall be kept away from locations where they may be trapped or may become heated or cooled excessively.

For buildings that are greater than 6 storeys, or 18 metres in height and 3 or more storeys, a second internal pressure tube shall be run to the centre of the highest floor level and a third internal pressure tube to the centre of the lowest floor level.



4.3.4 External Pressure Tube

The external pressure tube should be located away from the building envelope. This must terminate out of the air flows induced by the fan pressurisation system and sheltered from any wind. Where this is not possible, such as a top / intermediate floor apartment, the reference tube should be taken to an adjacent apartment or floor, and all the doors and windows opened to ensure a free air supply is provided. If this is not possible then the reference tube should be taken to the closest location where it can be positioned externally.

The tube termination should be pointed downwards to avoid rain and moisture obstructing the tube. Pressure tubes should be kept away from locations where they may be trapped or may become heated or cooled excessively.

4.3.5 'Pre-Test' External Temperature Shall be Measured and Recorded

External temperature shall be measured and recorded (T_{e1}). The temperature is taken from the location the air is drawn for the fan. Temperature shall be taken to the closest single decimal place, *e.g. 12.2°C.*

External temperature shall not be taken in direct sunlight.

4.3.6 'Pre-Test' Internal Temperature Shall be Measured and Recorded

Internal temperature (T_{i1}) shall be measured and recorded. For dwellings up to and including 3 storeys tall or for non-dwellings, or multi-unit buildings that are tested in their entirety, up to and including 6 storeys tall, this may be a single measurement in the approximate geometrical centre of the building.

For buildings that are greater than 6 storeys measurements shall be taken once for every 6 storeys or part thereof, and averaged *e.g. in a 7 storey building, 2 measurements shall be taken*.

4.3.7 'Pre-Test' Barometric Pressure Shall be Measured and Recorded

Barometric pressure is measured and recorded on the bottom storey of the building subject to the test. The barometric pressure shall be recorded to zero decimal place in Pa or to the closest single decimal place in hPA, *e.g. 101325 Pa or 1013.3 hPa.*

4.3.8 'Pre-Test' Zero Flow Pressure Differences are Measured

All pressure and flow measurement devices should be zeroed as necessary at this stage.

With the opening(s) of the fan pressurisation system temporarily covered, the pressure measuring devices should be connected to the internal and external pressure tubes. Record the zero-flow pressure differences to 1 decimal place in Pascal, *e.g. 1.0 Pa*. The following average zero flow pressure differences shall be calculated:

$\Delta P_{0,1+}$ *The average of positive values recorded*
$\Delta P_{0,1-}$ *The average of negative values recorded*
$\Delta P_{0,1}$ *The average of all values recorded*

Any values of 0 Pa are only to be included in the average of all values $\Delta P_{0,1}$.

Wind speed and temperature may be the cause of excessive zero flow pressure differences and waiting until the environmental conditions change may reduce the figure to an acceptable level as stated in Appendix B. It should also be confirmed that mechanical ventilation systems are suitably isolated so as not to cause this effect.

4.3.9 Fan on Test

Once acceptable zero flow pressure difference readings have been taken, covers from the fan pressurisation system should be removed. Fan pressurisation systems can then be turned on to pressurise or depressurise the building.

The fan shall be turned on and a building pressure differential applied with readings typically taken in the range of ±10 to ±90 Pa. It is recommended that fan pressurisation systems are switched on in a controlled manner. Great care must be taken to ensure that the building does not become over pressurised as this may present a risk to internal finishes, the fabric of the building and temporary seals applied.

4.3.10 Uniform Building Pressure Check

When additional internal pressure tubes are used a single building pressure differential must be recorded from each location. These shall be recorded simultaneously at a building pressure differential of 50Pa in the geometric centre of the building or at the highest building pressure achieved below this. This shall be used to ascertain that a uniform building pressure differential is achieved. See Section 4.3 Part 3 for details when this must be done.

4.3.11 Fan Readings and Building Pressure Differentials are Measured

The test is carried out by taking a series of measurements of air flow rates and corresponding building pressure differentials over a range of fan flows.

