

The image features a dark blue background on the left side, which contains the 'bre' logo in a yellow, lowercase, sans-serif font. A complex, abstract graphic of thin, yellow, curved lines originates from the bottom center of the blue area and extends across the right side of the page, creating a sense of movement and depth. The lines are dense and overlapping, forming a pattern that resembles a stylized fan or a series of overlapping arcs.

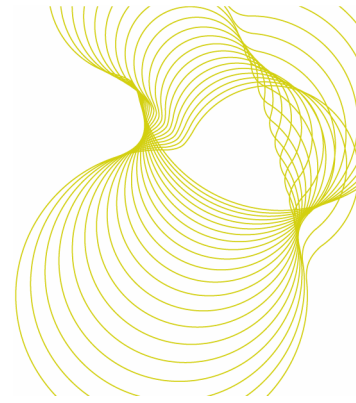
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**'Airtight sealant
process' remedial
sealing - further
BREDEM calculations**

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18 July 2005

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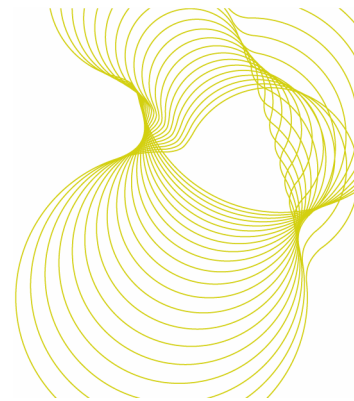
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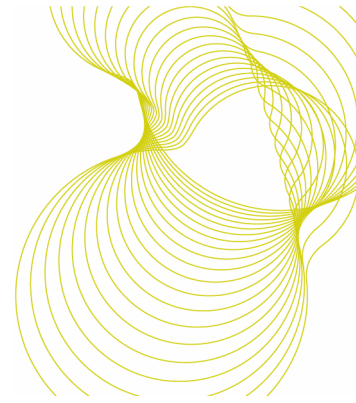
Executive Summary

Remedial sealing of air leakage paths in existing buildings can produce valuable energy savings, and reduce discomfort from draughts. Windows and doors may be draught-stripped, but research has shown that there are other significant air leakage paths. Many of these may be sealed, providing additional savings and improvement in comfort. 'Airtight Solutions Ltd' offers a system called 'Airtight Sealant Process' for draught-proofing windows and doors, and additionally sealing other air leakage where possible. The product is a silicon based sealant, and on windows and doors includes application of a release agent to enable them to be opened afterwards.

Pressurisation tests before and after such sealing were undertaken on a number of dwellings for 'Airtight Solutions' by BRE. The standard pressurisation test method was used, attaching a fan in place of a door and measuring the flow corresponding to a pressure difference of 50 Pa.

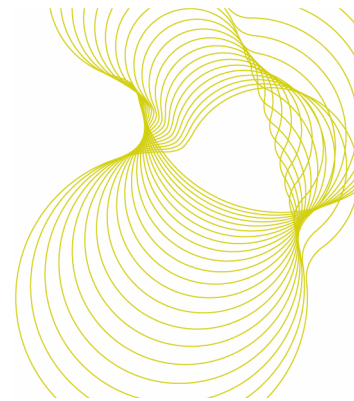
This report describes evaluation of these pressurisation test results, followed by analysis of energy savings specifically for the Energy Efficiency Commitment Scheme 2005-2008 (EEC 2005-2008). The methodology of this analysis is therefore consistent with that used in EEC 2005-2008, including the use of BREDEM, a widely accepted energy calculation model.

These results, from tests undertaken predominantly on flats, indicate valuable savings achieved by remedial sealing of air leakage paths. The resulting air leakage is thereby brought closer to standards for uncontrolled air leakage which are recommended for new buildings.



