Report on the Preliminary Air Leakage Testing of two maisonettes in Erneley Close, Manchester, being refurbished to the EnerPHit standard, in compliance with ATTMA TSL1 (2010)

Results: Satisfactory

Site address: **Erneley Close, Longsight, Manchester M12 5RB**

Test Reference No.:		**JALDAS5084/R1**	
Test Dates:		**14th & 15th January 2014**	
Testing carried out for:	**Client:**	**Tony Doran, Casey Construction**	
Testing carried out by:	**Test Engineer:**	**Paul Jennings**	
	Company:	**Aldas**	
	Contact Tel:	**01452 532878 / 07866 948200**	
	Contact E-mail:	**Doorfanman@hotmail.com**	
Property No.:		**18**	**3**
Target Air Changes, ACH^{-1} @ 50 Pa:		**< 1.05 (EnerPHit)**	
Achieved Air Changes, ACH^{-1} @ 50 Pa:		**1.03**	**0.94**
Achieved Air Permeability, $m^3/hr/m^2$ @ 50 Pa:		**0.83**	**0.79**
Data consistency, r^2 (requirement, $r^2 \geq 0.98$):		**0.999**	**0.998**
Slope, n (requirement, $0.5 \leq n \leq 1.0$):		**0.74**	**0.76**

ALDAS, 54 Melville Road, Churchdown, Gloucester GL3 2RG
Aldas is a trading name of Jennings Aldas Limited, Co. Reg 8409614
01452 532878 Director: Clare Corley 07528 599684
Air Leakage Specialist: Paul Jennings, BSc, MSc doorfanman@hotmail.com 07866 948200

Introduction & Set-Up:

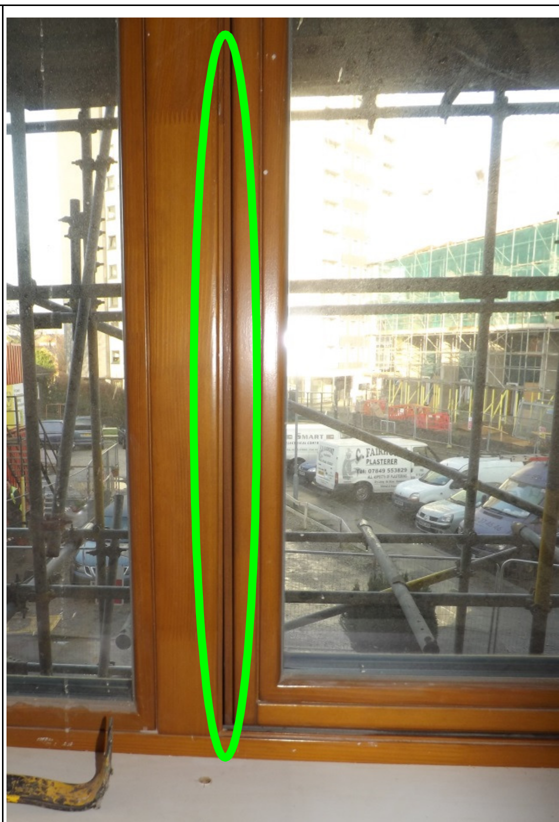
Preliminary air leakage testing of two of the ground floor maisonettes in Erneley Close, South Manchester, which are being refurbished to the EnerPHit standard, was carried out on the 14th and 15th of January 2014, following a previous visit to site on the 16th December last year. In all cases, testing was carried out using a Retrotec 3000SR high-power fan mounted in the front entrance door of each property.

Testing was carried out in accordance with the requirements of BS EN 13829 and the BINDT Quality Procedure, in conformance with the ATTMA TSL1 standard (2010), Method B, and the requirements of the PassivHaus Institute, in particular that dwellings are both pressurised and depressurised and the results averaged. Any queries or complaints about this test should be addressed in the first instance to the test engineer and in the second instance to BINDT.

BINDT contact details: Newton Building, St. George's Avenue, Northampton NN2 6JB
Tel: 01604 893860 www.bindt.org

All external doors and windows, other than that where the test equipment was mounted, were shut for the duration of testing. One damaged window awaiting repair in No. 3 was temporarily sealed for the testing, as were the back doors to both dwellings, which clearly require adjustment to achieve their most effective seal. Waste and other services were incomplete and where fitted were temporarily sealed for the duration of testing, the exception being the shower trap where water was added. The pictures below illustrate key parts of the equipment and test set-up used:

P3) Test equipment mounted in front doorway



P4) Damaged window in No. 3 was sealed for test

P5) Top of incomplete pipe sealed for test

Measurement Procedures:

Test procedures in accordance with the following standards: ATTMA TSL1, 2010, Method B. After a series of single-point preliminary depressurisation tests and extensive leakage checking, whilst further remedial sealing works were carried out, each maisonette achieved a near-satisfactory result and a full multi-point depressurisation test was then carried out. This was followed by a full multi-point pressurisation test, as required by the PassivHaus Institute.

The Envelope Area and Volume were calculated for each dwelling by the test engineer from measurements made directly on site. **Based upon:** BS EN 13829:2001. Because the internal partitions and surfaces were incomplete these are provisional values and will have to be checked and recalculated for the final acceptance test in each maisonette.

Dwelling	Envelope area m^2 (ATTMA conventions)	Volume m^3 (PHI conventions)
No. 18 Erneley Close	**193.0**	**155.9**
No. 3 Erneley Close	**192.4**	**161.7**

Measurements Recorded:

Averages of zero flow pressure differentials were recorded before and after each test, as were internal and external temperatures, windspeed and barometric pressure.

Equipment Calibration:

All test equipment and accessories are calibrated. The table below provides details of the equipment and the calibration validity for each:

Retrotec 3000SR Blower Unit	Serial No: PH001057	Expires 15th April 2014
Retrotec DM2A Digital Gauge	Serial No: 102036	Expires 15th April 2014
Testo 511 Digital Barometer	Serial No: 39107531/301	Expires 6th June 2014
Testo 110 Digital Thermometer	Serial No: 33949361/208	Expires 9th June 2014

No. 18 Erneley Close - Depressurisation Test

Numerous leakage sites were identified during the extensive leakage investigations carried out during the day. Because the initial readings were unsatisfactory by a significant margin, single-point depressurisation testing was initially carried out, with the full multipoint depressurisation test only being carried out once the sealing works had improved the dwelling to a near-satisfactory level. After the satisfactory multi-point depressurisation test was completed, the additional multi-point pressurisation test required for PassivHaus conformance was also undertaken.

Date: **14th January 2014** Time: **2.37 pm** to **2.54 pm**

Environmental Conditions:

Barometric Pressure:	**100.4**	KPa	Wind speed:	**1.0 m/s**
Temperature: Initial:	indoors	**8°C**	outdoors	**9°C**
Final:	indoors	**8°C**	outdoors	**9°C**

Test Data:

At least **3** static pressures taken for **10** sec each.
A minimum of **10** induced pressures taken for >**20** sec each.