Adequate time must be allowed for induced pressures to stabilise throughout the building for each measurement. Larger buildings, or buildings subject to a high wind load may take longer to settle, whereas a smaller building will settle very quickly. Buildings with an extremely low air leakage may take a long time (>60s) to stabilise.

Measurements shall be stable for 30 seconds before the reading is taken. Building pressure differentials shall be recorded to 1 decimal place in Pascal *e.g. 1.0 Pa*.

If fan flows are calculated from fan flow pressure then they shall be recorded to 1 decimal place in Pascal *e.g. 1.0 Pa*.

Testers that use automatic software may need to amend their settings to take measurements over an increased period. Manufacturers' instructions shall be followed if required.

Once steady pressure and flow readings are obtained, these shall be recorded. Where multiple fans are utilised, it must be ensured that flow measurement readings are taken for each fan.

Where possible measurements should be recorded over a range of at least 30 Pa between the lowest and highest building pressure differential.

During the test it should be confirmed and recorded that the building conditions have remained stable during the test, and that temporary seals and external doors, windows, and vents have remained closed.

4.3.12 The Fan is Switched Off and Covered

When a full set of data has been recorded, the fan pressurisation system should be switched off and the fan opening re-covered. A period of 60 seconds shall be allowed before point 13 commences.

4.3.13 'Post-Test' Zero Flow Pressure Differences are Measured

Record the zero-flow pressure differences. The following average zero flow pressure differences shall be calculated:

$\Delta P_{0,2+}$ *The average of positive values*
$\Delta P_{0,2-}$ *The average of negative values*
$\Delta P_{0,2}$ *The average of all values*

Any values of 0 Pa are only to be included in the average of all values $\Delta P_{0,2}$.

When a permanently compartmentalised building is being tested the zero flow pressure differences shall be recorded for each compartment.

The zero flow pressure differences do not need to be recorded in the existing building when undertaking a co-pressurisation test of an extension.

4.3.14 'Post-Test' Internal Temperature Shall be Measured and Recorded

Internal temperature (T_{i2}) shall be measured and recorded. See advice in Section 4.3 Part 6. Temperature shall be taken to the closest single decimal place, *e.g. 12.2°C.*

4.3.15 'Post-Test' External Temperature Shall be Measured and Recorded

External temperature shall be measured and recorded (T_{e2}). Temperature shall be taken to the closest single decimal place, *e.g. 12.2°C*.

4.3.16 'Post-Test' Barometric Pressure Shall be Measured and Recorded

Barometric pressure is measured and recorded on the bottom storey of the building subject to the test. The barometric pressure shall be recorded to zero decimal place in Pa or to the closest single decimal place in hPA, *e.g. 101325Pa or 1013.3 hPa.*

4.4 Test Results

The recorded test data must be analysed and corrected in accordance with the standard equations contained within Appendix A and checked that it is technically valid in accordance with Appendix B.

For this standard the final test result is expressed as the number of air changes within the building volume to occur every hour at a building pressure differential of 50 Pa ($m^3.h^{-1}.m^{-3}$ @ 50 Pa). This is calculated by dividing the total calculated leakage flow rate (Q_{50}) by the volume of the area subject to test (V).

Both a pressurisation and depressurisation test must be carried out, and an average of the results calculated.

Section 5 – Test Report

5.1 Companies Operating Within a Competent Person Scheme

Companies that operate within a recognised Competent Person Scheme (CPS) may demonstrate competence by using a Lodgement certificate supplied by using their Competent Person Scheme Lodgement System as evidence of a test having been conducted.

Whilst Lodgement certificates are not full test reports, they provide a sufficient amount of information required for the certifier or Building Control to decide about the validity of the test.