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Introduction

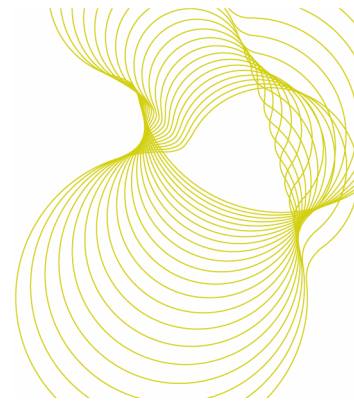
As discussed in an earlier report (1), uncontrolled leakage of air through gaps in the dwelling's envelope area results, in general, in unnecessary heat loss and discomfort to the occupants from draughts. Draught-stripping windows and doors reduces this leakage, however, research has shown that there are a variety of other significant air leakage paths. These include dry lining on dabs or battens, cracks, gaps and joints in the structure, joist penetrations of external walls, timber floors, internal stud walls, electrical components and service ducts, and unplastered masonry in areas hidden from view (2, 3).

Many of these air leakage paths may also be sealed. The extent to which this may be achieved in existing dwellings will vary, depending on the feasibility of identifying their location, and accessing them to undertake the sealing. A company, 'Airtight Solutions' offers a system called 'Airtight Sealant Process' for draught-proofing windows and doors, and additionally identifying and sealing other air leakage paths where possible. The product is a silicon based sealant which cures to form a flexible gasket, thus blocking and preventing air leakage. For windows and doors, a release agent is applied on one side, so that they are openable afterwards.

It should be noted that all dwellings need a supply of fresh air for the health and comfort of occupants, the control of condensation, removal of pollutants, and safe operation of some types of combustion appliances. Control of condensation and moisture is generally the most significant of these, for which a whole house ventilation rate of between 0.5 ach and 1.0 ach is normally sufficient (4). This may be considered as a 'target zone' for total air leakage, made up of both uncontrolled and controlled ventilation (examples of the latter include trickle vents, window opening, fans). In addition adequate ventilation must be present for certain combustion appliances, and areas with high moisture levels, such as kitchens and bathrooms.

Energy Efficiency Best Practice in Housing has published, for new housing, a 'Good Practice specification' (5) which includes air permeability of less than $7\text{ m}^3/\text{h}/\text{m}^2$ at 50 Pa^1 , and a 'Best Practice specification' of less than $3\text{ m}^3/\text{h}/\text{m}^2$ at 50 Pa . The airtightness of the existing stock of UK dwellings covers a wide range, from as low as 2 to above $25\text{ m}^3/\text{h}/\text{m}^2$ at 50 Pa , averaging $11.5\text{ m}^3/\text{h}/\text{m}^2$ at 50 Pa (2,3).

¹ $4\text{ m}^3/\text{h}/\text{m}^2$ at 50 Pa where there is a Heat Recovery Ventilation system



Description of the project

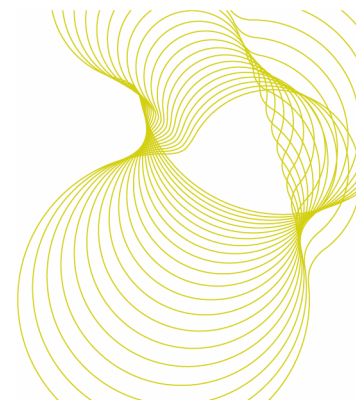
Air pressurisation tests, before and after remedial sealing, were carried out on four dwellings in August 2004. The standard method was used, that is, attaching a fan in place of a door and measuring the flow corresponding to a pressure difference of 50 Pa. The results of these tests were used to evaluate the energy savings for the four dwellings (1, 6). The small number of dwellings tested and the variation in results led 'Airtight Solutions' to arrange tests by BRE on additional dwellings. This significantly improves the evaluation, because the mean of the test results is likely to be closer to the mean result that would be obtained from a large number of dwellings.

This report describes the evaluation of energy savings for these additional, as well as the first four, dwellings. This evaluation is specifically for use in the Energy Efficiency Commitment Scheme 2005-2008 (EEC2). In EEC2, each gas and electricity supplier is required to achieve an energy saving target, by means of energy efficiency schemes for domestic dwellings. Energy savings have been tabulated for individual measures (e.g. loft insulation, wall insulation, replacement boilers, controls), usually depending on dwelling type, size, and heating fuel. These savings are credited to energy suppliers in pursuance of their target as they implement energy efficiency schemes.