Existing Pressure Differentials (Static pressure):

Baseline, initial [Pa]	-0.2	+0.2	-0.1	-0.2	-0.2	-0.1
Baseline, final[Pa]	-0.3	-0.4	-0.1	-0.4	-0.5	-0.3

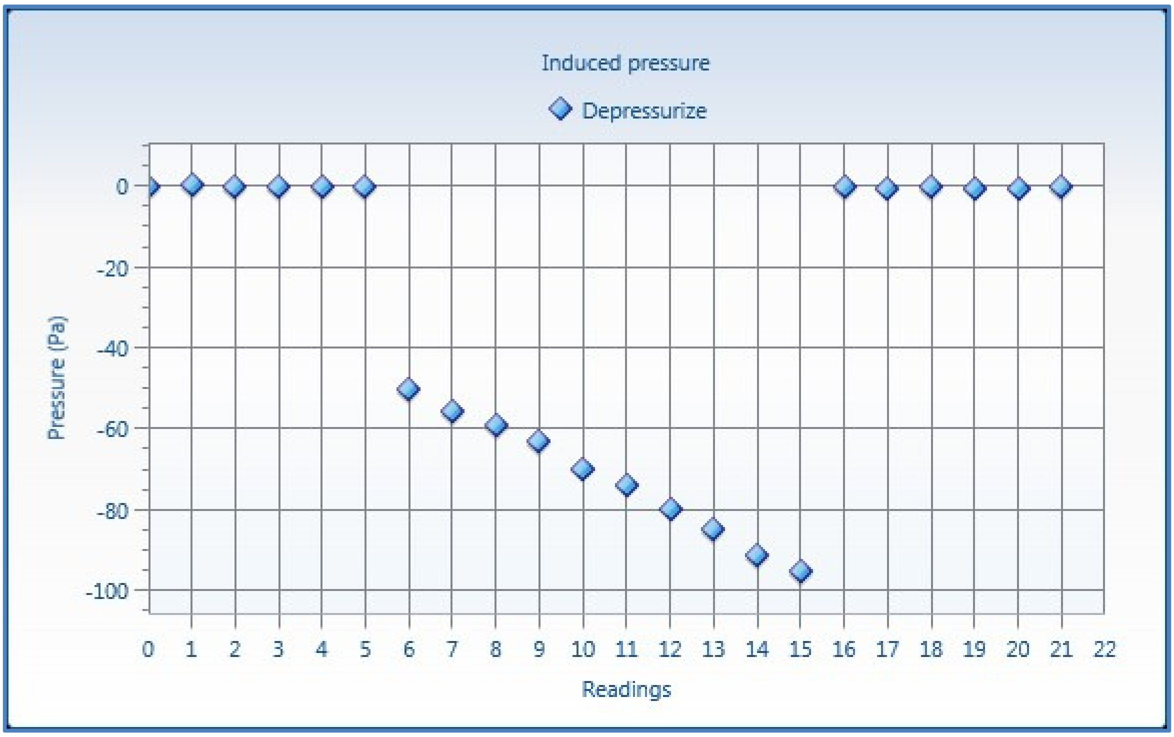
Static Pressure Averages:	initial [Pa]	ΔP_{01}	**-0.10**	ΔP_{01-}	**-0.16**	ΔP_{01+}	**+0.20**
	final [Pa]	ΔP_{02}	**-0.33**	ΔP_{02-}	**-0.33**	ΔP_{02+}	**+0.00**

Results:

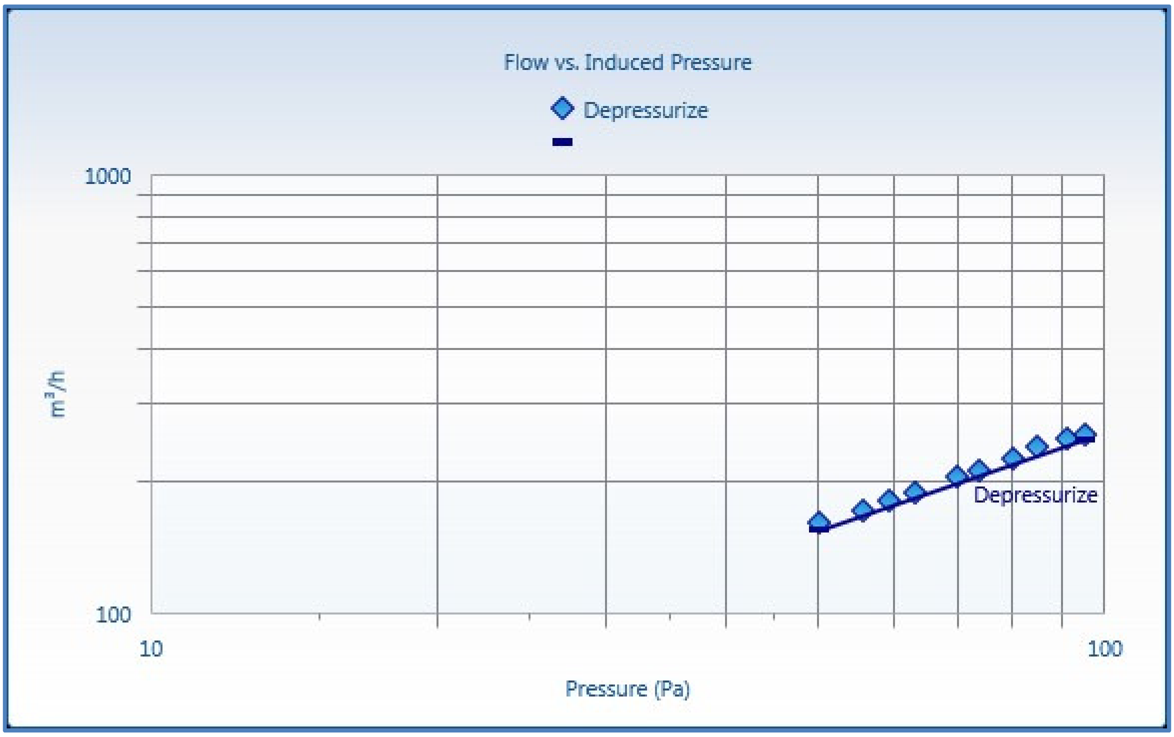
All results are compared to the standards set in Building Regulations 'Approved Document L1A – Conservation of fuel and power in new dwellings (2010)'. Results are calculated using the formula set out in ATTMA TSL1 (Section 3.2). Readings collected are detailed below:

Reading:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Induced Pressure [Pa]	-50.4	-55.9	-59.5	-63.5	-70.1	-74.1	-80.1	-85.1	-91.7	-95.7
Total flow, Q_r [m^3/h]	161.3	172.7	180.5	189.6	205.2	211.6	225.1	240.0	251.3	256.7
Corrected flow, Q_{env} [m^3/h]	156.3	167.4	175.0	183.8	198.8	205.1	218.2	232.6	243.6	248.8
Error [%]	+0.7%	-0.2%	-0.3%	-0.3%	+0.2%	-0.8%	-0.5%	+1.4%	+0.5%	-0.6%

G1: Graph of imposed pressure differentials, depressurisation:



G2: Graph of imposed pressure differential against airflow, depressurisation:



Depressurisation Test Results

	Results		
Correlation, r^2	**0.999**	95% confidence limits	
Intercept, C_{env} [$m^3/h.Pa^n$]	**8.44**	**7.56**	**9.42**
Slope, n	**0.74**	**0.72**	**0.77**

	Results	Uncertainty
Air flow at 50 Pa, Q_{50} [m^3/h]	**156.0**	**±1.1%**
Permeability at 50 Pa, AP_{50} [$m^3/h.m^2$]	**0.81**	**±1.2=-%**
Equivalent leakage area at 50 Pa [m^2]	**0.0078**	**±1.0%**
Air changes, n_{50}	**1.00**	**±1.2%**

No. 18 Erneley Close - Pressurisation Test

After extensive leak checking and remedial sealing, a satisfactory multi-point depressurisation test was achieved. A multi-point pressurisation test, as required for PassivHaus conformance, was then undertaken.

