Communities and Local Government

Performance Testing of Buildings

BD 2535

www.communities.gov.uk
community, opportunity, prosperity

Communities and Local Government

Performance Testing of Buildings

BD 2535

March 2008
Communities and Local Government: London

The authors of this report are employed by the Building Research Establishment (BRE). The work reported herein was carried out under contract placed by the Department for Communities and Local Government. Any views expressed are not necessarily those of the Department.

Department for Communities and Local Government
Eland House
Bressenden Place
London
SW1E 5DU
Telephone: 020 7944 4400
Website: www.communities.gov.uk

If you require this publication in an alternative format please email alternativeformats@communities.gsi.gov.uk

Communities and Local Government Publications
PO Box 236
Wetherby
West Yorkshire
LS23 7NB
Tel: 08701 226 236
Fax: 08701 226 237
Textphone: 08701 207 405
Email: communities@twoten.com
or online via the Communities and Local Government website: www.communities.gov.uk

March 2008

Product Code: 07HP05158

Executive Summary

This report is output number 227-293, Final report, of the Department of Communities and Local Government Cross Cutting Research Project ‘Performance testing of buildings’, BD 2535, contract reference CI 71/9/16.

The project has investigated the scope for extending the range of performance tests carried out on buildings to check for compliance with the Building Regulations. Performance testing can be used before completion (‘pre-completion testing’) to prove to building control bodies that Building Regulations requirements have been met, or for quality assurance purposes during or after construction as part of a system of Accredited Construction Details (in which performance tests are carried out on a sample of buildings to check workmanship and how well the construction details are working).

A range of pre-completion tests is already carried out to check for compliance with Building Regulations. They are either a requirement of the Regulations (for example air pressure testing), called for by guidance in Approved Documents (for example tests on drains), requested by building control bodies (for example tests on fire safety systems), or as part of commissioning building services (for example boilers and controls). Under Part L, commissioning tests are effectively mandatory now that a commissioning certificate must be issued to the local authority to show that building services and controls have been properly set up.

The project report describes tests that may be suitable as pre-completion tests or for use in conjunction with Accredited Construction Details. They include:

- Two-week and 12-week measurements of radon gas.
- Measurement of noise transmitted between dwellings across halls and small rooms and from building services.
- Measurements of mechanical ventilation system performance.
- Airtightness testing (as an extension to Part L tests) to determine equivalent areas of trickle vents, identify penetrations in fire barriers, check for leaks into flues around fireplaces, and check for air leakage in sub-floors where there is landfill gas.
- Measurement of ambient carbon dioxide and methane levels.
- Tests on flues under different weather conditions.
- Tests of insulation effectiveness.

- Measurements of water consumption and hot water run-off times.
- Measurement of the pull-strength of doors to show that they meet Part B requirements while not being too difficult to open.
- Checks for the presence of laminated safety glass.

Generally the study suggested that there is little enthusiasm in the construction industry for further mandatory pre-completion testing. To be useful, pre-completion performance tests must be quick and inexpensive. They must not delay occupancy, or have to be carried out after occupancy when they may become impracticable.

For a given test, identifying whether it will be suitable as a pre-completion test or for use with Accredited Construction Details will call for a cost-benefit analysis when the relevant Part of the Building Regulations is next reviewed.

Contents

Chapter 1

Introduction and objectives

This report is output number 227-293, Final report, of the Department of Communities and Local Government Cross Cutting Research Project 'Performance testing of buildings', BD 2535, contract reference CI 71/9/16.

Recent revisions to the Building Regulations (for example to Part E, 'Sound Transmission', and Part L, 'Conservation of fuel and power') suggest that performance testing of buildings can be a useful tool for determining whether or not a building complies with the Building Regulations. Performance testing can identify poor standards of workmanship that result in specified performance levels not being achieved in practice. A set of reliable, affordable and comprehensive non-destructive test methods that can be applied to new and refurbished buildings could be of great assistance to building control bodies.

This project has investigated the scope for extending the range of performance tests carried out on buildings to check for compliance with the Building Regulations.

The project has considered two applications for performance testing:

- Tests carried out before completion ('pre-completion testing') to prove to building control bodies that Building Regulations requirements have been met.

- Tests carried out for quality assurance purposes on a sample of buildings during or after construction as part of a system of Accredited ('Robust') Construction Details.

Information has been gathered for the project by consulting BRE specialists and outside experts (including with the aid of the questionnaire in Appendix B), reviewing the guidance in Building Regulations Approved Documents, and carrying out a literature search. The aim has been to identify:

1. Performance tests already used, to check for compliance with Building Regulations, and how well they are working.

2. Areas of construction where workmanship is poor, why defects occur, and therefore the Parts of the Regulations where requirements for further performance testing might be most useful.

3. Test methods already used in construction and other industries – in the UK and abroad – that may have application in Building Regulations performance testing.

4. The scope for introducing new requirements for performance testing into the Building Regulations – whether as pre-completion tests or in conjunction with Accredited Construction Details.

The overall aim of the project (as identified in the project proposal) was to determine the potential role of performance testing of buildings as a tool towards increasing the level of compliance with the Building Regulations. Specific aims were to identify:

- The areas where the intended performance is most likely to be sensitive to quality of workmanship.
- How often completed projects fail performance tests.
- How building control bodies deal with test failures.
- The practicability of carrying out remedial treatments following test failures.
- Any difficulties in interpreting test results and establishing compliance with Building Regulations.
- Where developments are needed in instrumentation and test procedures.
- If there are conflicts between requirements in different Parts of the Building Regulations, and how to avoid allowing remedial works to improve one aspect of a building's performance to the detriment of another.

The project aimed to identify the scope for introducing further performance testing, particularly where workmanship is a concern, and to provide guidance to Communities and Local Government on possible future approaches to improving compliance with the complete suite of Building Regulations.

Chapter 2

Programme of work

The project consisted of five main tasks:

Task 1: Review of existing Approved Documents – to identify through interview key areas where performance is affected by workmanship or by conflicts between requirements in different Parts of the Regulations.

Task 2: Review of existing test methods – to determine through interview how reliable and practical existing test methods are for checking compliance with Building Regulations.

Task 3: Development of workmanship/testing matrix and interim report – to identify the areas where there are problems with workmanship, where test methods exist already for checking workmanship and compliance with Building Regulations, and where test methods are needed. (The work carried out under the first three tasks was described in Interim Report no 227-291.)

Task 4: Development of existing test methods – to identify timescales for introducing new testing requirements in the Building Regulations based on existing test methods (for example ventilation rate measurement and infrared thermography), with suitable pass/fail criteria to give consistent and repeatable results.

Task 5: Technology transfer – to identify non-destructive test methods used outside the construction industry in the UK and abroad that could meet requirements for Building Regulations compliance testing.

The following sections present an analysis of the views of BRE and outside experts who have contributed to the project, either in face-to-face discussions or by completing the questionnaire in Appendix B.

2.1 Workmanship

Workmanship can have an impact in all areas of building work, but can be critical where construction details have a significant impact on performance. Good workmanship calls for the designer to clearly and accurately specify the construction details (which can be difficult even in 3D), and the builder to adopt good working practices.

Good detailing at junctions and interfaces is particularly important for achieving high standards of:

- Fire safety (Part B).
- Weather tightness and protection against contamination (Part C).
- Sound insulation (Part E).
- Airtightness and thermal performance (Part L).

Defects relating to other Parts of the Regulations, such as Part A (Structure) and Part M (Accessibility), can usually be checked by simple visual inspection, by making sure that the correct certified products and materials have been used, or by performing or checking calculations.

2.2 How compliance with the Building Regulations is checked

Building work may be checked for compliance with the requirements of the Building Regulations in a number of ways:

- Inspecting plans and drawings.
- Checking that materials and products meet relevant standards.
- Visual inspection of construction details during and after construction.
- Checking commissioning results for building services.
- Use of Accredited ('Robust') Construction Details by the builder, combined with formal on-site inspection and sample performance testing.
- Pre-completion performance testing.

Further details are given in section 2.5 against each Part of the Regulations.

2.3 Performance testing

The Regulations already require certain pre-completion tests to be performed – for example of sound transmission and airtightness – but in fact local authorities are empowered to carry out any tests they think necessary (although at their own expense).

For performance testing to be worthwhile as a means of enforcing compliance, it must be possible to complete the tests by or on completion. Tests that can only produce results weeks or months later will not help with enforcement, as delays to occupancy are unacceptable and once a building has been occupied remedial action becomes difficult. Whole building performance tests on blocks of flats can be particularly difficult, since occupancy can begin before the block is completed.

The scope for introducing further requirements for pre-completion testing is therefore limited. In any event, any new requirements for performance testing would need to be accompanied by a cost-benefit analysis to show that the benefits outweighed the costs.

A perennial concern is the lack of consistency shown by local authorities in interpreting and enforcing Building Regulations requirements. A benefit of pre-completion performance tests with clear pass-failure criteria would be to help eliminate this inconsistency.

2.4 Conflicts between requirements in the Building Regulations

Failure to comply with the Regulations does not arise from incompatible requirements in different Parts. Usually it happens as a result of poor workmanship on site, or because designers and installers fail to take account of all the differing requirements in the Regulations. Examples are:

- Radon protection. A way of providing radon protection is to incorporate a membrane in the ground floor that extends between the two leaves of a cavity wall. Mortar drops in the cavity can bridge the two leaves, increasing sound transmission and causing thermal bridging.

- Accessibility and weather protection. The requirement for level thresholds can impair moisture resistance and increase the risk of flooding if not done properly.

- Fire safety and accessibility. Fire doors must be self-closing but easy to operate by disabled users.

- Fire spread and ventilation. Fire doors can have a detrimental impact on passive ventilation, and fire dampers in ducts a detrimental impact on mechanical ventilation. This is a matter of proper design.

- Fire safety and insulation. Requirements in Part L for thermal insulation have led to an increasing use of combustible – and often highly toxic – materials in concealed spaces.