Savings for insulation and heating measures in EEC2 are calculated using the BRE Domestic Energy Model (BREDEM). BREDEM was developed in the early 1980s as a relatively simple but reliable calculation procedure for estimating energy use of dwellings. It continues to be subject to testing and development, and is widely used as a calculation tool. BREDEM has been extensively tested against the monitored energy consumption of real houses, and against more detailed and complex simulation models. The results show good agreement, and indicate that predictions of annual energy consumption from BREDEM are in general as good as those from the detailed simulation models used (7).

The analysis in this report uses methodology for BREDEM calculations which are entirely consistent with those used for other heating and insulation measures in EEC2 (8). The 'remedial sealing' undertaken by 'Airtight Solutions' is most closely related to (but may go beyond) draught-stripping of doors and windows in EEC. Draughtproofing is discussed in the 'Energy Efficiency Commitment 2005-2008 – Technical Guidance Manual' (9).

As stated there, "Because of the nature of air infiltration measurements, it is impossible to be precise about what should be taken as a baseline, that is, the air infiltration before draught-stripping. For this work it was agreed that the savings should be based on initial ventilation rates at the higher end of the range, consistent with the data available. This reflects the principle that Energy Efficiency Commitment should be targeting draught-stripping at such properties. In addition, the BREDEM ventilation algorithm assumes that if air infiltration is low, occupants will open windows. Because of this, draught-stripping savings become small if too low an air infiltration baseline is used."



Findings

1.1 The dwellings tested

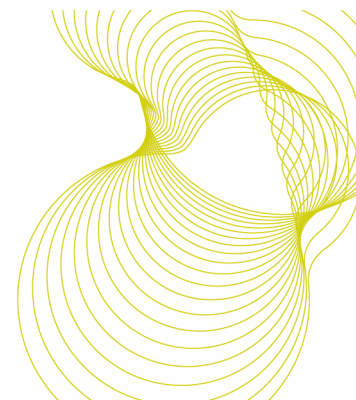
Table 1. Dwelling details

dwelling	location (London areas)	age	bed- rooms	storeys	
1	Enfield	1950s	3	3	end terrace, cavity walls
2	Stepney	1950s	1	low rise	1st floor flat, concrete frame
3	Whitechapel	1960s	1	low rise	2nd floor flat, concrete frame
4	Bow	Victorian	2	2	mid terrace, solid brick walls
5	Stepney	1950s	2	low rise	2nd floor flat, concrete frame
6	Wembley	1930s	3	2	end terrace, cavity walls
7	Whitechapel	1950s	2		3rd floor purpose built flat, brick
8	Marylebone	1960s	2	low rise	2nd floor flat, concrete frame
9	Poplar	1960s	3	highrise	14th floor flat, concrete frame
10	Poplar	1960s	2	highrise	9th floor flat, concrete frame
11	Poplar	1960s	2	highrise	19th (top) floor flat, concrete frame
12	Poplar	1960s	3	highrise	19th (top) floor flat, concrete frame

Table 2. Sealing undertaken and window types

dwelling	Window Closure	Sills	Glazing to Fabric	Frame to Structure	Loft Hatch	Exit Pipe & other	Window frame	Window type
1	yes	no	no	yes	yes	yes	aluminium	casement
2	yes	yes	yes	yes	no	yes	metal	casement
3	yes	no	no	yes	no	yes	metal	casement
4	yes	no	no	yes	no	yes	wood	sash&c'ment
5	yes	yes	yes	yes	no	yes	metal	casement
6	yes	yes	yes	yes	yes	yes	uPVC&wood	casement
7	yes	no	no	yes	no	yes	wood	casement
8	yes	yes	yes	yes	no	yes	wood	pivot
9	yes	yes	yes	yes	no	no	wood	pivot
10	yes	yes	yes	yes	no	no	wood	pivot
11	yes	yes	yes	yes	no	no	wood	pivot
12	yes	yes	yes	yes	no	no	wood	pivot

More detailed descriptions of the properties and work undertaken are given in BRE client reports (6, 10).