Date: **14th January 2014** Time: **3.00 pm** to **3.15 pm**

Environmental Conditions:

Barometric Pressure:	**100.4**	KPa	Wind speed:	**1.0 m/s**
Temperature: Initial:	indoors	**8°C**	outdoors	**9°C**
Final:	indoors	**8°C**	outdoors	**9°C**

Test Data:

At least **3** static pressures taken for **10** sec each.
A minimum of **10** induced pressures taken for ≥**20** sec each.

Existing Pressure Differentials (Static pressure):

Baseline, initial [Pa]	-0.3	-0.4	-0.1	-0.4	-0.5	-0.3
Baseline, final[Pa]	-0.2	-0.5	-0.4	-0.3	-0.2	-0.3

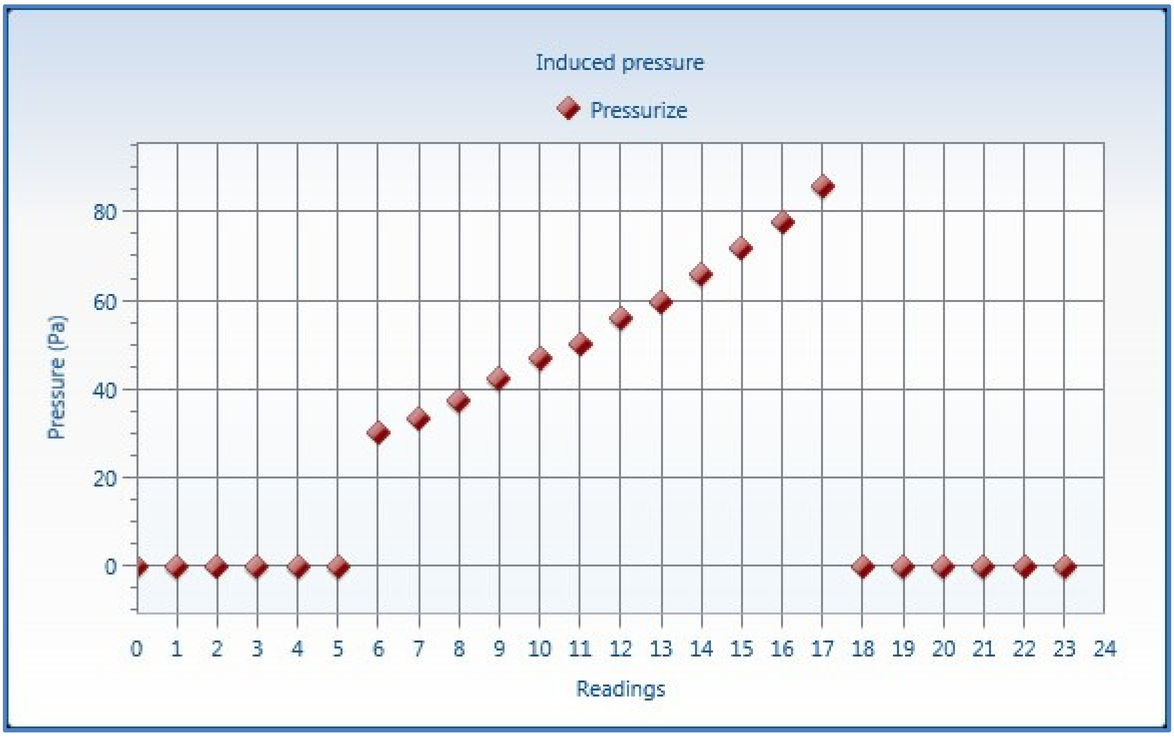
Static Pressure Averages:	initial [Pa]	ΔP_{01}	**-0.33**	ΔP_{01-}	**-0.33**	ΔP_{01+}	**+0.00**
	final [Pa]	ΔP_{02}	**-0.32**	ΔP_{02-}	**-0.32**	ΔP_{02+}	**+0.00**

Results:

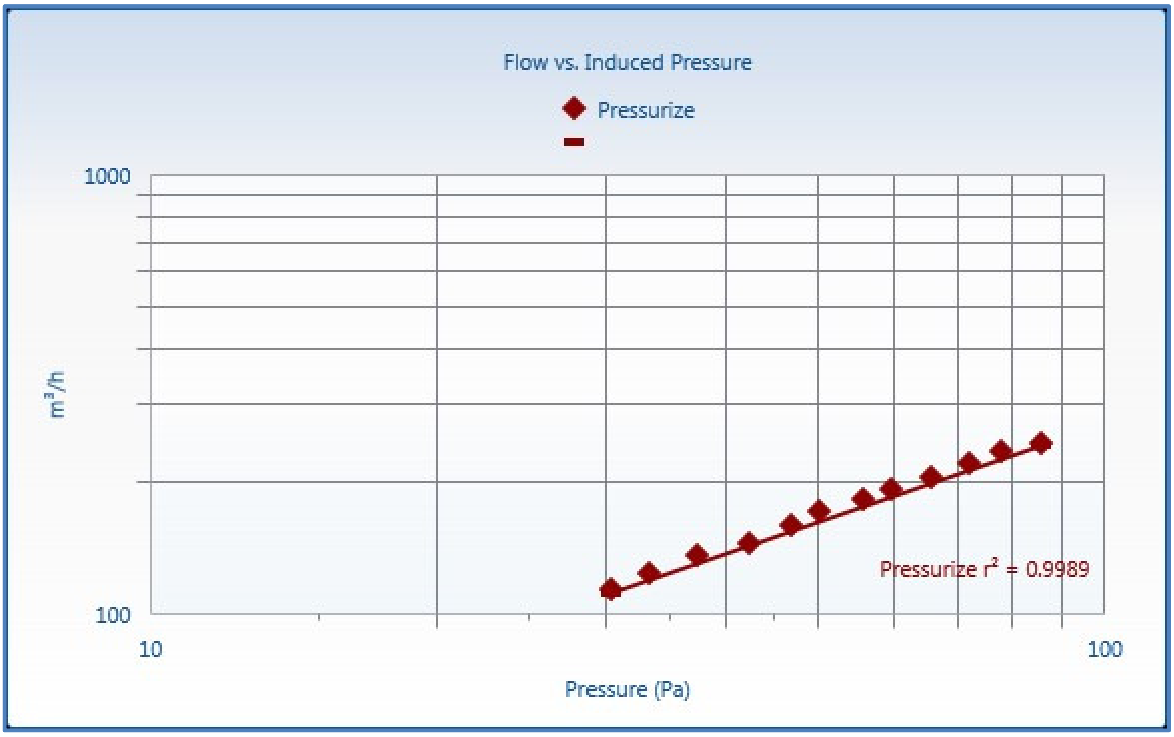
All results are compared to the standards set in Building Regulations 'Approved Document L1A – Conservation of fuel and power in new dwellings (2010)'. Results are calculated using the formula set out in ATTMA TSL1 (Section 3.2). Readings collected are detailed below:

Reading:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Induced Pressure [Pa]	30.0	33.0	37.0	41.9	46.4	49.9	55.4	59.5	65.5	71.5	77.5	85.5
Total flow, Q_r [m^3/h]	114.1	123.9	137.1	146.0	159.4	171.4	183.9	193.7	206.1	220.5	234.9	246.2
Corrected flow, Q_{env} [m^3/h]	110.4	119.9	132.7	141.3	154.2	165.8	177.9	187.3	199.3	213.4	227.2	238.2
Error [%]	-1.4%	-0.2%	+1.5%	-1.5%	-0.3%	+1.6%	+0.9%	+0.9%	-0.1%	+0.2%	+0.5%	-2.1%

G3: Graph of imposed pressure differentials, pressurisation:



G4: Graph of imposed pressure differential against airflow, pressurisation:



Pressurisation Test Results

	Results		
Correlation, r^2	**0.999**	95% confidence limits	
Intercept, C_{env} [$m^3/h.Pa^n$]	**8.83**	**8.00**	**8.83**
Slope, n	**0.74**	**0.72**	**0.74**

	Results	Uncertainty
Air flow at 50 Pa, Q_{50} [m^3/h]	**164.0**	**±0.8%**
Permeability at 50 Pa, AP_{50} [$m^3/h.m^2$]	**0.85**	**±1.0%**
Equivalent leakage area at 50 Pa [m^2]	**0.0082**	**±0.8%**
Air changes, n_{50}	**1.05**	**±0.9%**

Combined Test Data

	Results	Uncertainty
Air flow at 50 Pa, V_{50} [m^3/hr]	**160.0**	**+0.9%**
Permeability at 50 Pa, Q_{50} [m^3/h.m^2]	**0.83**	**+1.0%**
Equivalent leakage area at 50 Pa [m^2]	**0.0080**	**+0.9%**
Air changes, n_{50}	**1.03**	**+1.1%**
Average correlation, r^2	**0.999**	**n/a**
Average intercept, C_{env} [m^3/h.Pa^n]	**8.63**	**n/a**
Average slope, n	**0.74**	**n/a**

Conclusions:

The air leakage results achieved in the preliminary air leakage testing of No. 18 Erneley Close in Manchester were an Air Change Rate of 1.03 ACH^{-1} @ 50 Pa and an Air Permeability of 0.83 m^3/hr/m^2 @ 50 Pa. The Air Change Rate currently meets the EnerPHit (PassivHaus for refurbishment) airtightness target of an Air Change Rate of < 1.05 ACH^{-1} by a tiny margin, which is nevertheless a good result. A larger margin would of course be preferable, to provide security against possible, even likely, deterioration of the airtightness of the building fabric as the building services are completed and commissioned.

Hence we recommend that further sealing works be carried to eliminate known leakage as far as possible. In particular:

- the back door needs adjusting to seal effectively;
- residual leakage around the edge of the ground floor should be eliminated, which probably requires the application of another tape seal, as carried out in number 3;
- remaining unsealed areas of paramount partitioning need to be addressed, particularly adjacent to the stairs where the sealing of hidden brickwork is problematic

If any further areas of leakage are identified during additional investigations, such as were found in No. 3 – e.g. damaged sealing to the timber pattress at the top of the soil stack – these should also be addressed.

The Air Permeability is however already better than the Building Regulations maximum for newbuild properties (reduced to 5.0 m^3/hr/m^2 @ 50 Pa in last year's revision) by a considerable degree.

Further comments regarding the leakage found more generally at Erneley Close, and the actions and strategy we consider necessary to address it successfully, are provided in the final two sections of this report, ***Leakage Investigations*** and ***Recommendations***.

No. 3 Erneley Close - Depressurisation Test

Numerous leakage sites were identified during the extensive leakage investigations carried out on both days. Because the initial readings were unsatisfactory by a significant margin, single-point depressurisation testing was initially carried out, with the full multipoint depressurisation test only being carried out once the sealing works had improved the dwelling to a near-satisfactory level. After the satisfactory multi-point depressurisation test was completed, the additional multi-point pressurisation test required for PassivHaus conformance was also undertaken.

Date: **15th January 2014** Time: **3.30 pm** to **3.48pm**

Environmental Conditions:

Barometric Pressure:	**100.4**	KPa	Wind speed:	**1.0 m/s**
Temperature: Initial:	indoors	**13°C**	outdoors	**9°C**
Final:	indoors	**13°C**	outdoors	**10°C**

Test Data:

At least **3** static pressures taken for **10** sec each.
A minimum of **10** induced pressures taken for ≥**20** sec each.

Existing Pressure Differentials (Static pressure):

Baseline, initial [Pa]	0.0	-0.1	+0.2	+0.4	+0.4	+0.1
Baseline, final[Pa]	+0.3	+0.4	+0.1	-0.2	+0.3	0.0

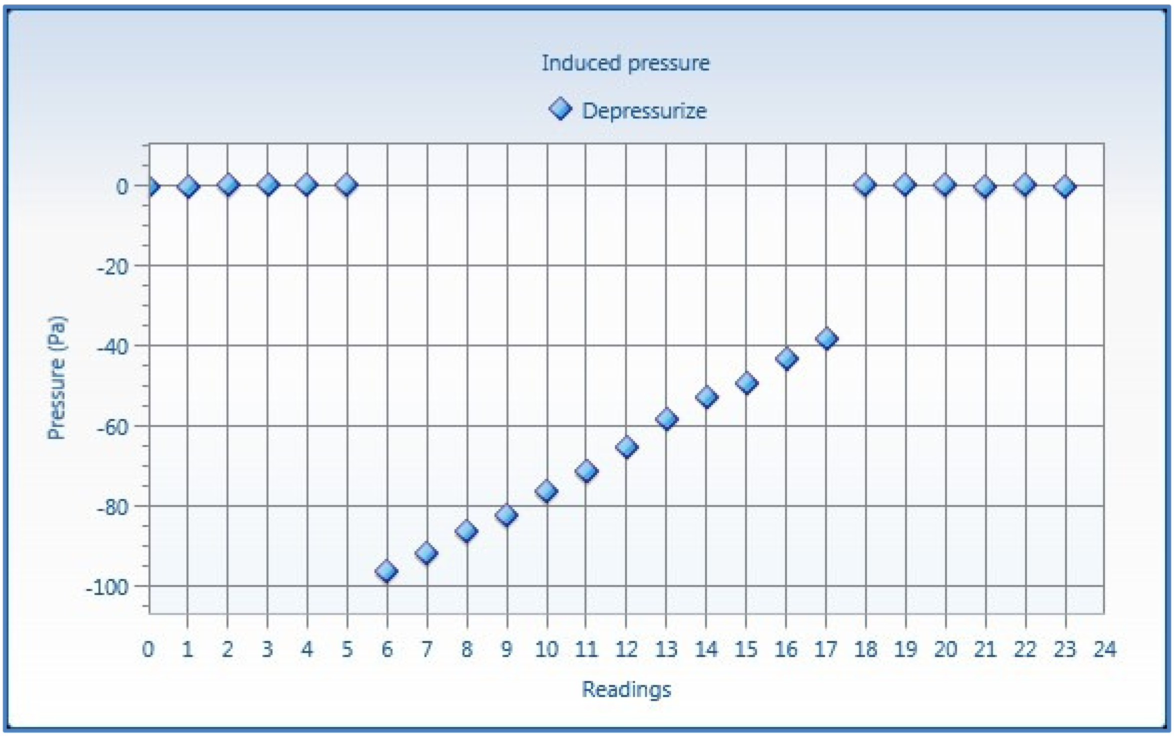
Static Pressure Averages:	initial [Pa]	ΔP_{01}	**+0.17**	ΔP_{01-}	**-0.10**	ΔP_{01+}	**+0.22**
	final [Pa]	ΔP_{02}	**+0.15**	ΔP_{02-}	**-0.20**	ΔP_{02+}	**+0.22**

Results:

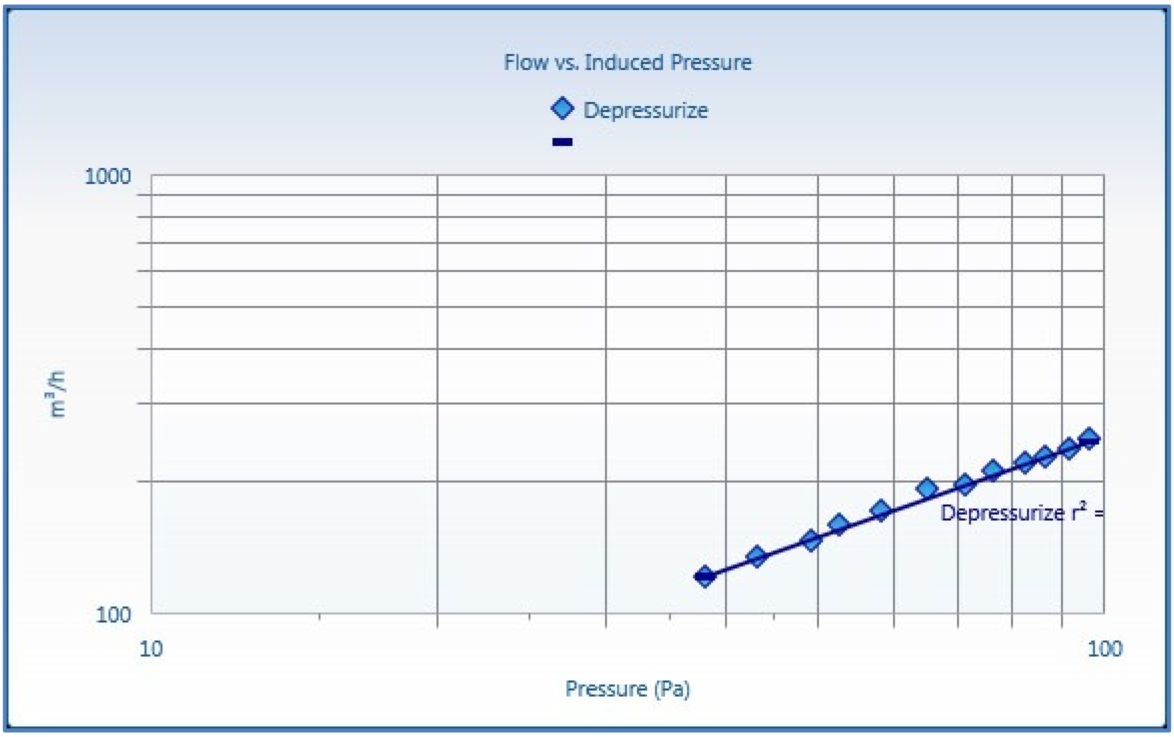
All results are compared to the standards set in Building Regulations 'Approved Document L1A – Conservation of fuel and power in new dwellings (2010)'. Results are calculated using the formula set out in ATTMA TSL1 (Section 3.2). Readings collected are detailed below:

Reading:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Induced Pressure [Pa]	-96.2	-91.7	-86.1	-82.1	-76.1	-71.1	-65.0	-58.0	-52.4	-48.9	-42.9	-37.9
Total flow, Q_r [m^3/h]	249.8	237.3	229.0	220.3	211.5	197.1	192.7	172.8	160.6	147.0	134.8	121.5
Corrected flow, Q_{env} [m^3/h]	246.5	234.2	226.0	217.3	208.7	194.5	190.2	170.5	158.4	145.1	133.0	119.9
Error [%]	-0.2%	-1.7%	-0.5%	-0.8%	+0.9%	-0.9%	+3.7%	+1.5%	+1.8%	-1.7%	-0.5%	-1.5%

G5: Graph of imposed pressure differentials, depressurisation:



G6: Graph of imposed pressure differential against airflow, depressurisation:



Depressurisation Test Results

	Results		
Correlation, r^2	**0.998**	95% confidence limits	
Intercept, C_{env} [$m^3/h.Pa^n$]	**7.57**	**6.46**	**8.86**
Slope, n	**0.76**	**0.73**	**0.80**

	Results	Uncertainty
Air flow at 50 Pa, Q_{50} [m^3/h]	**150.0**	**±1.5%**
Permeability at 50 Pa, AP_{50} [$m^3/h.m^2$]	**0.78**	**±1.6%**
Equivalent leakage area at 50 Pa [m^2]	**0.0075**	**±1.5%**
Air changes, n_{50}	**0.93**	**±1.6%**

No. 3 Erneley Close - Pressurisation Test

After the satisfactory multi-point depressurisation test, a multi-point pressurisation test, as required for PassivHaus conformance, was also undertaken.

Date: **15th January 2014** Time: **3.49 pm** to **4.10 pm**

Environmental Conditions:

Barometric Pressure:	**100.4**	KPa	Wind speed:	**1.0 m/s**
Temperature: Initial:	indoors	**13°C**	outdoors	**9°C**
Final:	indoors	**13°C**	outdoors	**10°C**

Test Data:

At least **3** static pressures taken for **10** sec each.
A minimum of **10** induced pressures taken for **≥20** sec each.

Existing Pressure Differentials (Static pressure):

Baseline, initial [Pa]	+0.3	+0.4	+0.1	-0.2	+0.3	0.0
Baseline, final[Pa]	+0.9	+0.8	+0.7	+0.3	+0.9	+0.7

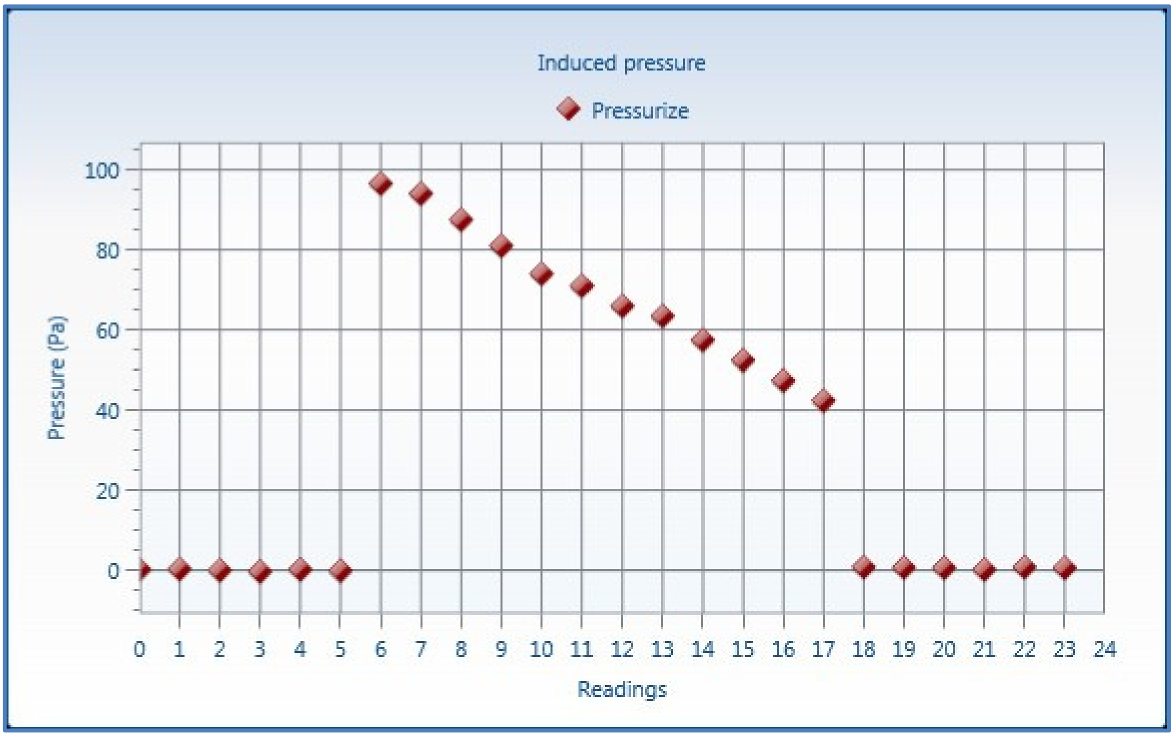
Static Pressure Averages:	initial [Pa]	ΔP_{01}	**+0.17**	ΔP_{01-}	**-0.10**	ΔP_{01+}	**+0.22**
	final [Pa]	ΔP_{02}	**+0.62**	ΔP_{02-}	**-0.00**	ΔP_{02+}	**+0.62**