5.1.1 Lodgement Certificate Contents

Lodgement certificates shall contain as a minimum:

a) Plot number
b) Site address
c) Tester name
d) Tester unique identifier / registration number
e) Testing company name
f) Level of competence within the CPS scheme
g) Temporary sealing applied
h) Deviations
i) Contact details of CPS, including address, contact number and email address
j) Unique certificate reference number (UCRN)
k) Building volume
l) Building envelope area
m) Date of test
n) Test standard and method adhered to
o) Air Changes results (pressurisation, depressurisation and averaged) to 2 decimal places
p) Flow Exponent (n) to 2 decimal places
q) Coefficient of Determination (r^2) to 3 decimal places

A full, compliant report in accordance with Section 5.2 may be sought by any industry stakeholder (Client, Building Control, Low Energy Building Certifier, etc.) and must be created if a request for the full report is made, subject to confidentiality clauses as necessary.

5.2 Companies which do not Operate within a Competent Person Scheme

For companies that do not operate within a Competent Person Scheme, the report shall contain at least the following information:

a) All details necessary which identify the building tested; postal address and estimated date of construction of the building.

b) A reference to this standard and any deviation from it.

c) Test object:
- Description of which parts of the building were subject to the test;
- Volume and envelope area;
- Documentation of test calculations so that the stated results can be verified;
- The general status of openings on the building envelope, latched, sealed, open, etc.;
- Detailed description of temporarily sealed openings, if any;
- The type of heating, ventilating and air conditioning system.

d) Apparatus and procedure:
- Equipment and technique employed;
- Serial number for each calibrated item of equipment used;
- Date of calibration expiry for each calibrated item of equipment used.

e) Test data for both pressurisation and depressurisation:
- Zero-flow pressure differences $\Delta P_{0,1+}$, $\Delta P_{0,1-}$, $\Delta P_{0,2+}$, $\Delta P_{0,2-}$, $\Delta P_{0,1}$ and $\Delta P_{0,2}$
  - Displayed to 1 decimal place
- Internal and external temperatures before and after the test
  - Displayed to 1 decimal place
- Barometric pressure before and after the test
  - Displayed to 0 decimal place in Pa, 1 decimal place in hPa.
- Table of building pressure differentials and measured and corrected air flow rates
  - To 1 decimal place
- Air leakage graph, with value of the coefficient of determination r^2
  - To 3 decimal places
- The air flow exponent, n
  - To 2 decimal places
- The air flow coefficient C_{env}
  - To 3 decimal places
- The air leakage coefficient C_L
- To 3 decimal places
- Air changes results
  - To 2 decimal places (pressurisation, depressurisation and averaged)
- Air permeability result
  - To 2 decimal places (pressurisation, depressurisation and averaged)

f) Date and time of test.

g) Name and address of organisation/individual carrying out the test and details.

Appendices

Appendix A - Equations and Corrections

A.1.0 Equations

A.1.1 Corrections for zero flow pressure differences

Zero flow pressure difference corrections should be applied to the observed building pressure differentials for wind and stack effects. Subtract the average zero flow pressure difference from each of the measured building pressure differentials, Δp_m, to obtain the induced building pressure differentials, Δp_{env}, using equation *1*: (The plus or minus signs should be included when undertaking this calculation)

$$\Delta p_{env} = \Delta p_m - \frac{\Delta p_{0,1} + \Delta p_{0,2}}{2} \qquad 1$$

Where $\Delta p_{0,1}$ is the average of all zero flow pressure differences at the start of the test and $\Delta p_{0,2}$ is the average of all zero flow pressure differences at the end of the test.

A.1.2 Calculation of air density

The air density, ρ, in kg.m^{-3}, at a temperature, θ, in °C and at the absolute pressure, p_{bar}, in Pa, can be obtained by equation *2.* This may be calculated as an average of temperature and absolute pressure readings taken immediately before and immediately after the test.

$$\rho = \frac{p_{bar} - 0.37802 \cdot p_v}{287.055 \times (\theta + 273.15)} \qquad 2$$

Where: $p_{v=\varphi e\left\{59.484085 - \left(\frac{6790.4985}{\theta + 273.15}\right) - 5.02802[\ln(\theta + 273.15)]\right\}}$

and, φ can be taken as 0.5 (i.e. 50% relative humidity)

A.1.3 Correction for actual and observed airflow through the measuring device

The actual flow rate Q_m through the fan is a function of the measured values at the last fan calibration and measured values during the air test.

$$Q_m = Q_c \frac{\rho_c}{\rho_m} \qquad 3$$

Where Q_m is the actual volumetric flow rate through the fan during the test, Q_c is the airflow rate from the last calibration of the fan, ρ_m is the density of air passing through the fan during the test (kg.m^{-3}) and ρ_c is the air density recorded during fan calibration.