1.2 Assessment of pressurisation test results

The results of the pressurisation test results, sorted in order of % reduction, are shown in Table 3. (The original four tests are dwellings 1, 4, 6, and 7 in this table).

Table 3

		Pressurisation test results at 50Pa				% reduction
		before		after		
dwelling		m3/h/m2	ach	m3/h/m2	ach	
1	end-terrace	16.2	14.70	14.8	13.46	8.4%
2	flat	5.7	8.1	3.8	5.4	33.3%
3	flat	8.5	12.8	5.6	8.4	34.4%
4	mid-terrace	15.0	16.12	9.6	10.27	36.3%
5	flat	6.7	8.2	4.0	4.9	40.2%
6	end-terrace	12.3	13.12	5.6	5.92	54.9%
7	flat	14.1	20.15	5.7	8.17	59.5%
8	flat	3.0	4.3	1.1	1.6	62.8%
9	flat	11.4	14.6	2.8	3.6	75.3%
10	flat	12.8	17.5	2.5	3.4	80.6%
11	flat	14.6	20.0	1.9	2.7	86.5%
12	flat			5.6	6.9	

In dwelling 12, it was not possible to obtain a stable reading before sealing, due to high winds causing severe meter reading fluctuations. However, this high rise flat is similar to dwellings 9, 10, and 11, which are all indicating similar 'before' measurements. An average of these three was therefore used as a 'before' measurement of dwelling 12. In this way, the 'after' measurement on dwelling 12, which was acceptably stable, could be used.

As described in the previous report (1), in dwelling 1 smoke tests showed a large amount of leakage in the loft conversion around skirting boards and architraves (and therefore through roof voids), at the back of the toilet and basin, and behind light fittings. In the living room air was seen leaking around the fireplace surround. Most of these gaps were inaccessible and could not be sealed. This is likely to account for the relatively small reduction in air leakage that was measured. The BRE Client Report on the pressurisation testing (6) states that this dwelling

“had significant air leakage paths that were the result of a loft conversion and the householder's DIY activities. Most of these paths were hidden behind kitchen and bathroom furniture and within the loft structure, and it was not possible to seal these gaps without a great deal of upheaval for the householder.”

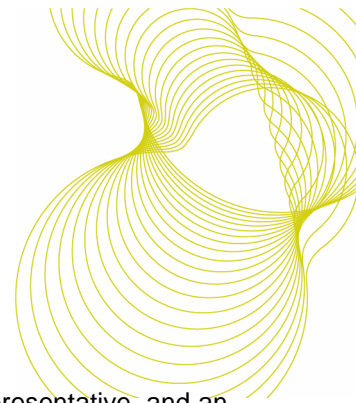
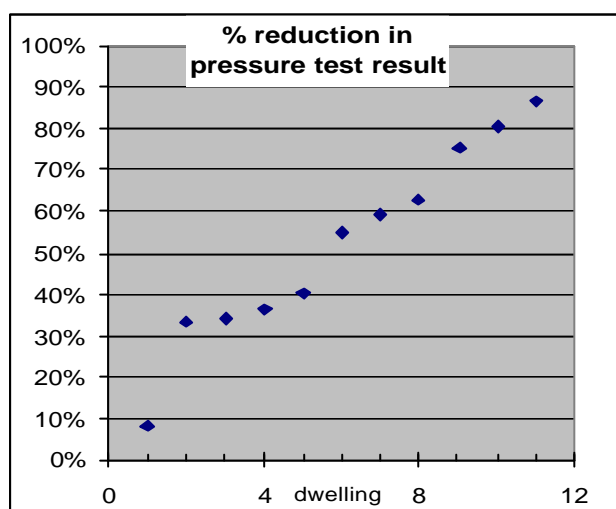


Figure 1 also suggests that this result is an outlier, and supports the case that it is unrepresentative, and an unusual case. It was therefore removed from the data set. (This altered the average % reduction value for the tests from 53% to 57%).