- Thermal insulation and electrical cables. Cables totally enclosed by thermal insulation have half the current carrying capacity of unenclosed cables clipped directly to a wooden joist or plasterboard. In dwellings in particular, increasing the size of conductors to compensate can make it difficult to terminate them in standard accessories, so total enclosure by insulation should be avoided if at all practical. In practice, it tends not to be a problem because cables are rated conservatively.

- Thermal insulation and sound insulation. It is generally believed that good thermal performance demands fluffy or lightweight materials with voids, whereas good acoustic performance demands dense materials. In fact lightweight constructions, including timber frame, steel frame and aircrete, can have good thermal and acoustic performance.

- Airtightness and ventilation. Buildings should be built so that they are airtight with adequate ventilation. There is a potential conflict between airtightness requirements in Part L and ventilation requirements in Part F – the result could be either under-ventilation or over-ventilation – but this has been addressed by the latest revisions to Parts F and L and should not present problems for designers.

- Conflicts between trades. Plumbers and electricians may puncture insulation or fire barriers and not make good afterwards.

- Energy efficiency and combustion appliances. Ventilation of open fires as required by Part J may result in appreciable heat loss and thus compromise the aims of Part L. This is particularly likely where luxury homes are built with an 'inglenook' fireplace or other appliance intended to create a primitive ambience, as these have a large opening area. In order to prevent smoking, there needs to be a certain air velocity across the opening and thus the total air volume flow rate is large. Conventional wisdom is that an open fire functions correctly if the airflow into the fireplace has a mean velocity of at least 0.24 m/s. Assuming an exterior winter temperature of 5°C with an internal temperature of 20°C, the flow of warm air from the living space into the fireplace and up the chimney represents a heat loss of 4.3 kW/m^2 of fireplace opening. For a typical fireplace opening (410 mm × 560 mm), maintaining a non-smoking fire entails a heat loss of 1 kW, but fireplaces can be up to 0.8 m^2 in area, at which size the heat loss is some 3.5 kW. The revised Part L addresses this issue now by calling for new buildings to comply with target carbon dioxide emission rates, so that houses with open fireplaces must be built to higher standards to compensate for the heat losses through the fireplace.

2.5 Workmanship, compliance and performance testing by Part

For each Part of the Building Regulations – where relevant and where it has been possible to obtain information – the following sections cover:

- Where workmanship can have an impact.

- How checking for compliance is carried out.

- Current performance testing requirements and methods.
- How well testing works in practice – cost, duration, consistency and reliability of results, how clearly compliance with requirements is established, failure rates.
- The consequences when a building fails a performance test – remedial action and delays to occupancy.
- Other tests that are available, and other tests that might be worth developing.
- Practice in other countries.

2.5.1 Structure

Part A requirements

A1 Loading.

A2 Ground movement.

A3 Disproportionate collapse.

Workmanship issues

- Areas where workmanship can be an issue are:
  - The construction of foundations – for example the depth of foundations and placement of void formers.
  - Support of timber floors on hangers.
  - Notching and drilling of joists.
  - Adequate bearings for beams, lintels and joists.

Performance testing

- Checking for compliance with Part A requirements is generally reliant on skilled specialists; and design rather than workmanship on site is the key factor.
- Poor choice of materials and poor workmanship can lead to structural distress, not necessarily failure. Improved workmanship on site will therefore lead to sounder construction and less cracking and movement.
- For structural and geotechnical engineering, the performance of a building is generally guaranteed by the use of certified components and quality control measures such as site testing of materials, usually before construction starts. In the case of concrete, quality control test cubes may be cast during construction and tested later. These tests are well established and happen before completion of the total structure, providing some opportunity for re-construction.

- Certain requirements in Approved Document A are prescriptive rather than performance-based – for example the size and geometry of structural elements, and detailing. Most are verified by inspection before or during construction, but some can also be inspected after construction. In particular, compliance with requirement A(3) – that buildings should be able to withstand accidents without suffering 'disproportionate collapse' – can only be assessed at the design stage and by checking for correct (visible) detailing.

- A performance test is sometimes carried out on roof coverings to check for ponding (which in severe cases can lead to structural failure). This can be a load test with a relevant measurement of deflection.

- Vibration testing following construction but before occupation can allow early remediation of problems that would be more expensive to correct after occupation.

- Existing structures that have deteriorated can be tested by taking samples of materials. Under investigation at the moment is the minimum number and location of samples required to predict the performance of the whole structure.

- There are performance requirements for components when structures are undergoing repair and rehabilitation. Tests during and after construction may not always be practical, but tests of the effectiveness of surface preparation would be worthwhile to avoid premature failure and expensive repairs.

- Repairs involving reinforcement with steel or composite plate can be tested using non-destructive techniques.

- The quality of concrete, especially the level of voids, can be determined using simple hammers or more sophisticated techniques.

- In situ tests are available for checking the strength of concrete as it cures, but their effectiveness needs evaluating.

- Only a limited amount of performance testing – like vibration and deflection – can be carried out on a building. 'Kentledge' testing for deflection can be carried out on suspect beams, floors and lintels, and methods exist for testing piles. Load tests are costly and lengthy, but they are reliable, and it is easy to interpret results and establish compliance. When such tests are carried out, rates of failure to meet the required performance standard are very low, but failure when it does occur can delay occupancy by many days.

- Such proof load tests only give an indication of strength, but in combination with structural analysis this is the best available. A comprehensive test of safety, strength and stability cannot be performed without damaging the structure. Measures such as non-destructive testing on repair, testing of samples of materials from existing structures, checking for voids in concrete using hammers, in situ concrete tests, etc, as mentioned above, cannot be considered to be 'performance measures' of the structure and components. These properties themselves do not guarantee good performance as the end effect depends on the interaction of several phenomena or properties. They are not performance tests in relation to Building Regulations, but are quality control/assessment methods to see whether a structure is built as it should be. These could be considered to be indirect methods of performance checking.

2.5.2 Fire safety

Part B requirements

B1 Means of warning and escape.

B2 Internal fire spread (linings).

B3 Internal fire spread (structure).

B4 External fire spread.

B5 Access and facilities for the fire service.

Workmanship issues

- Approved products are used for fire protection but workmanship remains an issue. For example:

  – Workmanship can have a significant impact on protecting against internal and external fire spread. Unskilled tradesmen are often unaware of the importance of fire barriers, and fail to make good after penetrating them with cables and pipes. Provision of cavity barriers may also be unsatisfactory.

  – Dry lining installers are often unaware of the need to ensure that multiple layers of plasterboard are all fixed with the correct number of screws or nails and that all joints are staggered. Contractors often ensure that the visible layer is correctly fixed, skimmed and taped but may not be so particular about the bottom layer. This will have a significant impact on the performance of the building in the event of a fire.

  – Bonding between dissimilar construction materials, if not carried out correctly, can lead to failure of composite constructions in a fire, leading to smoke leakage, loss of integrity and deterioration in fire resistance. Workmanship is critical in pressurised escape routes.

- Requirements in Part L for thermal insulation have led to the increasing use of combustible – and often highly toxic – materials in concealed spaces.

Performance testing

- In situ testing of building materials and structure for fire safety is not generally an option – fire testing is destructive!
- The fire performance of products is generally assessed using standard laboratory test methods for both reaction to fire and fire resistance.
- There is a non-destructive test method for smoke movement within a building. This is the hot smoke test and is normally used as a commissioning test to satisfy the regulatory authorities. However, it is generally only used for large, complex or prestigious structures such as airport terminals.
- Building control bodies inspect fire safety systems and expect functional tests to be carried out on fire alarm systems and fire safety systems. These include tests of fire dampers, emergency lighting, sounder audibility, smoke detectors, break glasses, door closers and emergency locks.
- Such fire system tests are inexpensive and can be carried out quickly – perhaps half an hour for each type of component in a non-domestic building, where the tests usually form part of the commissioning process.
- If relevant, escape routes must be pressure tested.
- Passing these tests is essential if occupancy is not to be delayed – although it has been known for use to be made of hand bells and torches to avoid delays! Failure to pass these tests occurs in perhaps 1% of cases. Many of these issues should be assessed on a regular basis under the Regulatory Reform Order (RRO).
- Airtightness testing on parts of buildings might be a way of identifying penetrations in fire barriers as an extension of the airtightness testing required by Part L.

2.5.3 Radon and landfill gas

Radon and landfill gas are perhaps the two hazardous soil gases that are of most concern. The principal components of landfill gas are methane and carbon dioxide, but many other gases and vapours may also be present that can give rise for concern. A wide range of volatile organic compounds (VOCs) can be found in landfill gas, many of which are toxic and flammable as well as being highly odorous. VOCs can also be present on sites subject to spillage of organic solvents and fuel oils.

Part C requirements

C1 Site preparation.

C2 Resistance to contaminants.

C3 Resistance to moisture.

Workmanship issues

- Part C workmanship issues include:

  – Failure by builders to carry out correct levels of excavation, so that deleterious material is left in place.

  – Incorrect detailing (lapping and jointing) where damp proof courses and damp proof membranes are linked. Although correct detailing is important for moisture resistance, it can be critical to protect against radon, carbon dioxide, methane etc. where these are present.

  – Damage to membranes during construction.

Performance testing

- The requirement in Part C is to provide radon protection in certain areas of the country, but there is no requirement to carry out testing to show that the protection measures have been effective. There is also no requirement to test the efficacy of measures designed to exclude other hazardous soil gases.

- In the 1990s, research showed that radon protection measures had only a 1% to 2% failure rate, but more recent research suggests that failure rates are rising.

- The only way of telling whether protection against radon and other hazardous soil gases is working is by testing.

- While radon testing is relatively simple and inexpensive, it can take three months to obtain accurate results under normal conditions of occupancy. Testing for methane and carbon dioxide is also relatively straightforward through the use of portable infrared devices but, as with radon, indoor levels will fluctuate significantly in response to changing meteorological conditions and the way in which the building is occupied. Therefore, obtaining representative results in the short-term may prove difficult, although it should be possible to diagnose extreme problems rapidly. Measurement of VOCs is more specialised, generally requiring greater expertise and more expensive equipment.