Results:

All results are compared to the standards set in Building Regulations 'Approved Document L1A – Conservation of fuel and power in new dwellings (2010)'. Results are calculated using the formula set out in ATTMA TSL1 (Section 3.2). Readings collected are detailed below:

Reading:	**1**	**2**	**3**	**4**	**5**	**6**	**7v**	**8**	**9**	**10**	**11**	**12**
Induced Pressure [Pa]	97.1	94.6	88.0	81.5	74.5	71.5	66.5	64.0	58.0	52.9	47.9	42.9
Total flow, Q_r [m^3/h]	253.9	245.7	233.3	220.3	206.8	202.1	192.5	182.1	173.4	159.3	147.2	134.1
Corrected flow, Q_{env} [m^3/h]	254.3	246.1	233.6	220.6	207.0	202.4	192.8	182.3	173.6	159.5	147.4	134.3
Error [%]	+0.4%	-0.9%	-0.6%	-0.5%	0.0%	+0.9%	+1.6%	-1.1%	+1.6%	0.0%	-0.2%	-1.1%

G7: Graph of imposed pressure differentials, pressurisation:



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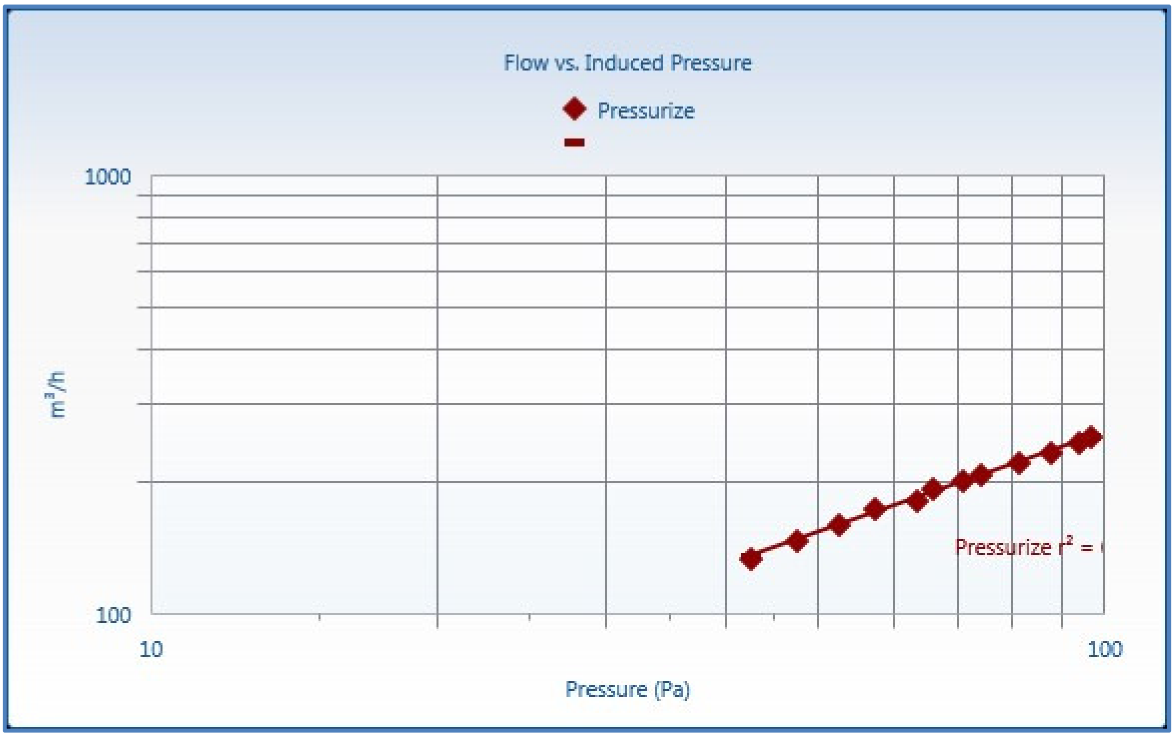
G8: Graph of imposed pressure differential against airflow, pressurisation:



Pressurisation Test Results

	Results		
Correlation, r^2	**0.999**	95% confidence limits	
Intercept, C_{env} [m^3/h.Pa^n]	**7.90**	**7.11**	**7.90**
Slope, n	**0.76**	**0.73**	**0.76**

	Results	Uncertainty
Air flow at 50 Pa, Q_{50} [m^3/h]	**153.5**	**±1.0%**
Permeability at 50 Pa, AP_{50} [m^3/h.m^2]	**0.80**	**±1.1%**
Equivalent leakage area at 50 Pa [m^2]	**0.0077**	**±1.0%**
Air changes, n_{50}	**0.95**	**±1.1%**

Combined Test Data

	Results	Uncertainty
Air flow at 50 Pa, V_{50} [m^3/hr]	**152.0**	**±1.2%**
Permeability at 50 Pa, Q_{50} [m^3/h.m^2]	**0.79**	**±1.0%**
Equivalent leakage area at 50 Pa [m^2]	**0.0076**	**±1.2%**
Air changes, n_{50}	**0.94**	**±1.1%**
Average correlation, r^2	**0.998**	**n/a**
Average intercept, C_{env} [m^3/h.Pa^n]	**7.73**	**n/a**
Average slope, n	**0.76**	**n/a**

Conclusions:

The air leakage results achieved in the preliminary air leakage testing of No. 3 Erneley Close in Manchester were an Air Change Rate of 0.95 ACH^{-1} @ 50 Pa and an Air Permeability of 0.79 $m^3/hr/m^2$ @ 50 Pa. The Air Change Rate currently meets the EnerPHit (PassivHaus for refurbishment) airtightness target of an Air Change Rate of < 1.05 ACH^{-1} by some margin, and is an excellent result. A larger margin would of course be preferable, to provide security against possible, even likely, deterioration of the airtightness of the building fabric as the building services are completed and commissioned.

Hence we recommend that further sealing works be carried to eliminate known leakage as far as possible. In particular:

- the back door needs adjusting seal effectively;
- there is considerable leakage through a double electrical socket in the kitchen party wall;
- and there clearly remains some leakage through the soil stack, as made plain by the smells of drains in the hall when the maisonette is depressurised

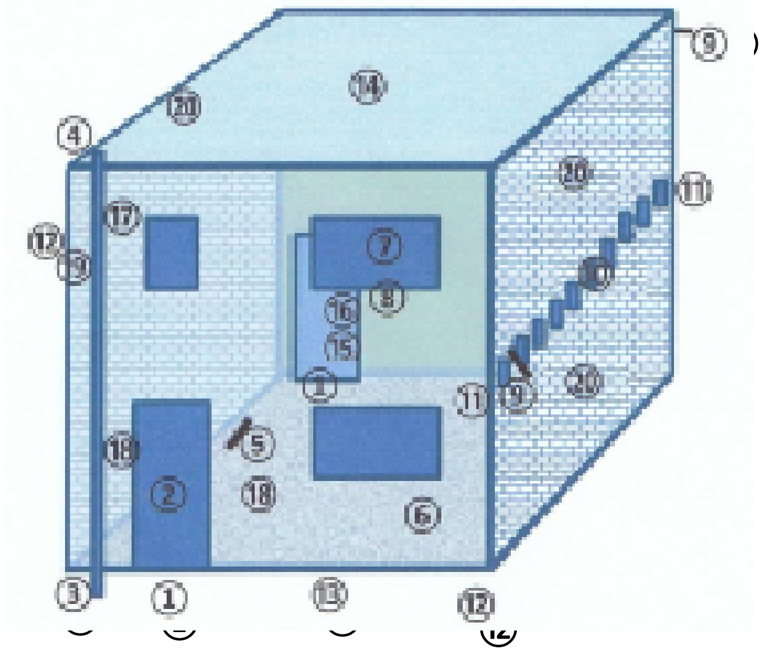
The Air Permeability is however already better than the Building Regulations maximum for newbuild properties (reduced to 5.0 $m^3/hr/m^2$ @ 50 Pa in last year's revision) by a considerable degree.