Figure 1

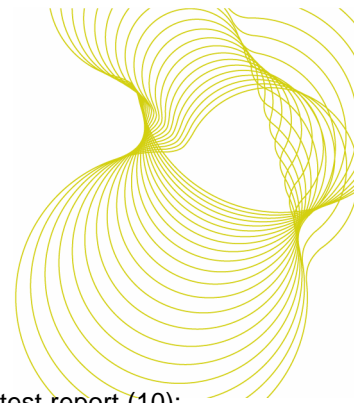


Note that in the earlier set of tests (dwellings 1, 4, 6, and 7) small smoke tubes were used during the pressurisation test to investigate the presence and extent of gaps. This helpfully indicated to 'Airtight Solutions' that in general most air leakage is through visible and obvious gaps. However, such a smoke test would not be possible in a normal installation of the 'Airtight Sealant Process' where there would be no pressurisation testing of the dwelling. To ensure this gave no advantage, no smoke tests were carried out in the second set of tests. Figure 1 shows no indication that the earlier tests in dwellings 1, 4, 6, and 7 gained an advantage in this respect.

It is clear that the sealing has been very successful in improving the airtightness of the dwellings. It is also notable that the highest reductions in pressure test results, those above 60%, were achieved in flats, and mostly through sealing poorly fitting wooden frame windows, and few other leakage routes. These reductions contrast strongly with the results of BRE research (2, 3) in a sample of 35 dwellings, where the proportion of air leakage through windows and doors contributed an average of only 16% (ranging from zero to 44%) of the total air leakage. (This BRE research measured the contribution of different leakage routes with pressurisation testing and reductive sealing, i.e. each leakage route sealed in turn).

It is the experience of both 'Airtight Solutions' and BRE that in general the highest reductions in air leakage are achieved in flats. It therefore seems clear that this sample of flats, and flats in general, have a potential for reducing air leakage through windows which is significantly different to the housing stock in general.

This is considered to be due, at least in part, to the limited number of potential leakage paths in comparison with other dwelling types. Two 'non flats' (dwellings 4 and 6) were tested in this work, with % reductions of 36% and 55%; although in these dwellings, air leakage routes other than windows and doors were sealed. It can be seen that some of the flats which were tested show similar % reductions, but three flats in particular (9, 10, 11 in Figure 1) show high results.



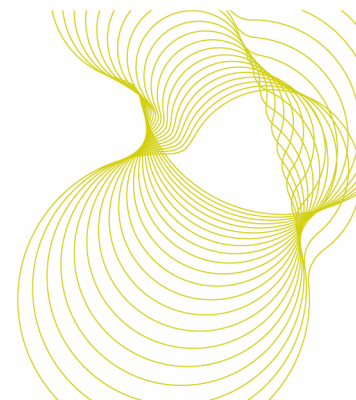
These particular flats are described in the following extract from the BRE pressurisation test report (10):

“The airtightness improvement performance was significantly greater in the flats that had precast concrete panel cladding. This is because this system is constructed in such a way that gaps are kept to a complete minimum. Therefore the greatest air leakage potential is around the windows. The windows in the tower block were particularly leaky, with large gaps visible around the pivoting opening casements. With these large gaps sealed there are virtually no other potential air leakage routes through the envelope area.”

A greater mix of dwelling types would have been preferable, but this proved difficult to achieve given the dwellings that were available for testing. Given:

- the predominance of flats in the sample,
- that the greatest reductions in pressure test results were achieved by sealing mainly windows in flats,
- the large difference between these results where mainly windows were sealed, and the results from the more diverse sample of 45 dwellings tested by BRE where again only windows were sealed.

it is concluded that these results are applicable to the type of inner city flats and housing which were tested, but may not be applied to the UK housing stock in general.



1.3 Analysis of savings using BREDEM and EEC2 assumptions

As a result, the data used for the analysis of energy savings has been restricted to the flats, and these are shown in Table 4.