- Radon tests can be completed in two weeks in unoccupied buildings if the building is sealed and the heating is turned up, although results may still be inaccurate.

- If a building fails a radon test, it is unlikely that a passive barrier specified for low-risk areas will be repairable. However, the building could then be fitted with a sump or sub-floor void and fan, normally required only in high risk areas, but introducing not insignificant running costs.

- It is possible to measure concentrations of the landfill gases carbon dioxide and methane, both in sub-floor voids and within the building. ‘Trigger’ concentrations for these areas are defined in Environment Agency documents, but the difficulty is defining how a representative measurement is to be taken. In theory, the above two-week radon test could be adapted for methane and carbon dioxide, although operating portable equipment over this extended time period may be challenging. There would also be a need to log gas readings on a regular basis (for example hourly).

- A possibly useful performance test would be of the airtightness of a suspended floor to give an indication of how much soil gas could enter a building. Generally, this could only be used for suspended pre-cast concrete floors (for suspended timber floors the soil gas protective measure is usually applied at the concrete oversite level). Such a test could apply to all hazardous soil gases and could be an extension of the airtightness testing discussed under Part L. Although the test would produce results very quickly, it would need further development work as experience is very limited. To complement it, smoke tests could be undertaken (again as mentioned in the context of Part L) in order to identify specific leakage paths.

- There are already performance criteria for indoor air pollutants in Approved Document F, Ventilation – for moisture, carbon monoxide, volatile organic compounds and bio-effluents. Testing for carbon dioxide and methane could, in principle, form part of a Part F performance test before occupation.

- Environment Agency guidance is that air quality should be monitored after land has been treated to check that the work was successful.

- Building control bodies can call for a survey of contaminants following remedial treatment – but they would have to pay for this.

- Part C could require a two-week radon test to be performed if a builder has neglected to install a radon barrier, to demonstrate that measures are not necessary, or better to show that post-construction measures (such as installation of a sump) have been effective.

- Testing for radon, landfill gas and VOCs could be more cost-effective when used in conjunction with Accredited Construction Details to test a sample of buildings.

Test methods
There are several techniques that can be used for testing buildings to establish the indoor radon level. These range from the use of devices that take five-minute grab samples to provide a result, to techniques that take samples over 2 to 3 days, 7 to 14 days, or 3 months or more.

To obtain the most accurate assessment of radon levels and risk to the occupier, a long-term measurement over several months is required. The reason for needing a long measurement period is to minimise the effects of short-term weather changes on the results. Radon levels within a building will vary from day to day with changes in pressure, wind, sun, rain, and cold, all of which can impact on how radon moves from the ground into the building. In addition, occupier life style can have an impact upon the radon level in the house – for example, heating a house will increase the stack effect which draws radon into the building from the ground, while opening or closing doors and windows will increase or decrease the ventilation and therefore dilution of radon that enters a building.

While it is preferable to use long-term measurement, these techniques do not lend themselves easily to performance testing during construction. It is possible to conduct a three-month reading once the building is occupied, but under current Building Regulations this would take place after the building has received its certificate of completion from the building control body and so would be difficult to police.

An alternative approach would be to carry out a 7 to 14 day test in the building before occupation. This would be more practical to build into the construction programme and could be completed ahead of issuing a completion certificate. The downside is that it would not reflect usage of the building in terms of ventilation and heating. This technique is already in use in cases where it is found that radon protection barriers have not been installed or have been incorrectly installed and it is too late to remedy the situation. Instead a short-term test is carried out with the house closed up and the heating on. If the result comes back above a recommended threshold, then remedial measures are carried out – such as fitting an active subfloor depressurisation system (sump system with fan). This approach has been recommended by the Health Protection Agency to assist with the small number of cases where protective measures have not been correctly installed. By requiring the building to be closed up and to have the heating on during the test, it is probably placing the property into a worst case situation. Further discussion and development of the protocol would be needed. It could be argued that this worst case scenario could be realised for householders who set their heating high and do not ventilate their homes, as might be the case with some elderly people.

It should be noted that there is currently discussion within Government and Communities and Local Government about making changes to the requirements relating to radon protective measures. Four issues are currently being reviewed:

- Should radon protective measures be incorporated within all new properties within the UK, as the measures also provide damp protection and a degree of protection from landfill gas and other contaminants in the ground? This would eliminate the question as to which areas of the country need radon protection measures, which can result in measures not being installed when they should be.

- Should inspection of the radon barrier during construction be a compulsory check point for building control bodies – in the same way that drainage and foundations are inspected?

- Should the specification for the material used as a radon barrier be raised? For example, thicker or stronger materials are less likely to be damaged during construction.

- Should new buildings be tested for radon on completion, and if so how should they be tested and should all buildings be tested or just a sample?

2.5.4 Sound

Part E requirements

E1 Protection against sound from other parts of the building and adjoining buildings.

E2 Protection against sound within a dwelling, house etc.

E3 Reverberation in the common internal parts of buildings containing flats or rooms for residential purposes.

E4 Acoustic conditions in schools.

Part E specifies minimum airborne sound insulation values for separating walls and floors, and minimum airborne impact sound insulation values for floors.

The Regulations call for pre-completion sound tests to be carried out on dwelling houses, flats and rooms for residential purposes, unless a builder is using design details approved by an Accredited Construction Details company.

Design and construction guidance is contained in both Approved Document E and the Robust Details book.

Workmanship issues

- Generally for good airborne sound insulation, elements need to have a high mass per unit area, with each side of a floor or wall well isolated from the other.

- Poorly constructed flanking elements to which separating floors are attached can allow flanking sound transmission, which can significantly reduce the sound insulation between vertically separated dwellings.

- Timber separating floors can represent a greater risk of failing to meet minimum standards of sound insulation than concrete separating floors, and must be used with appropriate flanking elements (external, internal and separating walls).

- Examples of poor workmanship associated with walls and floors are:

Masonry separating walls

- Not using a full bed of mortar across 215mm width of dense concrete blocks laid flat and not filling perpendicular joints fully, so that a wall is not as heavy as it should be.

- Using deep chases for electrical cables and boxes, and fitting boxes back to back.

- Not filling joints properly may introduce air paths, particularly if the wall is lined with plasterboard on dabs rather than being sealed with wet plaster.

- Substituting lightweight blocks for heavier blocks.

- Not installing plasterboard on dabs properly. Dabs should be arranged so that when the plasterboard is pushed onto them there is a continuous line of adhesive around the plasterboard's perimeter and continuous lines of adhesive behind the rest of the boards. Often boards are held in place by discrete dabs creating a continuous cavity behind the plasterboard. If the wall to which the plasterboard is fixed is leaky or excessively porous, the expected or designed airborne sound insulation may not be achieved by the structure.

- Using wall ties with a dynamic stiffness that is too high – for example by substituting double triangle ties for butterfly ties.

- Allowing mortar to fall down the cavity of separating walls, which can couple together the two leaves of the wall more effectively than they should be coupled.

Timber and steel stud separating walls

- Substituting specified plasterboard with lighter plasterboard so that separating walls are not as heavy as they should be.

- Penetrating plaster board – for example with pipes and electrical sockets.

- Rigidly connecting the frames of twin leaf stud walls together – for example fitting internal pipes incorrectly so that the leaves are connected together (pipes feeding showers in separating walls should be boxed in within the cavity), or using the wrong ties in cinema walls.

- Not overlapping twin layers of plasterboard on each side of the wall, so that there is a continuous joint between the layers beneath any plaster skim.

- Not taking plasterboard down to base floors, but instead stopping just below the top of the skirting board.

- Not installing resilient bars (not covered by Approved Document E or Robust Details, but sometimes used in separating stud walls) in accordance with the manufacturer's instructions. It is important that the screws used to fix plasterboard to resilient bars are not so long that they are able to go through the board, bars and into the studs (where the resilient bars are fixed to the studs). This creates a rigid connection, and reduces isolation and airborne sound insulation.

- Using faced mineral wool, or mineral wool of the wrong density, in stud separating walls.

- Not following the guidance on junctions with other walls and floors in Approved Document E, Robust Details or manufacturers' instructions.

- Using inappropriate combinations of separating walls and floors. For example, Robust Details state that it is not acceptable to use any Robust Detail timber separating floor with any masonry or steel supporting wall.

- Not carrying up separating walls to the underside of roofs, but instead stopping above the ceiling of the uppermost rooms, or constructing the separating wall from blocks and plasterboard with a mass per unit area that is too low.

Concrete separating floors

- Not grouting fully the joints between concrete planks in separating floors.

- Using concrete separating floors, and levelling screeds on concrete plank floors, with too low a mass per unit area.

- Not using appropriate ceiling treatments on different types of concrete floor, for example resilient bars for concrete plank floors, timber battens and plasterboard for concrete slabs.

- Not fitting floating floors – which can act as a soft floor covering to reduce impact sound transmission – properly and in accordance with the manufacturer's instructions (although the risks associated with concrete floors are not as great as for timber floors). If mineral wool is used as the resilient layer beneath a sand cement screed, the paper backing must be uppermost and overlap at joints to stop the concrete penetrating the wool. Mineral wool concrete layers can also be damaged by running wheelbarrows full of screed over them. Sand and cement floating screeds need to be isolated from walls by turning up the resilient layer at the edges. Supervision and installation need to be adequate.

- Installing concrete separating floors so that they pass through separating masonry cavity walls (although they should pass through solid dense concrete block separating walls).

- Not installing cavity stops in masonry cavity external walls at separating floors.

Timber separating floors

- Installing floating floors without a 'flanking strip' around their perimeter and in direct contact with skirting boards, so that they are not isolated and impact insulation is reduced.