Further comments regarding the leakage found more generally at Erneley Close, and the actions and strategy we consider necessary to address it successfully, are provided in the final two sections of this report, ***Leakage Investigations*** and ***Recommendations***.

Leakage Investigations

Extensive leakage investigations were carried out in No's 20, 18 (particularly on the 16th December 2013) and No. 3 Erneley Close. The pictures below and on the following pages illustrate the key leakage sites identified to date. It must also be noted that because the investigations have largely been limited to ground floor maisonettes, there may be additional leakage issues that come to light when similar detailed leakage investigations are carried out (assuming they prove necessary) in one or more top floor maisonettes.

To recap the overall leakage situation using a revised and site-specific version of the Air Barrier Strategy Summary introduced during the Airtightness Champions Training held on site back in September 2013:



Referring to the above diagram, the following actual and potential leakage sites are:

1) Associated with the thresholds beneath both the front and back doors, where the sealing between the structural foam and the adjacent surfaces appears to be problematic;
2) Around the front door, which because it is used to position the test equipment is not directly tested. Hence, care needs to be taken to ensure that front door is properly adjusted so that the draughtseals fitted to it are effective;
3) At the bottom of the soil vent pipe where it passes through the ground floor (lower maisonettes) or the concrete slab beneath the upper maisonettes. Using a wet concrete mix has not proved completely effective with residual leakage still being found. Some leakage was also identified on joints in the soil vent pipe itself;
4) At the top of the soil vent pipe, which is fitted with a timber pattress sealed back to adjacent surfaces with foam and mastic. This seal has been found to be damaged on several occasions, so it is clearly vulnerable and must be robustly sealed. This may require some sort of wet concrete or levelling screed being applied from above once the timber pattress has been secured from below. At the very least the efficacy of the sealing must be checked before the soil vent pipe is boxed in;

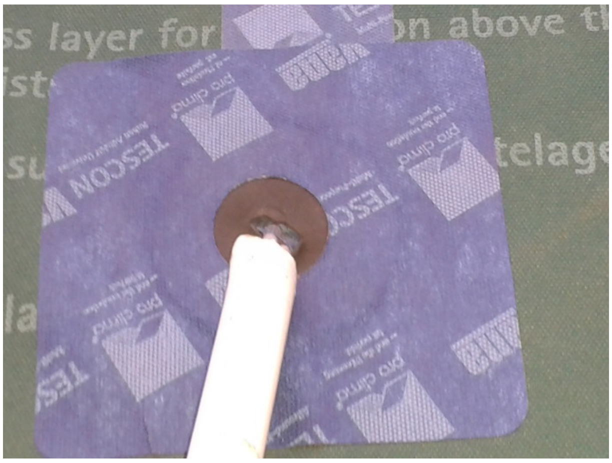
5) Cable penetrations through the front and rear facades, for example to connect to external lights, door bells and entry systems;
6) Leakage through the new ground floors, which essentially are sealed using a subfloor membrane tapes and sealed to both perimeter walls and internal partition walls;
7) A damaged window found upstairs in No. 3, which apparently has been opened too rapidly giving rise to damaged hinges with the consequent failure of the draughtseals to engage effectively, particularly at the bottom left corner (viewed internally);
8) Leakage found around the window sills of various windows, at front, back and edges (although typically not all of these on any one window);
9) Penetrations through the internal party walls, in particular some 2” square cable trunking typically located in the intermediate floor void. This is another leakage site that has often been found to require resealing after ongoing installation works between airtightness tests;
10) Leakage around floor joists embedded in the brickwork party walls and gable end walls. This is particularly an issue when there are cable penetrations close to the joist ends. Comparative testing in No. 3 suggested that sealing these leakage sites on both sides of a midblock dwelling could contribute as much as 0.2 ACH^{-1} of the reduction in the air change rate achieved. Hence it is clearly essential that this measure is effectively undertaken throughout the Erneley Close maisonettes;
11) Significant leakage occurring between the final floor joist and the front and back façade walls, particularly in the corners near where the party walls project as external fins. Hence particular care needs to be taken to effectively seal this location;
12) More general leakage through the brick party walls, and to a greater extent through the gable end wall (in No. 12), which has made it essential to seal the whole of these elements. It is clear that the brick party walls are not airtight, and apparently allow air to track through them for considerable distances. Hence even though the projecting brick piers on the front and rear façades have been rendered, there remains the likelihood of leakage connecting into the subfloor volume as well as to adjacent properties. A further concern is leakage associated with the stairs, where limited access makes it very difficult to ensure an effective seal is accomplished;
13) The DA membrane used to provide airtightness on the front and back facades, over new OSB, has been damaged and repaired in many places, and additional sealing has been carried out around the resin-anchored bolts by which the steelwork supporting the external insulation is secured. We suggest that it is advisable to carry out a pressurisation leakage check and inspect externally each dwelling once the steelwork is fitted but before the insulation is fitted, this should ensure that the DA membrane is fully sealed;
14) Other than at locations such as around the soil vent pipes, we are reasonably confident that the concrete roof to the upper storey of the lower maisonettes, which forms the lower floor of the upper maisonettes, is airtight, although concern has been raised about the perimeter channel. However this cannot be verified until the roof insulation is complete and we begin preliminary testing in the upper units. This is the equivalent of the floor leakage in the lower maisonettes, item (6);
15) Around the rear door, where differential tests have identified residual leakage of more than 0.1 ACH^{-1} with the rear doors as currently installed. Hence both satisfactory results were achieved with temporary sealing, using Gaffa tape around the rear doors.

Therefore, it is essential that rear doors are adjusted to ensure that the draughtseals fitted to them are effective. The satisfactory preliminary results are only valid once the rear doors have been adjusted to seal effectively;

16) Another part of both rear doors that were temporarily sealed for the preliminary tests were the holes cut ready for the door furniture to be fitted. As was the case on the Lancaster co-housing project (44 newbuild PassivHaus's), substantial leakage occurs around and through the door locks. Hence we recommend that careful mastic sealing be undertaken behind the door furniture to reduce this leakage, which proved a useful contribution the airtightness on the Lancaster development;
17) Another location at which residual leakage may be found is around the inlet and outlet ducts connecting to the MVHR heat exchanged mounted on the bathroom wall in these two units. The holes for these ducts have not yet been cut through the external façade, so there is the potential for additional leakage to occur as these – and other – services are finalised;
18) Incoming electrical services through the new ground floor required additional sealing, and considerable leakage was found in some locations where the brick of the party and gable end walls had to be routed out to fit switch boxes, both for electrical sockets and other switches. It appears advisable to parge behind all electrical and other switch boxes, and indeed behind conduit where fitted, to prevent air passing through the brickwork into the dwelling around the various electrical services;
19) Leakage was found through unsealed brickwork was exposed behind the soil vent pipe in the bathroom of No. 3. This was parged over and eliminated, but does emphasise that it appears to be essential to seal all the pathways by which air in the brickwork party and gable walls – including walls to the central stairwell – can track into the dwellings;
20) Leakage was also found to occur through the masonry internal partition walls, which was addressed in No. 3 by cutting back plaster at the party wall to partition wall joint, foam sealing along the interface and then plastering over. This stopped the leakage and it appears advisable to carry out this measure generally to again prevent air in the brickwork tracking into the maisonettes.