Table 4

	Pressurisation test results at 50Pa				
	before		after		% reduction
dwelling	m3/h/m2	ach	m3/h/m2	ach	ach
2 flat	5.7	8.1	3.8	5.4	33.3%
3 flat	8.5	12.8	5.6	8.4	34.4%
5 flat	6.7	8.2	4.0	4.9	40.2%
7 flat	14.1	20.15	5.7	8.17	59.5%
8 flat	3.0	4.3	1.1	1.6	62.8%
9 flat	11.4	14.6	2.8	3.6	75.3%
10 flat	12.8	17.5	2.5	3.4	80.6%
11 flat	14.6	20.0	1.9	2.7	86.5%
12 flat		17.37	5.6	6.9	60.3%
average		13.7			59.2%

The analysis of savings uses the *% reduction*, not the *difference*, in each pair ('before' and 'after') of pressurisation test results. The *difference* is constrained by the magnitude of the 'before' result. If the 'before' result is small, the difference between 'before' and 'after' results is limited to a greater extent than if the 'before' result is large. (A graph of the 'differences' against the 'before' results shows this relationship). Using *% reduction* values normalises for the 'before' leakiness of each dwelling, giving a result which is more representative of a larger number of results. In practice, in this particular analysis, the use of *% reduction* rather than *difference* has little effect on the final result.

Items which affect air tightness are characterised in terms of air changes per hour (ach) for input to BREDEM. To derive this, the average *% reduction* is applied to the average 'before' result of 13.7 ach. This gives a result of 8.09 ach at 50 Pa reduction, to be attributed to 'Airtight Solutions' remedial sealing. Using BREDEM with the base parameters used for heating and insulation measures in EEC 2005-2008 (9), and applying this value, gives the results in Table 5. The EEC 2005-2008 draughtproofing savings are also tabulated for comparison.

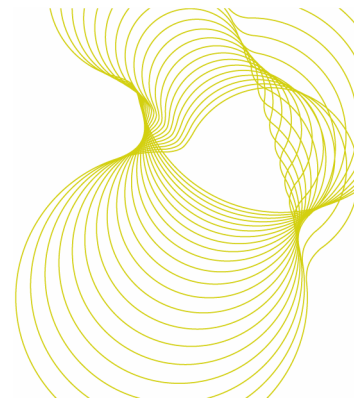


Table 5

	Remedial sealing saving kWh	EEC2 draughtproofing (doors & windows) kWh	factor
Gas Central Heating			
Flat 3 ext walls	1026	442	2.32
Flat 2 ext walls	1044	439	2.38
Electric Storage Heating			
Flat 3 ext walls	1069	462	2.31
Flat 2 ext walls	999	434	2.30

The following tables give the savings calculated for other heating systems, and the variant dwelling type sizes in EEC.

Gas central heating

	bedrooms	kWh/yr
Flat 3 ext. walls	1	706
Flat 3 ext. walls	2	1026
Flat 3 ext. walls	3	1497
Flat 2 ext. walls	1	719
Flat 2 ext. walls	2	1044
Flat 2 ext. walls	3	1523

Oil central heating

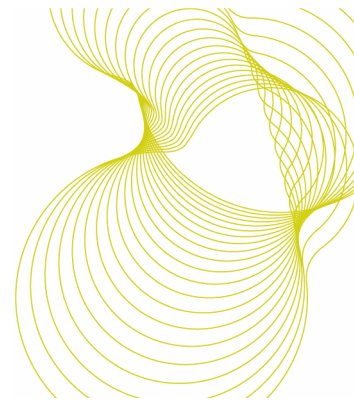
	bedrooms	kWh/yr
Flat 3 ext. walls	1	687
Flat 3 ext. walls	2	998
Flat 3 ext. walls	3	1456
Flat 2 ext. walls	1	676
Flat 2 ext. walls	2	982
Flat 2 ext. walls	3	1433

Electric storage heating

	bedrooms	kWh/yr
Flat 3 ext. walls	1	736
Flat 3 ext. walls	2	1069
Flat 3 ext. walls	3	1560
Flat 2 ext. walls	1	688
Flat 2 ext. walls	2	999
Flat 2 ext. walls	3	1458

Solid fuel central heating

	bedrooms	kWh/yr
Flat 3 ext. walls	1	1178
Flat 3 ext. walls	2	1711
Flat 3 ext. walls	3	2496
Flat 2 ext. walls	1	1151
Flat 2 ext. walls	2	1671
Flat 2 ext. walls	3	2439