- Not using specified materials and systems: the mass per unit area of the walking surface, the depth of the timber battens and the nature and thickness of the resilient layer beneath the battens can all affect the impact sound insulation of timber raft floating floors.

- Using screws that are too long to fix the walking surface (usually tongue and groove chipboard) of timber raft floating floors to the timber battens. If the timber battens are fixed rigidly to the base floor, the isolation of the walking surface from the base floor can be reduced along with the impact sound insulation.

- Not taking sufficient care in the handling and storage of resilient materials. If systems with resilient layers are stored incorrectly or with heavy weights on them, the resilient layers can be squashed beyond the point at which they will recover fully. In this case, the dynamic stiffness of the resilient layer may be reduced leading to reductions in impact sound insulation.

- Not fitting an independent ceiling with Approved Document E type 3.1 timber separating floors. Robust Details give guidance for timber separating floors with ceilings incorporating resilient bars to which two layers of plasterboard are fixed. The correct type of resilient bar must be used since their isolation performance can vary, and they must be fixed in accordance with the manufacturer's instructions. The air gap, mass per unit area of plasterboard and length of screws must be as specified, otherwise sound insulation performance may be affected.

- It is claimed that the introduction of the system of Robust Details has improved Part E compliance for floors from 60% to 90%, and for walls from 70 to 98% (see section 2.7).

- Acoustic failures can occur as a result of poor design, but more often failures arise from poor on-site workmanship. Guidance is needed on how to improve acoustic performance when carrying out work on existing buildings and when buildings undergo a change of use. Insufficient Robust Details are available to show how to bring old buildings up to modern acoustic standards.

Performance testing

- The performance values for airborne sound insulation that must be achieved by separating walls and floors and for impact sound insulation by floors are given in Approved Document E, and the standard methods for field testing are given in European standards.

- Robust Details Ltd specify their own airborne and impact airborne test methods, as well as a test method for downlights.

- There are standard European laboratory test methods for measuring the improvement in impact airborne sound insulation brought about by floor coverings.

- Sound tests can take two to three hours and cost around £1000 per test. This imposes a disproportionate burden on small builders, who may therefore benefit more than large builders from adopting Robust Details.

- Experts are needed to carry out the tests. Approved Document E says that the person carrying out the building work should arrange for sound insulation testing to be carried out by a test body with appropriate third party accreditation. Members of the ANC Registration Scheme are regarded as suitably qualified to carry out pre-completion testing.

- Robust Details Ltd say the overall failure rate for walls is now 2%, but for floors 10%, mainly due to the continued use of beam and block floors. A building control officer's experience is that failure rates are nearer 50%, and that failure to comply can delay occupancy by three weeks or more.

- Whole building tests can be difficult on blocks of flats which people start to occupy before completion of the block.

Current test methods
Approved Document E contains the performance standards for airborne sound insulation of separating walls and airborne and impact sound insulation of separating floors between dwellings and rooms for residential purposes. In addition, it contains the performance standard for airborne sound insulation of internal walls and floors (within a dwelling).

Currently, airborne and impact sound insulation between dwellings are measured in accordance with BS EN ISO 140-4:1998 and BS EN ISO 140-7:1998 respectively. Single-number quantities for airborne and impact sound insulation between dwellings are calculated in accordance with BS EN ISO 717-1:1997 and BS EN ISO 717-2:1997 respectively.

It is obviously desirable that the single-number quantities used to describe sound insulation should have some correlation with people's subjective impression of noise transmission or disturbance from noise transmission from adjacent properties. Therefore, a correction term is included in the single-number quantity for airborne sound insulation which makes the low frequency airborne sound insulation more significant. This is considered appropriate due to the growing use of, for example, home cinema systems which can produce high levels of low-frequency sound.

Impact sound insulation is measured using a standardised device called a tapping machine which comprises five 0.5 kg hammers repeatedly dropped from a height of 40mm onto the floor under test at a specified rate. Other devices for measuring impact sound insulation have been developed to reproduce the sound of heavy footfalls on floors more realistically than the standard tapping machine does. However, the tapping machine is widely used and usually results in ranking the impact sound insulation of floors in the same order as other devices. Therefore, at present, there is no compelling reason for discontinuing the use of the standard tapping machine.

Approved Document E contains guidance on boxing in soil pipes and other services running through dwellings but does not contain guidance on maximum sound levels in rooms generated by them.

Scope for further testing

Approved Document E states that testing should not be carried out between living spaces and corridors, stairwells or hallways, or between hallways. Methods for carrying out such tests, and also tests involving small rooms, are not currently specified. This means that sometimes it is not possible to measure sound insulation between attached dwellings for regulatory purposes, for example in:

1. Terraced houses that have hallways, stairs and rooms too small for sound insulation measurements adjacent to living spaces in adjacent properties.

2. Semi-detached properties that have halls and rooms too small for sound insulation measurements (in both properties) adjacent to the separating wall.

For situation 1 above, there is no guidance in Approved Document E for assessing potential disturbance due to impact sound being transmitted into living spaces in adjacent properties.

For situation 2, there is no guidance in Approved Document E for measuring sound insulation between dwellings. Such a layout ought to be encouraged since it has less sensitive areas adjacent to the separating wall with living spaces remote from it. Therefore, the risk of disturbance to or from occupants in the adjacent property due to normal activities is minimised.

Currently, Ecohomes credits can be awarded for:

- Situation 2 above because 'where there are no habitable rooms adjacent to separating walls or floors, no testing is needed and the dwellings can be treated as detached homes'[1].

- Situation 1 above where tests cannot be conducted if 'alternative evidence of performance' is provided.

Consideration could be given to developing a standardised method of measuring sound insulation between dwellings with layouts such as those described in 1 and 2 above. Impact sound insulation can be measured

1 Ecohomes guidance 2006.

between horizontally separated dwellings, particularly between stairs in one dwelling and living spaces in the other. Measurements of impact sound pressure level in horizontally separated rooms, as well as in vertically separated rooms, are already conducted in dwellings in Sweden.

Stairs that have a separating function have to meet the same performance standards for airborne and impact sound insulation as separating floors in England and Wales. BS EN ISO 140-14:2004 contains guidance on impact sound insulation measurements on stairs. Therefore, including a performance standard for impact sound insulation between horizontally separated dwellings in the Building Regulations would not require a new test method to be devised. However, research may have to be carried out to determine whether the rating system for floors defined in BS EN ISO 717-2:1997 is appropriate where rooms are separated horizontally.

BS EN ISO 140-14:2004 contains guidance on measuring airborne sound insulation in special situations in the field such as:

- In open plan spaces.
- Between corridors and rooms.

Research into whether the guidance in this standard could be used for measuring between adjacent halls on each side of a separating wall or between halls and living spaces could be advantageous for the reasons mentioned above and, as with the impact sound insulation measurements, may lead to improved occupant satisfaction.

Similarly, there has been research into measuring sound insulation between small rooms (for example Hopkins and Turner[2]) where measurement of low-frequency sound pressure levels is difficult. For the reasons above, identifying a measurement protocol that is suitable for regulatory purposes could bring benefits.

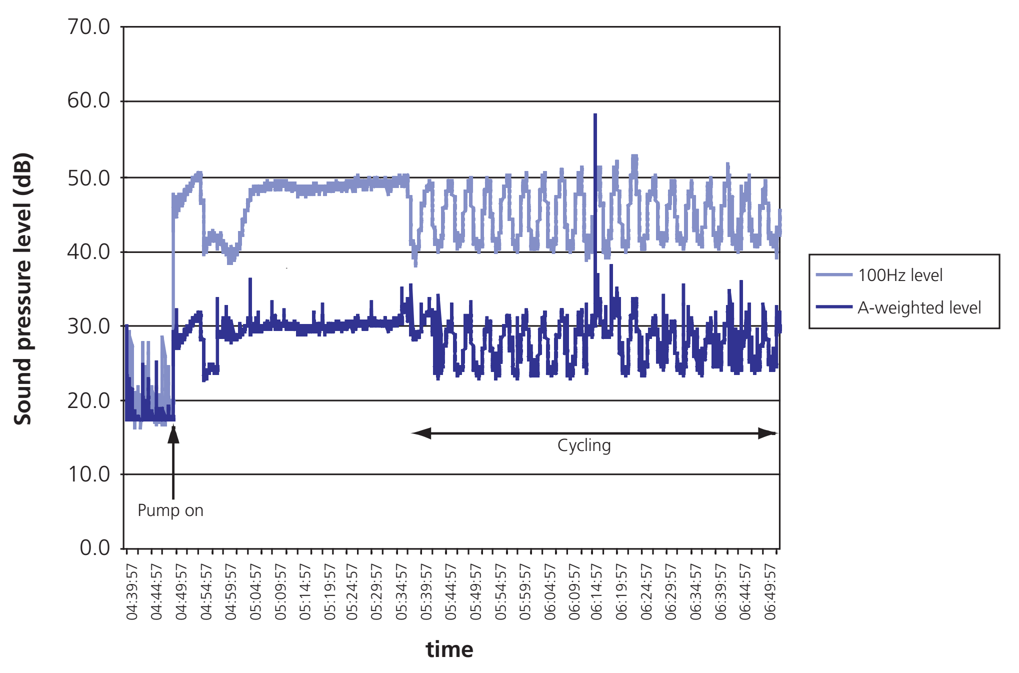
BRE has been approached by people seeking reductions in noise from sources such as extractor fans and central heating pumps in neighbouring properties in addition to noise from services. Measuring sound pressure levels in rooms that can be attributed to such sources is not straightforward because the noise may be at or even below background noise levels and still be discernible. However, research into the structure-borne power of, for example, central heating pumps[3] could lead to guidance on appropriate installation conditions and/or performance characteristics for such appliances that could be included in Building Regulations guidance.

2 'Field measurement of airborne sound insulation between rooms with non-diffuse sound fields at low frequencies', C Hopkins, P Turner, Applied Acoustics 66 (2005) 1339-1382.