A.1.4 Correction for internal/external air density differences

A correction is required for the internal/external density differences between air passing through the airflow measuring device and air passing through the building envelope. The correction to be applied depends on whether the building is being pressurised or depressurised.

*A.1.4.1 Corrections to airflow rate for **pressurisation** tests:*

Convert the measured airflow rate, Q_m to airflow through the building envelope, $Q_{env(out)}$, for pressurisation using equation *4*:

$$Q_{env(out)} = Q_m \frac{\rho_e}{\rho_i} \qquad 4$$

Where $Q_{env(out)}$ is the actual air flow volume out through the envelope, ρ_e is the mean external air density (kg.m^{-3}) and ρ_i is the mean internal air density (kg.m^{-3}).

*A.1.4.2 Corrections to airflow rate for **depressurisation** tests:*

Convert the measured airflow rate, Q_m, to airflow through the building envelope, $Q_{env(in)}$, for depressurisation using equation *5*:

$$Q_{env(in)} = Q_m \frac{\rho_i}{\rho_e} \qquad 5$$

Where $Q_{env(in)}$ is the actual air flow volume in through the envelope, ρ_e is the mean external air density (kg.m^{-3}) and ρ_i is the mean internal air density (kg.m^{-3}).

A.1.5 Determination of constants C and n using a least squares technique

The results from a steady state building test will give a dataset comprising of building pressure differentials (Δp_{env}) and corresponding air flow through the envelope (Q_{env}). There are several curve fitting approximations available to produce a best-fit line between these points. The most straightforward of these is the least squares approximation.

$$y = mx + b$$

Where

$$y = \ln(Q_{env})$$
$$x = \ln(\Delta p_{env})$$

The points recorded are fitted through the points $(x_1, y_1), \ldots, (x_i, y_i)$ so that the sum of the squares of the distances of those points from the straight line is minimised. The airflow rates and corresponding building pressure differentials are plotted on a log-log graph for pressurisation and depressurisation as required.

The calculation of the factors m and b for a given (de)pressurisation test are as follows:-

$$d\sum XY = \sum(ln[\Delta p_{env}] \times ln[Q_{env}]) \quad 6$$

$$d\sum XX = \sum(ln[\Delta p_{env}] \times ln[\Delta p_{env}]) \quad 7$$

$$d\sum YY = \sum(ln[Q_{env}] \times ln[Q_{env}]) \quad 8$$

$$d\sum X = \sum ln[\Delta p_{env}] \quad 9$$

$$d\sum Y = \sum ln[Q_{env}] \quad 10$$

$$m = \frac{(d\sum X \times d\sum Y) - (i \times d\sum XY)}{(d\sum X \times d\sum X) - (i \times d\sum XX)} \quad 11$$

Where

i = number of data points

$$b = \frac{(d\sum X \times d\sum XY) - (d\sum XX \times d\sum Y)}{(d\sum X \times d\sum X) - (i \times d\sum XX)} \quad 12$$

from this the air flow coefficient, C_{env}, and air flow exponent, n, are obtained:

$$C_{env} = e^b \quad 13$$

and

$$n = m \quad 14$$

A.1.6 Correction of airflow rates through the building envelope to standard temperature and pressure

The relationship is established between volumetric flow rate through the envelope and the induced building pressure differential:

$$Q_{env} = C_{env} \times \Delta p_{env}{}^{n} \quad 15$$

Where Q_{env} is the air flow rate through the building envelope ($m^3.h^{-1}$) and Δp_{env} is the induced building pressure differential, in Pa.