Conclusion and recommendations

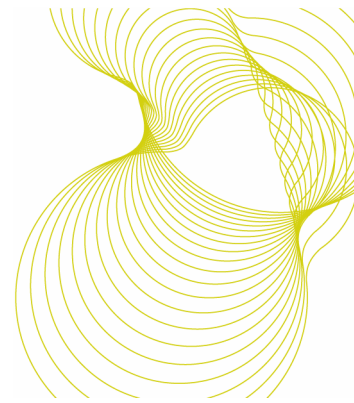
The results from air pressurisation tests 'before' and 'after' remedial sealing by 'Airtight Solutions' have been assessed. The sample is predominantly flats, except for two end-terraces and one mid-terrace. A greater mix of dwelling types would have been preferable, but this proved difficult to achieve given the dwellings that were available for testing. 'Airtight Solutions' and BRE experience is that higher reductions can be achieved in flats – this is probably due in part to a larger variety of potential leakage paths in other dwelling types, which are generally more difficult to improve. The majority of leakage paths sealed in the dwellings tested here were window frames, particularly in the flats.

Given this, and the contrasting results of BRE research on leakage through windows and doors on a sample of 35 dwellings, these results should only be considered representative of the type of dwellings, i.e. flats, that the tests were carried out on. Within this type of dwelling, these results indicate a successful improvement in airtightness. Similar dwellings would benefit significantly from such an improvement in airtightness.

The reduction in air tightness has been used in BREDEM calculations of energy saving, using identical base parameters to those for all other heating and insulation saving calculations undertaken for EEC 2005-2008 (9). The results for the average reduction in air tightness are given in this report.

As stated earlier, the Energy Efficiency Best Practice in Housing 'Good Practice specification' for new housing includes an air permeability of less than $7\text{m}^3/\text{h}/\text{m}^2$ at 50 Pa. It may be noted from Table 1 that only in dwelling 4 and 1 (both not flats) was this not achieved. However, all the flats achieved this standard.

It should also be noted that in achieving these increased levels of air tightness, down to 2 and $3\text{m}^3/\text{h}/\text{m}^2$ in some cases, it is important that the occupier be advised to actively use sufficient purpose provided ventilation; for fresh air, control of excess humidity, removal of pollutants and odours. Purpose provided ventilation e.g. trickle vents, extract fans, window opening, should be used as required, particularly in bathrooms and kitchens. Provision must also be made for any fuel burning appliances, as stated in Part J of the Building Regulations.



References

- (1) BRE client report 221134. 'BREDEM calculations for Airtight Sealant Process, Jan 2005
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- (3) Stephen, R. "Airtightness in UK dwellings: BRE's test results and their significance". BRE Report 359. 1998.
- (4) Perera, M.D.A.E.S. and Parkins, L.M. "Build Tight – Ventilate Right".
- (5) "Energy Efficiency in New Housing, Summary of Specifications for England, Wales and Scotland" CE12. Energy Efficiency Best Practice in Housing
- (6) BRE Client Report 219597 'Airtightness survey and air leakage audit of four dwellings for Airtight Solutions Ltd'. August 2004.
- (7) Dickson, C.M., Dunster, J.E., Lafferty, S.Z., and Shorrocks, L.D. "BREDEM: Testing monthly and seasonal versions against measurements and against detailed simulation models". CIBSE A: Building Serv. Eng. Res. Technol. 17(3) 135-140(1996).
- (8) Annex to "Energy Efficiency Commitment 2005-08: illustrative mix of possible measures" on: <http://www.defra.gov.uk/environment/energy/eec/index.htm>
- (9) "Energy Efficiency Commitment 2005-2008 – Technical Guidance Manual Issue 1", page 62 in Appendix 1 on: <http://www.ofgem.gov.uk/ofgem/work/index.jsp?section=/areasofwork/energyefficiency>
- (10) BRE Test Report 222190 'Airtightness Test results of flats in London before and after remedial sealing carried out by Airtight Solutions Ltd utilising the Airtight sealant process'. February 2005.
Note that some corrections were communicated by M.Jaggs after the Test Report was written. Some values in the above Test Report therefore differ from with those tabulated and used in this report.