3 'Structure-borne power from mechanical installations in lightweight buildings', Barry M Gibbs, 2nd International Symposium on Advanced Timber and Timber-composite Elements for Buildings, Acoustic Performance and Low-frequency Vibration, 27 April 2006, Biel, Switzerland.

Noise transmitted into rooms or dwellings from adjacent properties from central heating pumps can be significant – see Figure 1. In this case, the problem was alleviated by decoupling pipes connected to the pump from the separating wall. Here, the measured A-weighted noise level can be almost entirely attributed to the level in the 100 Hz third octave frequency band. The criteria for assessing the likelihood of complaints from such noise using procedures in BS 4142:1997, 'Method for rating industrial noise affecting mixed residential and industrial areas', could be adapted and used in dwellings for regulatory purposes.

Figure 1 Noise from central heating pump in adjacent property



2.5.5 Ventilation

Part F requirements

F1 Means of ventilation.

- Part F of the Building Regulations specifies 'adequate means of ventilation for people in the building'. Approved Document F provides recommendations on how this can be achieved.

- Part F sets indoor air quality performance standards. Designers can aim to:

  – meet these performance standards, or

  – meet specified air supply and extract rates, or

  – follow ventilation system guidance derived from the performance criteria.

- It is difficult to prove that a design will meet the performance criteria, or that on installation the performance criteria are being met. Furthermore, indoor air quality is affected by the occupants and their activities.

- Mechanical systems should be properly commissioned, in accordance also with Part L requirements, to provide a greater certainty that they will meet the performance requirements. However, it is difficult to commission natural ventilation systems before use.

- There are European test standards to evaluate the performance of ventilation systems in the laboratory, but testing may not be in 'as installed' conditions.

- Building control bodies are unlikely to have the knowledge or the time to check that appropriate laboratory performance tests have been carried out and that systems have been properly set up.

Workmanship issues

- Examples of poor workmanship observed in dwellings are:

  – Installation of wrong type of fan (for example axial instead of centrifugal).

  – Failure to connect duct to outside terminal.

  – Failure to insulate duct.

  – Failure to securely fix fan.

- Measurements in non-domestic buildings have shown that mechanical ventilation system flow rates can be only half that required by the Approved Document. As buildings become more airtight, so ensuring that there is adequate ventilation becomes far more important. Significant shortfalls in airflow can be uncomfortable for occupants and result in black mould growth.

- To control workmanship, some manufacturers operate registered installer schemes. Also, there are now a number of Competent Person Schemes covering work under Parts L and F, authorised by the Government to coincide with the April 2006 revisions to Parts L and F.

- The materials and equipment used in ventilation systems are usually factory manufactured to recognised standards.

Performance testing

- There are no requirements for pre-completion testing in Part F, but Part L does call for air leakage tests to be carried out on ventilation ductwork. Other tests – for example of air flow rates at terminals – will be carried out as part of the commissioning process. Part L calls for heating and hot water systems and controls in dwellings to be commissioned in accordance with the ‘Domestic Heating Compliance Guide’, and for the building services in non-domestic buildings to be commissioned in accordance with the ‘Non-domestic Heating, Cooling and Ventilation Compliance Guide’. A certificate signed by a suitably qualified person must be issued to local authorities showing the results of tests confirming that the performance of the building services is in accordance with the proposed designs.

- Large commercial organisations will employ a third party to witness the commissioning and testing of their building services. This will include the measurement and balancing, with a manometer, of air flows from heating, ventilation and air conditioning terminals in order to distribute energy evenly – in addition to adjusting and setting up temperature controls, checking the operation of the fire alarm system and emergency lighting, etc.

- Large commercial organisations have done these air flow tests in the past to satisfy their own requirements rather than to comply with regulations. However, such commissioning and testing has now become a requirement of Part L.

- Part F specifies the required open areas for ventilation in dwellings in terms of ‘equivalent areas’. Equivalent areas of vents are usually measured using a laboratory-based test rig, but testing could also be carried out in situ using the same equipment as for airtightness testing. The total equivalent area of a building, or the equivalent area of a section of building, could be measured by carrying out an airtightness test with the vents sealed and then repeating the test with the vents open. The difference between the two tests would represent the effect of the open vents and would allow the equivalent area to be calculated.

Domestic buildings

For domestic buildings, the building control body should check whether the ventilation provisions are sufficient. Under Approved Document F 2006, trickle ventilators should have a permanent or temporary marking of the equivalent area. Approved Document F references a European standard (EN13141-1) to measure the equivalent area, although the standard covers only certain types of trickle ventilator (non-controllable, temperature controllable and pressure controllable). A new European standard is being prepared to cover humidity-controlled trickle ventilators.

For passive stack systems, the duct sizing can be checked to conform to that recommended in Approved Document F. However, for controllable systems (for example humidity-controlled), it is difficult to assess whether the ventilation provided is adequate. The building control body can be given a checklist of key installation issues to watch out for.

Approved Document F references a number of European standards for the testing of different mechanical systems. Building control bodies need to ensure that they have the appropriate test report for the fan-type installed and that it meets the air flow required. Again, a key issue is the impact of installation. A check list can be useful here. A more comprehensive solution would be to actually measure the flow through the mechanical system at different settings using equipment such as balometers or flowfinders. This would allow the ventilation rates in mechanically ventilated buildings to be assessed and matched against the recommendations in the Approved Document. However, this might prove to be too time-consuming and expensive (perhaps £1000 to £2000 per building).

Non-domestic buildings
The commissioning engineers should commission and certify a mechanical system to demonstrate that it meets the operational requirements. Similarly, the ductwork installation contractor can test and certify that the leakage requirements are met.

It is much harder to commission a natural ventilation system. The DfES has developed a tool called ClassVent for designing natural ventilation systems for school classrooms. It determines the equivalent areas required for a number of different natural ventilation designs given user-inputted classroom parameters. By following these recommended areas, the classrooms are deemed to comply with Building Bulletin 101 'Ventilation of school buildings'. Clearly this is one way forward that could be applied to other building types.

Section 2.5.9 on Part L suggests a way in which the total equivalent area could be measured.

France
In France, performance testing of ventilation is not compulsory.

In the case of large housing estates, checks are made by control bodies like VERITAS, APAVE or SOCOTEC. They measure airflows and pressure in various locations (generally at the top and bottom of the vertical ducting). They also check the marking on products that are sensitive to high humidity.

For individual houses, and estates with fewer than 30 dwellings, conformity is checked on drawings when planning permission is requested, and no testing is carried out on site.

In some cases, installers will carry out testing as part of their own quality control procedures, or at the request of the contractor or the project manager.

2.5.6 Hygiene

Part G Requirements

G1 Sanitary conveniences and washing facilities.

G2 Bathrooms.

G3 Unvented hot water storage systems.

Workmanship issues

- Workmanship issues under Part G arise rarely, but those mentioned in the consultation were:

  – Use of excessively long pipe runs, which increases the risk of legionella, and wastes water and energy.

  – Inadequate provision for discharge from unvented hot water systems – use of plastic instead of metal pipe, wrong diameter, too many bends, wrong termination.

Performance testing

- No tests are currently carried out on-site.

- An inexpensive requirement would be to set a standard for run-off times for hot water services, which could be measured very easily.

- Part G is currently being reviewed. A new requirement may be introduced into Part G – or possibly as a new Part Q – to control water efficiency. Techniques for measuring the flow rates of appliances would be easy to develop.

2.5.7 Drainage

Part H requirements

H1 Foul water drainage.

H2 Wastewater treatment systems and cesspools.

H3 Rainwater drainage.

H4 Building over sewers.

H5 Separate systems of drainage.

H6 Solid waste storage.

Workmanship issues

- Installing drains below ground at wrong depths and with wrong gradients.

- Installing drains with damaged seals.

- Failure to comply with agreed or acceptable design layout.

- Occasional problems due to multiple connections from appliances.

Performance testing

- Air or water pressure tests on drains and manholes have been a requirement of Part H for many years. The tests are straightforward and effective at picking up poor workmanship.

- Drain tests have a low failure rate, but failures can delay occupancy by several days.

- Specialist firms can carry out camera surveys if drains are found to be blocked. Surveys can take several hours, but are effective at finding blockages.

2.5.8 Combustion appliances

Part J requirements

J1 Air supply.

J2 Discharge of products of combustion.

J3 Protection of buildings.

J4 Provision of information.

J5 Protection of liquid fuel storage systems.

J6 Protection against pollution.

Workmanship issues

a) Ventilation

- Approved Document J requires the provision of non-adjustable ventilators of specified size to admit air to appliances and their flues and, in some cases, to cool appliances. Poor installation of ventilators can lead to the air flow through them being throttled by debris, snots of mortar or restricted apertures in substrates or walls (for example where a fascia plate hides an inadequate opening in plasterboard). Of secondary importance, but of concern in homes, is that a poor choice of location could lead to draughts.

b) Flue construction and flue repairs

- Flues can be built with: leaky joints; inappropriate insulation around liners; liners placed the wrong way up; and obstruction of the bore by mortar or sealant and litter. Mortar particularly accumulates at bends, and litter can be adhered to the bore by mortar or sealant.

- The effects of obstructions are fairly obvious (and potentially very dangerous). Leaking joints can allow flue gases to escape back into the building or into neighbouring buildings, particularly at high level. At low level, leaks can allow cool air to be induced into the flue gas flow leading to localised condensation with a risk of eventual obstruction. Inappropriate insulation is also a cause of condensation. Condensate running down a flue ought at least to be contained within it but can escape into the surrounding structure where flue liners are upside down.

- A number of proprietary systems are in use for relining existing flues, including the use of flexible metal liners and cast in situ systems. Their durability can depend upon such matters as the initial cleaning of the flue and the path taken by the lining. For cast systems, poor centring of the former around which the lining is cast can result in new flue walls which are dangerously thin in parts.

c) Support of flueblock chimneys

- Where flueblock chimneys are not to be bonded into surrounding blockwork (in timber framed buildings), the extent to which they are adequately supported by other means will depend upon the manufacturer's instructions and how well these are executed by builders. (There is no detailed guidance in Approved Document J.)

d) Openings in plasterboard

- Where dry lining is used, openings into fireplaces should be sealed around the perimeter to prevent flue gases penetrating the void behind the boards. Omitting this might not be evident on inspection.