Pictures relating to most of these leakage sites are provided below and on the following pages:

		
P6) Substantial leakage at edge of finished floor in No. 3, beside front door threshold (Items 1 & 6)		P7) Concreting around base of soil vent pipe in No. 3 did not eliminate leakage (item 3)

	
P8) Partially effective sealing at base of soil vent pipe, also tape seal over joints (item 3)	P9) Tape along front edge of window sill to stop leakage at corner joint in plasterboard (item 8)
	
P10) The timber pattress at the top of the soil vent pipe in both No's 3 (shown) & 18 has had to be resealed more than once (item 4)	P11) Ineffective seal where cable penetrates front façade (item 5)

P12) Damage to subfloor membrane identified & then repaired before Vacupor insulation and floating floor installed (item 6)

P13) Edge of floating floor sealing with Tescon tape to eliminate edge leakage (item 6)

P14) Leakage along unfinished edge of window reveal (item 8)

P15) 2” trunking sealed with foam and around with mastic – more than once (item 9)

P16) Tape and some foam sealing around floor joists into party wall (item 10)

P17) Torn DA membrane, viewed externally (item 13)

P18) Resin anchor fixed through DA membrane externally, sealed with Orcon-F mastic before insulation & steel applied (item 13)

P19) Insulation slotted over anchor then more mastic applied before steel bolted down (item 13)

P20) Edges of Tescon tape over DA membrane not smoothed down so may leak (item 13)

P21) Location of MVHR duct through external wall – risk of additional leakage (item 17)

P22) Significant leakage found through brickwork behind electrical socket (item 18)

P23) Foam and mastic sealing required to eliminate substantial leakage through switch box in hallway of No. 3 (item 18)

	
P24) Leakage through unsealed brickwork behind soil pipe in No. 3 (item 19)	P25) Parge coat provides seal over brickwork behind soil pipe (item 19)
	
P26) Leakage through brickwork behind the stair stringer reduced by injecting foam – photographed during smoke test – (item 12)	P27) Leakage at the interface between the brick party wall and the masonry internal Paramount partition walls eliminated by foam sealing and then over-plastering (item 20);

Recommendations

1) It should be assumed that the internal surfaces of the brickwork dividing walls, including gable end walls and the walls to the central stairwell as well as party walls, may permit considerable leakage and therefore need to be sealed throughout as far as possible. This requires:
    a. Sealing around floor joists;
    b. Parging brickwork between floor joists, including above the ceiling in the cupboard beneath the stairs;
    c. Sealing as far as is practicable behind the stair stringer – and even considering taking out the stairs in particularly risky locations, such as against gable walls;
    d. Sealing all penetrations through the brickwork – and ensuring that this is rechecked and redone if necessary after any further cables are installed;
    e. Parging behind electrical socket and switch boxes wherever accessible;
    f. Parging any unsealed brickwork before it is hidden behind boxing, kitchen units or similar;
    g. Sealing with foam and plaster the ends of the paramount partitioning both where it abuts the brickwork party walls and also where it is adjacent to internal doorways;
2) The sealing of the DA membrane on the front and rear facades needs to be checked in a pressurisation test, with a thorough external inspection, after the steelwork has been fixed in place but before the insulation is fitted;
3) All the edges of the ground floor of the lower maisonettes need to be effectively sealed, including to internal dividing walls. Rather than sealing the edge of the DA membrane before the Vacupor insulation is installed, we suggest that the alternative approach discussed on site is adopted. In this the DA membrane in turned up around the perimeter, with careful folding and taping in corners. The Vacupor insulation is the installed, followed by the floating floor – with care to ensure that the corners of the floating floor do not tear the DA membrane. The turned up DA is then trimmed to size - approximately a 20mm projection above the top of the floating floor – and Tescon tape is used to seal the edge of floating floor to the DA membrane and then to the wall, using two runs of Orcon-F mastic, one between the DA and the plaster of the wall, the second between the Tescon tape and the plaster of the wall. This carried out on both internal and external walls and , and then a depressurisation leakage check is carried out once the Orcon-F mastic has had time to go off;
4) The top and bottom of the soil vent pipes are clear weak points from a leakage perspective, made even worse by the leakage identified from actual joints on the soil vent pipe in No. 3. Attempting to seal the leakage around the bottom of the soil vent pipe with concrete proved ineffective, hence we suggest consideration be given to using some self-levelling compound at this location, which could then be painted over with liquid latex to ensure an effective seal before the soil vent pipe is boxed. Similarly at the top of the soil vent pipe, the timber pattress has proved to be very vulnerable to being disrupted by further works and localised movement. Hence care needs to be taken to ensure this location is effectively sealed, perhaps with self-levelling compound and liquid latex from above, before the soil vent pipes are boxed in. We are particularly concerned about the effectiveness of the seal around the soil vent pipe through the roof of the upper maisonettes;

5) Wherever leakage is detected from joints in the soil vent pipes, usually by smell during a depressurisation test, this must be addressed, both to eliminate leakage and to minimise any chance of returning residents complaining. We suggest that the Orcon Line pre-dried mastic or equivalent product be utilised to ensure an effective seal;
6) Clearly the doors and windows have the potential to contribute significant amounts to the residual leakage of the dwellings, perhaps as much as 0.3 ACH^{-1} @ 50 Pa from the two doors and potentially significant amount from any windows which are damaged and do not close properly, such as the upstairs front bedroom window identified in No. 3 during the previous visit to site. Whilst there is little point in carrying out a final adjustment on the two doors until the dwellings near completion, a depressurisation leakage check would be advisable on each door shortly before the final acceptance test on each dwelling, with fine adjustment being carried out where necessary. We also suggest that the gaps around the ironmongery on each door are carefully mastic sealed, to minimise the residual leakage through each lock, as was carried out on the Lancaster Co-Housing dwellings. Damaged windows that do not close properly, such as that in No. 3, mean that a dwelling cannot get an acceptance certificate in conformance with the requirements of the PassivHaus Institute. Hence it is essential that any such damage is minimised, perhaps by tightening the window mechanisms to prevent shocks to the fittings by being slammed wide open, and any that is identified is tackled before the acceptance airtightness testing;
7) We suggest that works be prioritised in at least one upper maisonette to enable the airtightness issues and potential weaknesses in these dwellings to be evaluated;
8) Finally, we strongly advise that works which make further airtightness sealing difficult or excessively costly be restricted to dwellings where a satisfactory level of airtightness has been achieved, preferably with an Air Change Rate of $\leq$ 0.85 ACH^{-1} @ 50 Pa to allow some margin for deterioration as services are installed and dwellings finished off. We appreciate that this may limit the scope for installing kitchens and bathrooms, but the satisfactory results achieved so far are very marginal, and having to remove kitchen cupboards to reseal the floor edge behind them, for example, would be both costly and more time consuming in the long run. Get the sealing right, prove it by testing, ensure that subsequent trades appreciate the onus on them to protect the airtightness that has been achieved at considerable cost and difficulty - then proceed with such fit-out works. Similarly the soil vent pipe must not be boxed in until the robust airtightness of the top and bottom penetrations, and the wall to be enclosed within the boxing, have been proven.