The air leakage coefficient, C_L, is obtained by correcting the air flow coefficient, C_{env}, to standard conditions *(i.e. 20 °C and 101,325 Pa)*.

For **pressurisation** use equation:

$$C_L = C_{env} \times \left(\frac{\rho_i}{\rho_s}\right)^{1-n} \qquad 16$$

For **depressurisation** use equation:

$$C_L = C_{env} \times \left(\frac{\rho_e}{\rho_s}\right)^{1-n} \qquad 17$$

Where ρ_i is the indoor air density (kg.m^{-3}), ρ_e is the outdoor air density (kg.m^{-3}) and ρ_s is the air density at standard conditions (kg.m^{-3})

The air leakage rate, $Q_{\Delta p_{env}}$, for a given building pressure differential, Δp_{env}, can be calculated using equation:

$$Q_{\Delta p_{env}} = C_L \times (\Delta p_{env})^n \qquad 18$$

Where C_L is the air leakage coefficient, in m^3.h^{-1}·Pa^n), Δp_{env} is the induced building pressure differential (Pa) and n is the air flow exponent.

A.1.7 Air Changes per Hour

The air change rate, N_{50}, is the air leakage rate at a building pressure differential of 50 Pa, divided by the building volume V (m^3). It defines the length of time required to completely change the volume of air within the building. Units are m^3.h^{-1}.m^{-3}. The air change is calculated using equation *19*:

$$N_{50} = \frac{Q_{50}}{V} \qquad 19$$

Where $Q_{50} = C_L \times 50^n$, from equation *18*.

A.1.8 Air permeability

The air permeability, AP_{50}, is the air leakage rate at a building pressure differential of 50 Pa, divided by the building envelope area A_E(m^2). Units are m^3.h^{-1}.m^{-2}. The air permeability is calculated using equation *20*:

$$AP_{50} = \frac{Q_{50}}{A_E} \qquad 20$$

Where $Q_{50} = C_L \times 50^n$, from equation *20*.

A.1.9 Coefficient of Determination (r^2)

The coefficient of determination (r^2) is a measure of the strength of the relationship between the observed building differential (Δp_{env}) and corresponding fan flow rates.

$$r = \left(\frac{S_{xy}}{\sqrt{\sigma^2}}\right)^2 \qquad 21$$

Where

$$\sigma^2 = [(i \times d\sum XX) - (d\sum X \times d\sum X)] \times [(i \times d\sum YY) - (d\sum Y \times d\sum Y)]$$

$$S_{xy} = (i \times d\sum XY) - (d\sum X \times d\sum Y)$$

Appendix B – Technical Validity

B.1.1 Zero-flow pressure differences

A minimum of 10 readings shall be recorded both before and after test with each set of readings being recorded over a minimum of 30 seconds.

If any of the average zero flow pressure differences (*ΔP0,1, ΔP0,1+, ΔP0,1-, ΔP0,2, ΔP0,2+ and ΔP0,2-)*, are found to be more than ±5 Pa, conditions are not suitable to undertake a valid test, and the client should be advised.

B.1.2 Building pressure differentials

Due to the instability of building pressure differentials at lower levels, the minimum measured and corrected building pressure differentials must be the greater of 10 Pa, or five times the maximum average zero flow pressure difference measured prior to the test (the greater of *ΔP0,1+, ΔP0,1-*).

Building pressure differential readings shall not be taken above 90 Pa as this may over pressurise the building and present a risk to internal finishes, the fabric of the building and temporary seals applied.

The highest building pressure differential (measured and corrected) must be greater than 50 Pa. If the highest building pressure differential achieved is less than 50 Pa, the test is not valid. Building pressure differentials taken at low pressures will be more adversely affected by environmental conditions and any conclusions drawn from such a report should be treated with caution.

Measured and corrected building pressure differentials shall be taken both above and below 50 Pa.