- Poor sealing around the perimeter of a fireplace can also increase air leakage from a building – the path being through penetrations of the plasterboard by pipes, cables and electrical accessories into the void, then into the flue and the open air.

e) Fuel storage

- Approved Document J requires fire walls to be interposed between some fuel storage tanks and adjacent buildings, or to be integrated into those buildings. Their effectiveness in achieving their fire rating (actually, those for LPG protection are also intended to obstruct gas leaks) may depend upon workmanship to an extent, and those that are free-standing could be at risk of collapse if poorly built.

- The effectiveness and durability of bunds constructed around some oil tanks will be dependent upon quality of construction.

f) Timber frame

- With one exception, Approved Document J does not directly address timber-frames. However, special construction details must be adopted when installing combustion appliances in timber-frame buildings to counter shrinkage and the greater prevalence of combustible material. The effectiveness of these measures may be dependent upon good workmanship.

Performance testing

a) Impact of mechanical ventilation on open-flued appliances

- Flue spillage tests should be performed wherever mechanical extract ventilation and open-flued appliances are located in nearby spaces, to demonstrate that the appliance is not adversely affected. The disturbances due to ceiling fans should be included in some tests.

b) Checking natural draught flues

- When bringing existing flues back into service, or when new flues are completed, their compliance with the requirement J2 is to be demonstrated by tests from the set described in Appendix E of Approved Document J. These tests are:

  – Sweep the flue – demonstrate that it is clear and investigate debris for evidence of decay.

  – Coring ball test – a simple test to show that it is not obstructed. However, it may not reveal the presence of flexible debris that has adhered to the flue interior (real life example: crisp packet stuck to inside of gas flue).

  – Smoke tests to demonstrate that the flue is leaktight and that it draws. There is an inconsistency in the guidance in Approved Document J, which advises that tests should be carried out at an early stage when the structure of the chimney is visible, so that leaking smoke can be seen – that is, it should be done before dry lining is installed. It has been pointed out that this is not compatible with the exhortation to test with internal doors closed.

- In addition, Approved Document J advises that flue spillage tests should be carried out to show compliance with requirement J2 as part of the procedure to commission an appliance and to check for compliance with Part L or as required by the Gas Safety (Installation and Use) Regulations.

- If the plasterboard around a fireplace is not properly sealed, and penetrations of the plasterboard by pipes, cables and electrical accessories are also not sealed, air leakage can occur from the void behind the plasterboard into the flue and to the open air. It would be disproportionate to specifically test for such leakage paths, but they could be revealed in domestic airtightness testing if the fireplace opening through the decorative finish was sealed for the purpose. This possible leakage path is one that air pressure testers should be made aware of.

- The need for testing can arise when bringing a flue back into service or it is to be used with a different type or rating of appliance. The Approved Document lists various tests that can be used for this.

- A new chimney, even if well built in accordance with the prescriptions in the Approved Document, in some cases might not function for topographical or climate reasons. The tests on new flues are largely intended to reveal deficiencies of construction, and might not show that they fail to draw, or that deficiencies might develop at some point after occupation. Specific tests may need to be developed, therefore, to show (for example) that in all normal weather conditions flues should:

– Be capable of conveying the products of combustion to external air.

– Achieve internal temperatures that will prevent the formation of condensation within them, or provide for the control of such condensation as cannot be avoided.

– Resist the effects of chimney fires with minimal damage to the flue and no damage to the building within a normal duration.

– Enable the discharge of products of combustion such that they do not re-enter the building in dangerous concentration and do not pose a risk of fire to combustible roof coverings.

– Be resistant to blockage by nests, malign persons etc.

– Not leak to an extent that will lead to condensate forming in them, flue gases re-entering the building or adjacent buildings.

2.5.9 Energy conservation

Part L requirements

L1 Conservation of fuel and power.

Workmanship issues

- Insulation performance (continuity) and airtightness are the key areas affected by workmanship.

- Designers need to specify construction details of joints and interfaces to show how to avoid thermal bridges and air leakage.

- Poor thermal performance can result from use of incorrect materials – for example insulation of wrong type or thickness.

- Good on-site workmanship is important.

- Poorly or incorrectly fitted insulation can be less effective, particularly if air is free to circulate around the insulation, enabling air on the warm side of the insulation to mix with air on the cold side of the insulation. Designers might be able to reduce the risk of this problem occurring by giving clear instructions about how the insulation should be installed.

- Cold bridging can be caused by failure to pack insulation into tight places.

- Poor airtightness can result from poorly constructed masonry walls, and not sealing between elements or around services.

Performance testing

a) Airtightness

- Most new dwellings and new non-domestic buildings, and large extensions to non-domestic buildings, must now be pressure tested for airtightness. Air pressure testing can be avoided for small developments of dwellings and for buildings with a floor area not greater than 500m^2 by assuming high levels of leakage when calculating the CO_2 emission rate. However, this may not be a realistic option as construction costs will increase and it may encourage poor workmanship. Under Part L 2002, the requirement was to pressure test only buildings over 1000m^2 (although compliance with the requirement was poor). Air pressure testing of dwellings is a new requirement.

- Air pressure tests of junctions ideally need to be carried out at an early stage to check the design and workmanship. Remedial measures at the end of construction tend to be practical solutions – quick, short-term fixes with a limited life.

- Air pressure testing aims to pick up poor workmanship in general, not just airtightness.

- Some owners and developers when they issue design and build contracts demand even higher airtightness standards than required by Part L – 5 m^3/m^2/hr now and perhaps 3 m^3/m^2/hr in future (at a pressure difference of 50 Pa). They will pay for the first air pressure test themselves, but will require the developer to pay for any subsequent ones that might be needed. They believe testing is important because it is not possible to inspect everywhere – one building was left by the builder with the equivalent of a 3m diameter hole in it! Smoke tests are used to identify the location of leaks.

- Air pressure testing can take up to a day depending on the size of a building.

- Results are reasonably consistent, and easy to interpret by a specialist to show whether or not compliance has been achieved.

- It is not difficult to meet the airtightness standards in Part L, but failure rates are still quite high so that remedial work has to be carried out. Failure can delay occupancy by a week or more.

b) Commissioning

- Owners and developers of non-domestic buildings consider proper commissioning of heating, ventilation, air conditioning and other building services to be important. They may employ commissioning engineers to check and set up the building services systems for them.

- Commissioning involves:
  - Checking that installed components and systems are not faulty; that there are no gas or water leaks, or blockages in water pipes, air ducts or drains; that all electrical and hydraulic systems work.
  - Setting up and adjusting lighting and HVAC services – so that automatic and dimmable lighting reacts correctly to the amount of daylight; and heating and cooling systems are balanced, have the correct set-point temperatures, and are properly tuned to cope with changing loads and outside temperatures.
  - Checking that fire alarm and security systems all work correctly – smoke detectors, sounders, emergency lighting, etc.
- The whole process can take up to two weeks to complete.
- There is a requirement in Part L for a log book to record the results of commissioning tests and adjustments. In the past, building control bodies have tended not to ask to see the logbook, but it would be a useful check of how well building services have been installed and set up.
- Part L 2006 now makes it a requirement for a certificate to be issued to local authorities, signed by a competent person, confirming that building services have been properly commissioned.

c) Ventilation and cooling ductwork

- Apart from air pressure testing, the only other specific test required by Part L 2006 is air leakage testing of ductwork in non-domestic buildings, for systems served by fans with a design flow rate greater than 1 m^3/s.

d) Low-emissivity glazing

- Building control bodies use an electronic device to check that double glazed units installed in new and existing dwellings (by unregistered installers) have a low-emissivity coating on the outer face of the inner pane.
- All the windows of a house can be checked in less than 30 minutes. The failure rate is around 2%. Failure can cause delays of one to four weeks while the windows are replaced.
- The device does not indicate the quality of the coating, which some in building control feel would be useful.

e) Infrared thermography

- Infrared thermography can be used to give a qualitative indication of the thermal performance of buildings, and identify thermal bridges.

- Tests must be carried out by trained specialists, but thermography costs are falling as equipment costs fall.

- Tests on a large hospital may take five hours and cost £2000. Several dwellings an hour can be tested.

- Results are reasonably reliable but may need to be followed up by an endoscopic (borescope) examination – see g) below.

- It may not be practicable as a pre-completion test, however, because:

  – Tests may not be possible in sunny or windy conditions.

  – Tests are often carried out at night in the heating season and so might not be possible until six months after completion.

- The test might be more useful for checking the performance of a sample of buildings as part of an Accredited Construction Details system.

f) U-value measurement

- In situ U-value testing of walls and roofs is possible, but difficult as there are a number of potential pitfalls.

- For most walls and roofs, it requires two weeks of continuous monitoring.

- There is currently a lack of published literature showing how to measure U-values reliably, and it is a very specialist activity.

- For a hospital wing or a dwelling, U-value measurement might take three weeks and cost £2000.

- Results – unlike for thermography – are quantitative with a 10% error.

- Tests on dwellings and other buildings have shown that around 30% fail to comply with Building Regulations requirements.

- Measurements could be made cheaper and more routine, but it would need product development.

g) Borescope surveys

- Borescope surveys, for example of external walls, can take several hours. A great deal of judgement is needed to establish whether or not compliance has been achieved. Failures could cause delays of several days.

- Thermographic surveys can complement borescope surveys by identifying the suspect areas where inspection holes should be drilled, thereby speeding up the process.

International practice

Switzerland is the only country, other than the UK, known to have a mandatory requirement for airtightness testing. Accredited Construction Details-type systems appear to be the preferred means of demonstrating compliance in most other countries.

2.5.10 Accessibility

Part M requirements

M1 Access and use.

M2 Access to extensions to buildings other than dwellings.

M3 Sanitary conveniences in extensions to buildings other than dwellings.

M4 Sanitary conveniences in dwellings.

Workmanship issues

- Compliance with Part M is mostly about good design rather than workmanship on site.
- An issue is the pull strength of entrance doors. Part M calls for the opening force at the leading edge of the door to be no greater than 20N, but 98% of manually-operated doors currently installed do not comply. Fitting automatic doors which do comply is expensive.

Performance testing

Testing the pull strength of doors is not a requirement of Part M. Equipment is available but it is expensive. Pull strengths can be measured in a matter of minutes quite easily and reliably.

2.5.11 Glazing

Part N requirements

N1 Protection against impact.

N2 Manifestation of glazing.

N3 Safe opening and closing of windows, skylights and ventilators.

N4 Safe access for cleaning windows etc.

Workmanship issues

- Building control bodies find that safety glass is not used in around 5% of the cases where it should be to comply with Part N requirements.

Performance testing

- To qualify as a safety glass, glass must be given a BS 6206 marking on manufacture. The mark will be visible on installed toughened glass (which is heat treated after cutting), but may not be visible on installed laminated glass which can be cut from larger sheets.

- Laminated glass can be identified in situ using specialist ultra-sound or laser instruments.

- Glazing can be tested in a matter of minutes. Failure to comply can delay occupancy by a week or more.

2.5.12 Electrical safety

Part P requirements

P1 Design and installation of electrical installations in dwellings.

Workmanship issues

- Concern about the poor standard of electrical installation work in dwellings led to the introduction of Part P of the Building Regulations in 2005, along with a number of Government-authorised Competent Person Schemes to register installers doing electrical work. Installers who register with one of the Part P Competent Person Schemes are allowed to self-certify compliance with the Building Regulations. The scheme operators police their work, carry out an annual inspection, investigate complaints, require work to be re-done if necessary, and can eventually remove incompetent installers from their lists.

- Many unregistered electricians who do work in dwellings are not qualified to certify their own electrical work. Under Part P, building control bodies become responsible for checking electrical work in dwellings carried out by unregistered installers.

- This is a problem for many local authorities, who used to employ electrical specialists to inspect pubs, music halls and dance halls, etc, but no longer do so. Many building control departments therefore contract out the work to qualified electricians. Others are training their inspectors to carry out ‘first fix’ visual inspections of domestic electrical installations, but relying on outside contractors to carry out the electrical safety tests on completion of work.

- Non-domestic electrical work is not covered by Building Regulations, but may nevertheless be relevant. Most non-domestic contractors are members of the Electrical Contractors’ Association or registered with the NICEIC who police their work. The HSE investigate serious accidents.

- Owners and developers of commercial buildings find electrical workmanship on site can be poor. They tend to rely on consultants and commissioning engineers to check installations and the IEE certification provided by electricians. It is difficult to police electrical work as it quickly becomes hidden. A great deal of reliance is therefore placed on the IEE certificate, although random tests are also carried out.

Performance testing

- Performance testing of electrical installations is already a requirement of BS 7671 and Part P. A complete set of tests following a house rewire can take half a day if done properly.

- As part of periodic electrical testing, some owners of commercial buildings may use infrared thermography to check the quality of electrical connections, but it is expensive.

2.6 Consequences of non-compliance

- If a building fails a pre-completion test, it is the norm for building control bodies to ask for the test to be repeated following remedial action.

- Building control bodies will ultimately take a pragmatic approach to dealing with non-compliance so long as safety is not an issue. They will always insist that fire and emergency lighting systems should pass performance tests.

- They will accept trade-offs under Part L – for example where a poor U-value in one part of a building can be compensated for by a better U-value elsewhere. But trading-off is not appropriate under other Parts of the Building Regulations – for example Part E.

- The difficulty of implementing remedial treatments can vary considerably. For example, installing extra insulation in a loft is easy, but it can be very difficult elsewhere particularly if dealing with multiple composite constructions.

- Building services can be relatively easy to fix or replace, but dealing with faulty construction details is more difficult.

- If a wall fails an acoustic test, for example, remedial action can become very involved.

- Remedial measures following an air pressure test failure can be very expensive to carry out properly – if not simply impracticable. Rebuilding a roof, for example, would be out of the question, and so builders adopt the only practicable solution – which is to use fillers such as expanded foam with a life of only 10 to 15 years.

- Delays to building programmes can be very expensive if they delay occupancy. The duration and cost of performance tests and any subsequent remedial treatments are important issues for developers and owners.

- Building control bodies would welcome more advice on acceptable remediation strategies similar to that for air pressure testing during the Part L transition period to 31 October 2007. Required remedial treatments should be difficult so that builders will learn from their mistakes, but not so difficult that they become impracticable.

2.7 Accredited Construction Details

A disadvantage of pre-completion testing is that it identifies construction faults at a late stage when correcting them can be difficult, expensive and delay occupancy. It can encourage builders to take remedial measures on failing a test that are unsatisfactory – for example using fillers to plug air leaks or adding extra layers of plasterboard to improve sound insulation.

An alternative to pre-completion testing for showing compliance with Building Regulations is the 'Accredited Construction Details' system. It was first introduced as 'Robust Details' for dwellings under Part E to reduce the need for expensive sound tests, and combines the use of guidance in a best practice handbook with site inspection, sample pre-completion testing and long-term performance monitoring. The system is claimed to be less expensive, particularly for small builders, and more effective than a system that relies purely on pre-completion testing.

For Part E, housebuilders pay an Accredited Construction Details company for the use of construction details from their handbook. Work must be inspected under a formal scheme during construction – which is when identifying faults is most useful, rather than at the end of construction as with pre-completion testing. Some pre-completion testing is still carried out, but on a sample of only 2% of houses compared with 10% when not using robust details. The Accredited Construction Details company investigates and diagnoses failures that occur during sample tests and longer term performance monitoring, and can feed back the results to improve the details in the best practice handbook. Required standards are higher than for pre-completion testing – 50 dB for airborne sound insulation compared with 40 dB without robust details. It is claimed that the robust details system has pushed the industry into building better houses, and now sound insulation standards in England and Wales are higher than in any other European country, apart from Austria. Initial results from the Part E robust details scheme are encouraging. There is no uncertainty over the outcome of testing, which is what builders want.

Accredited Construction Details have been introduced under Part L 2006 as a way of showing compliance with requirements for airtightness and continuity of insulation. The use of Accredited Construction Details reduces the sample of dwellings that must be air pressure tested by half – from two to one of each type of dwelling. Accredited Construction Details, combined with an on-site inspection regime, are also specified in the Approved Document as a way of ensuring continuity of insulation.

Accredited Construction Details systems can be a good alternative to pre-completion testing. However, pre-completion testing must be made mandatory for builders who do not adopt Accredited Construction Details, and on-site inspection and policing must be effective to ensure good workmanship. Higher standards must also be set to compensate for the smaller amounts of testing that take place.

Pre-completion test methods must in any event be available to builders wanting to adopt innovative methods of construction not covered by the Accredited Construction Details handbook.

Accredited Construction Details may also not be appropriate in other circumstances. For example, the guidance and details for flue design given in the Approved Document J will work in the majority of cases, but there will be some where they will not work even if well executed. Accredited design and inspection therefore cannot fully substitute for pre-completion testing. Even the present Part J testing regime is not fully rigorous as results may depend upon the weather, and it is likely that some remedial work will continue to be needed whatever level of compliance with the Approved Document is achieved.

2.8 Performance testing in other countries

Approaches to organisations and building research professionals across Europe – for example, members of the European Network of Building Research Institutes (ENBRI) and through personal contacts (see Appendix D) – along with literature and Internet searches (including of European government websites) revealed little evidence of statutory requirements for pre-completion testing in other European countries.

- In Sweden there is a requirement to test the performance of ventilation systems and their controls in both new and existing buildings.

- Switzerland carries out airtightness testing as in the UK.

- In Spain, requirements for carrying out performance tests on HVAC systems are being introduced under the Spanish Building Technical Code (CTE) as part of implementing the Energy Performance of Buildings Directive. (New and refurbished buildings must now provide between 30% and 70% of domestic hot water by solar thermal energy.) Tests carried out on HVAC systems include:

  – Water, air conditioning and refrigerator pipework leakage.

  – Pipework radial expansion and contraction.

  – Flue airtightness.

  – Air and water distribution system balancing.

  – Commissioning, as part of a regulatory check, of air distribution systems and air conditioning. equipment under normal conditions.

  – Efficiency of heat generators (boilers, etc), heat exchangers and refrigeration equipment.

- Efficiency of and contribution by renewables.
- Control system settings and function.
- Operation of fans and other electrical equipment under normal conditions.
- Temperature and temperature drop for distribution systems and terminal units.
- Energy losses on water distribution systems.

Several countries require radon testing of new buildings. In most cases this involves testing once the building is occupied using a three-month radon measurement. This is the case in Sweden and several US states. However, the uptake of measurement is sporadic, few people report their results to the authorities and little appears to be known as to whether people remediate their buildings if the results exceed action levels. There is also a requirement to test completed buildings in the Czech Republic. In the Republic of Ireland occupiers of new buildings are recommended to test after purchase. In Switzerland some Cantons require testing but generally it is only a recommendation. The Cantons have a legal right to demand that properties are tested but there is little evidence to suggest that this has happened, and testing to date has been voluntary. Measurement in most cases relies upon three month measurement after occupation.

Generally, the approach taken in other countries to achieving compliance with building regulations is prescriptive, or by the use of Accredited Construction Details-type systems, or by requiring or expecting construction work to be carried out by qualified installers. In France, for example, unqualified home owners who carry out work themselves can find it difficult to get work approved by inspectors or to get insurance cover. In the UK, by contrast, anybody can carry out construction work once planning permission and building regulations approval have been given. Inspection and testing by building control bodies therefore becomes more important.