A minimum of 7 building pressure differential measurements must be taken, with intervals between pressures being no greater than 10 Pa. It is recommended that 10 building pressure differentials are recorded. When the difference between the lowest and highest zero flow differences recorded before the test is greater than 5 Pa a minimum of 10 building pressure differential measurements shall be recorded.

When a uniform building pressure check is undertaken the building pressure differentials shall be within ±10% of the building pressure differential recorded from the geometric centre of the building. Additional information on ways to remedy readings in excess of this can be found in Section 3.4.

B.1.3 Coefficient of Determination (r^2)

The coefficient of determination, or r^2, is indicative of the accuracy with which a curve fitting equation can be applied to a set of results. For a building air tightness test an r^2 value of greater than 0.980 must be obtained. Test results that do not attain this minimum standard figure shall be declared not valid and this may be due to adverse environmental conditions or substandard test and data collection techniques.

B.1.4 Air flow exponent (n)

The air leakage paths through a building envelope under test will consist of several cracks and holes of varying shapes and size. The constants C and n are derived from the power law relationship. The air flow exponent, n, is used to describe the airflow regime through this orifice. Values should range between 0.5 and 1.0. If the value of n is not within these limits, then the test is not valid and should be repeated.

For information, n values which approach 0.5 will have fully developed turbulent flow through the building elements and represents air flow through rather large apertures, which tend to be indicative of rather leaky structures. Values of n which approach 1.0, will indicate a more laminar like flow through the building elements and generally represent very tight structures, or those with a myriad of very tiny holes, or convoluted air leakage paths.

Appendix C - Test Equipment Requirements

C.1.0 Introduction

The requirements for the accuracy of measurements are based primarily around BS EN ISO 9972:2015 - 'Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method'.

Any readings taken outside of the calibrated ranges of the instruments shall not form part of the test data and may require the test to be undertaken again.

C.2.0 Accuracy

The following is a list of the required measurements and tolerances:

C.2.1 Building Pressure Differential Measurement (micromanometer)

An instrument capable of measuring pressure differentials with an accuracy of ±2 Pa in the range of -100 to 100 Pa. *Note: ISO 9972:2015 states that the pressure measuring device is capable of measuring pressure with an accuracy of ±1 Pa in the range of 0 Pa to 100 Pa.*

C.2.2 Air Flow Rate Measurement

The device must measure the air flow rate to within ± 7 % of the reading. The reading of the air flow rate shall be corrected according to air density in accordance with Section A.1.3.

C.2.3 Temperature Measurement devices

The accuracy of temperature measurement must have an accuracy of ±1.0 °C within the range of -20.0 to 40.0 °C. *Note: ISO 9972:2015 states that the temperature measuring device is capable of measuring temperature with an accuracy of ±0.5 K.*

C.2.4 Barometric Pressure

A barometer must have an accuracy of ± 5 hPA in the range 950 - 1050 hPA.

C.3.0 Resolution

The resolution of an instrument is a factor which contributes to uncertainty in a measurement. It is therefore a consideration when selecting the suitability of an instrument used for testing. *i.e. for a micromanometer, which is used to measure zero flow pressures typically in the range of ±5 Pa, must have a resolution of 0.1 Pa rather than 1Pa as the resolution uncertainty is 0.05 Pa rather than 0.5 Pa.*

C.4.0 Calibration

All instrumentation must be calibrated in accordance with national requirements to the following specification by a laboratory that is accredited by a national accreditation body that is a signatory of the ILAC mutual recognition arrangement. All calibration certificates must bear the logo of the accreditation body, with laboratory number, and ILAC logo to be considered acceptable. Note that a confirmation of performance is not compliant and cannot be treated as such.

The flow measurement device will require to be calibrated against a recognised test procedure. Such test procedures will have to satisfy national requirements.

There are two standards worthy of reference, BS ISO 3966:2020 'Measurement of fluid flow in closed conduits. Velocity area method using Pitot static tubes' and BS 848-1:1997 (ISO 5801:2017) 'Industrial fans. Performance testing using standardized airways', or later.

It will also be a requirement for companies accredited through national accreditation schemes to calculate estimates of uncertainty for not only the individual parameters but also a final uncertainty budget from the square root of the sum of the squares of the standard deviation of each source of uncertainty.

Appendix D - Equivalent Leakage Area (ELA)

D.1.0 Approximate leakage surface area

It is often useful for the test engineer to translate the results of an air leakage test into a more readily understandable form such as an equivalent leakage area, A (m^2). Area of 'holes' left in the structure can be a useful guide, but it is only an aerodynamic equivalent area based on a sharp-edged orifice and should therefore be regarded as approximate.

The flow rate of air can be expressed by:

$$Q_{\Delta p_{env}} = C_d \times A \times \left(\frac{2 \times \Delta p_{env}}{\rho_s}\right)^n \qquad 22$$

Where:

The discharge coefficient, C_d for a sharp-edged orifice can be taken as 0.61, standard air density ρ_s is taken as 1.20 $kg.m^{-3}$, n can be taken as 0.5, the test pressure is 50 Pa, and Q_{50} is in $m^3.s^{-1}$, which allows equation to be simplified and rearranged to:

$$A = \frac{Q_{50}}{5.57} \qquad 23$$

Most buildings do not exhibit an air flow exponent (*n*) of 0.5 because the air leakage paths can be long and convoluted, etc. and as such the above equation is only approximate.

The above should be treated with extreme caution since 'holes' in buildings tend to look considerably larger than they actually are, since the other side of the 'hole' may have a tortuous exit route or be occluded by a hidden membrane.

The equivalent leakage area should only be used as a guide for remedial measures and not to determine the final air permeability value.

Appendix E – Software verification process

E.1.0 Introduction

To verify custom test software, the following readings and calibration data have been provided, along with the result. This can provide a method of checking that the software is working, particularly after software upgrades, this data shall be entered, and the result verified. If this test data is inappropriate for checking new/upgraded software, then the software algorithms should be checked manually using a different method such as a spreadsheet or by hand.

There are 4 ways that the test can be set up:

1. Pressurisation test with the fan reference tube inside the building
2. Pressurisation test with the fan reference tube outside the building
3. Depressurisation test with the fan reference tube inside the building
4. Depressurisation test with the fan reference tube outside the building

This verification provides figures for each method.

E.2.0 Data – Fan Calibration

Static Pressure (Pa)	Flow Pressure (Pa)	Volume Flow ($m^3.s^{-1}$)	Exponent	Coefficient ($m^3.s^{-1}$)
-50.5	260.2	1.2803	0.482111	0.087691
-50.5	175.4	1.0589		
-50.6	133.3	0.9278		
-50.2	90.9	0.7713		
-50.3	50.4	0.5803		

Calibration Air Density for Volume Flow ($kg.m^{-3}$)
1.200

E.3.0 Test Data – Common to All Methods

Building Tested Details	
Envelope Area	367.0 m^2
Volume	332.0 m^3

Environmental Readings	Before	After
Temperature Internal (°C)	15.0	13.0
Temperature External (°C)	10.0	10.0
Barometric Pressure (Pa)	99400	99400

Zero Flow Pressure Readings (Pa)										
Before	0.6	0.4	0.3	0.1	-0.6	0.6	0.0	0.1	0.0	0.2
After	0.8	1.4	2.0	1.2	0.4	2.4	1.6	1.4	1.8	0.8

Zero Flow Pressure Averages	Before ($\Delta P_{0,1}$)	After ($\Delta P_{0,2}$)
Positive Readings	0.33	1.38
Negative Readings	-0.6	0.00
All Readings	0.17	1.38

E.4.0 Data – Pressurisation Test

Test Type	Channel A		Channel B	
	Input +	Ref -	Input +	Ref -
Pressurise	○ Inside	○ Outside	○ Fan	○ Outside
	Building Pressure (+)		Flow Pressure (-)	

Reading	Building Pressure (Pa)	Flow Pressure (Pa)	Corrected Flow $Q_{env(out)}$ ($m^3.h^{-1}$)
1	57.4	-245.0	4,470
2	56.9	-232.0	4,354
3	52.6	-227.0	4,308
4	50.6	-211.0	4,159
5	49.5	-201.5	4,068
6	46.1	-187.0	3,924
7	40.6	-153.0	3,562
8	34.7	-130.0	3,293
9	30.7	-108.0	3,012
10	25.1	-91.0	2,773

Results	
Air Flow Coefficient (C_{env})	425.45 $m^3.h^{-1}\cdot Pa^n$
Air Leakage Coefficient (C_L)	425.96 $m^3.h^{-1}\cdot Pa^n$
Air Flow Exponent (n)	0.581
Coefficient of Determination (r^2)	0.993
Flow at 50 Pa (Q_{50})	4,141 $m^3.h^{-1}$

Air Permeability (AP_{50})	11.28 (±0.2%)
Air Changes Per Hour (N_{50})	12.47 (±0.2%)

E.5.0 Data – Depressurisation Test

Test Type	Channel A		Channel B	
	Input +	Ref -	Input +	Ref -
Depressurise	○ Inside	○ Outside	○ Fan	○ Inside
	Building Pressure (-)		Flow Pressure (-)	

Reading	Building Pressure (Pa)	Flow Pressure (Pa)	Corrected Flow $Q_{env(in)}$ ($m^3.h^{-1}$)
1	-74.0	-252.1	4,466
2	-69.2	-240.5	4,365
3	-64.3	-220.0	4,182
4	-59.7	-195.0	3,945
5	-56.2	-172.4	3,718
6	-50.7	-162.0	3,608
7	-45.3	-123.0	3,159
8	-41.4	-124.0	3,172
9	-36.1	-100.7	2,869
10	-32.9	-87.0	2,674

Results	
Air Flow Coefficient (C_{env})	270.10 $m^3.h^{-1}\cdot Pa^n$
Air Leakage Coefficient (C_L)	271.75 $m^3.h^{-1}\cdot Pa^n$
Air Flow Exponent (n)	0.653
Coefficient of Determination (r^2)	0.989
Flow at 50 Pa (Q_{50})	3,494 $m^3.h^{-1}$

Air Permeability (AP_{50})	9.52 (±0.2%)
Air Changes Per Hour (N_{50})	10.53 (±0.2%)

Appendix F – Checklists

F.1.0 Building Condition Requirements (initial sealing works)

Step	Description	Completed?
1	Drainage traps are temporarily sealed for the test.	
2	Incoming or outgoing service penetrations have been made and have permanent sealing works completed around the penetrations.	
3	External doors, including integral garage doors, are fitted with seals and closed as necessary.	
4	External windows are fitted with seals and closed as necessary.	

F.2.0 Building Condition Requirements (stage 2)

Step	Description	Completed?
1	All drainage traps are filled with water.	
2	Incoming or outgoing service penetrations have been made and have permanent sealing works completed around the penetrations.	
3	External doors, including integral garage doors, are fitted with seals and closed as necessary.	
4	External windows are fitted with seals and closed as necessary.	
5	Electrical items such sockets must be fitted to the wall without items plugged in, other than for the operation of the fan pressurisation system.	
6	Light switches shall be fitted to the wall.	
7	Internal doors are restrained open and remain open for the test.	

F.3.0 Building Condition Requirements (stage 3)

Step	Description	Completed?
1	All drainage traps are filled with water.	
2	Incoming or outgoing service penetrations have been made and have permanent sealing works completed around the penetrations.	
3	External doors, including integral garage doors, are fitted with seals and closed as necessary.	
4	External windows are fitted with seals and closed as necessary.	
5	Electrical items such sockets must be fitted to the wall without items plugged in, other than for the operation of the fan pressurisation system.	
6	Light switches shall be fitted to the wall.	
7	Lighting shall be fitted in the ceilings.	
8	Internal doors are restrained open and remain open for the test.	
9	Heating systems shall be installed.	
10	Ventilation systems shall be installed.	
11	Kitchen units shall be installed	