2.9 Technology transfer

The project has not identified any need for introducing performance tests into the Building Regulations from other industries. Performance tests that have been identified are already in use within the construction sector, although many need further development to become standard test methods. A search for non-destructive test methods was nevertheless carried out, and the following websites found to be the most useful.

There are numerous British, European and International standards covering a wide range of standard test methods used in other industries. It is outside the scope of this project to review them, but further details are available at the BSI website, www.bsonline.bsi-global.com.

Descriptions of a wide range of construction-related test methods can also be accessed at the websites of ENBRI members through http://enbri.cstb.fr/members.asp.

Information about non-destructive test methods can be obtained through the website of the British Institute of Non-destructive Testing (BINDT) at www.bindt.org. Links are provided to test methods including:

- Acoustic emission methods.
- Coating thickness measurement.
- Eddy current testing.
- Laser-based inspection.
- Leak testing.
- Liquid penetrant inspection.
- Magnetic flux leakage methods.
- Magnetic particle inspection.
- Neutron radiography.
- Optical metrology and holography.
- Radiography.
- Radioscopy.
- Resonant inspection.
- Stress measurement.
- Thermography.
- Ultrasonic flaw detection and sizing.
- Ultrasonic thickness gauging.

Chapter 3

Conclusion

Compliance and workmanship

- Respondents to the consultation felt that failure to comply with the Building Regulations does not arise from incompatible requirements in different Parts of the Regulations. Rather it happens as a result of poor workmanship on site, or because designers and installers fail to take account of all the differing requirements in the Regulations.

- Workmanship can have an impact in all areas of building work, but is particularly important where performance depends on the correct design and implementation of construction details, such as at joints and interfaces. Relevant Parts of the Building Regulations in England and Wales include B (Fire safety), C (Site preparation and resistance to contaminants and moisture), E (Resistance to the passage of sound), J (Combustion appliances and fuel storage systems), L (Conservation of fuel and power) and P (Electrical safety). These are the areas where performance testing has the greatest potential to be useful. For other Parts of the Regulations – such as A (Structure) and M (Accessibility) –compliance can be checked for the most part by simple visual inspection, by making sure that accredited products and materials have been used, or by checking or performing calculations.

Performance testing

- A range of pre-completion tests is already carried out to check for compliance with Building Regulations. They are either a requirement of the Regulations, called for by guidance in Approved Documents, requested or carried out by building control bodies, or a part of commissioning building services.

- Under Part L, a commissioning certificate must now be issued to the local authority to show that building services and controls have been properly set up. The commissioning procedure is described in two ‘second tier’ documents, ‘Domestic Heating Compliance Guide’, and ‘Non-domestic Heating, Cooling and Ventilation Compliance Guide’.

- Tests that are called for in the Building Regulations or Approved Documents are:

  – Sound transmission in dwellings and rooms for residential purposes.

  - Effectiveness of drains.
  - Effectiveness of flues and ventilation for combustion appliances.
  - Airtightness of dwellings and other buildings.
  - Airtightness of ductwork in non-domestic buildings.
- Other tests that may be requested or carried out by building control, or that are part of commissioning are to check:
  - Fire safety system functionality (fire dampers, emergency lighting, sounder audibility, smoke detectors, break glasses, door closers, emergency locks, etc).
  - Smoke movement within a building (generally only for large, complex or prestigious structures such as airport terminals), and, where relevant, airtightness of fire escape routes.
  - Heating, ventilation and air conditioning system performance.
  - Lighting performance.
  - Correct orientation of low-emissivity windows.

Consequences of failing a test

- Following a failure to comply with a performance test, building control bodies will usually ask for remedial measures to be taken and then a repeat test. However, they will ultimately take a pragmatic approach to dealing with non-compliance – depending on the cost of remedial works, the likely delay to occupancy, and whether safety is an issue.
- They will accept trade-offs under Part L – for example where a poor U-value in one part of a building can be compensated for by a good U-value elsewhere – but trading off is not appropriate under other Parts of the Building Regulations.
- Building control bodies would welcome more advice on acceptable remediation strategies.

Scope for further performance testing

- There is not much enthusiasm on the part of developers and owners for additional mandatory pre-completion tests to be introduced into the Regulations. They are concerned that, in addition to increasing costs, testing will delay occupancy, especially if remedial treatments are identified as being necessary. The duration and cost of performance tests and of any subsequent remedial treatments are significant issues for developers and owners.

- To be useful, pre-completion performance tests must be quick. They must not delay occupancy, or have to be carried out after occupancy when they may become impracticable.

- Certain performance tests are carried out on buildings to identify building defects or for research purposes. Some may be suitable for inclusion in the Building Regulations as pre-completion tests. Others, owing to their complexity, cost, duration, etc, may be more suited for use in conjunction with Accredited Construction Details – as quality assurance tests on a sample of buildings, during or after construction, to check workmanship and how well the Accredited Construction Details perform in practice.

- Tests that could be considered for use as pre-completion tests or with Accredited Construction Details schemes (see also Table 1) include:

  – *Penetration of fire barriers*. Local airtightness testing – as an extension to airtightness testing under Part L – could be used to identify penetrations of fire barriers. (Part B)

  – *Radon testing*. A requirement could be introduced for a two-week radon pre-completion test if a builder has neglected to install a radon barrier in a radon area, to demonstrate that measures are not necessary, or better to show that post-construction measures (such as installation of a sump) have been effective. A 12-week radon test could be used in conjunction with an Accredited Construction Details scheme. (Part C)

  – *Sound insulation between attached dwellings across hallways, stairs and small rooms*. Methods for carrying out such tests are not currently specified in Approved Document E, so that sometimes it is not possible to measure sound insulation between terraced and semi-detached houses for regulatory purposes. Consideration could be given to developing standardised test methods based on existing British Standards. (Part E)

  – *Measurement of noise from building services*. Noise generated by equipment such as extractor fans and central heating pumps can be disturbing to occupants in adjacent properties. Procedures in existing standards for rating industrial noise could be adapted and used in dwellings for regulatory purposes. (Part E)

  – *Landfill gas testing*. A pre-completion airtightness test of ground floor suspended floors – again as an extension to Part L airtightness testing – could be a requirement to show that landfill gases will not be able to enter a building. Measurements could also be made of ambient carbon dioxide and methane levels. (Part F)

  – *Mechanical ventilation system performance*. As buildings become more airtight, so it becomes more important to ensure that there is adequate ventilation. Measurements on mechanical ventilation systems have shown that there can be significant shortfalls in airflow, which can lead to occupant discomfort and black mould growth. It is possible to measure the flow through a mechanical ventilation system at different settings, using equipment such as balometers or flowfinders, to compare ventilation rates with the recommendations in the Approved Document, but doing so may not be cost-effective as a pre-completion test. (Part F)

- *Measurement of equivalent area*. DfES Building Bulletin 101 'Ventilation of school buildings' suggests a way of measuring equivalent area of trickle ventilators. The measurement could be an extension to airtightness testing under Part L. (Part F)

- *Water consumption*. Simple tests for measuring toilet flush volumes and flow rates from showers, etc, could be specified to accompany proposed new requirements to limit water consumption in buildings. (Part G or new Part Q)

- *Performance tests on flues*. These are intended to show that flues have been properly constructed. Tests could be developed to show that flues draw successfully in a range of normal weather conditions and that they will not experience premature failure. Airtightness testing under Part L could be used to check seals around fireplaces. (Part J)

- *Infrared thermography*. This is a well established test method for qualitative observation of thermal performance and locating thermal bridges. It can be carried out only during the colder times of the year, or at night when a 10°C temperature difference between the inside and the outside of a building can be achieved, and may therefore not be useful as a pre-completion test. (Part L)

- *Borescope surveys of external walls*. These can be used in conjunction with infrared thermography to determine the condition of insulation and whether it has been installed effectively. (Part L)

- *In situ measurement of U-values*. This measurement method is used for research purposes but requires further development if it is to become a standard test method. It is unlikely to be suitable as a pre-completion test. (Part L)

- *Hot water run-off times*. A simple test to measure hot water run-off times could be useful when installing, for example, combination boilers. (Part L and Part G or new Part Q)

- *Pull strength of entrance doors*. Instruments are available for measuring pull strengths to check that fire doors are not too difficult to open. (Parts B and M)

- *Presence of laminated safety glass*. Laminated safety glass is not installed when it should be in around 5% of cases. Unlike toughened glass, laminated glass can be cut to size and may show no identification marks. Laminated glass can be identified in situ using specialist ultra-sound or laser instruments. (Part N)

Accredited Construction Details

- Under Accredited ('Robust') Construction Details schemes, the use of construction details from an approved handbook is combined with a formal system of inspection, sample testing and long-term performance monitoring.

- Supporters of Accredited Construction Details schemes argue that they result in a better standard of workmanship than do requirements to carry out pre-completion testing. Pre-completion testing is more costly and penalises small builders disproportionately. It also identifies defects at a late stage in the construction process when proper remedial action is often difficult, and therefore encourages unsatisfactory, short term solutions.

- To be effective, an Accredited Construction Details scheme would need to be offered in the Regulations as an alternative to mandatory pre-completion testing.

- Pre-completion tests would need to be available in any event for builders wanting to adopt innovative methods of construction not covered by the Accredited Construction Details handbook.

Testing in other countries and other industries

- Generally, the approach taken in other countries to achieving compliance with building regulations is prescriptive, or by the use of Accredited Construction Details-type systems, or by requiring or expecting construction work to be carried out by qualified installers. In the UK, because anybody can carry out construction work once planning permission and building regulations approval have been given, more reliance must be placed on inspection and testing by building control bodies.

- There are numerous British, European and International standards covering a wide range of standard test methods used in construction and other industries. Information about them can be obtained from the BSI website at www.bsonline.bsi-global.com, from members of the European Network of Building Research Institutes through http://enbri.cstb.fr/members.asp, and from the website of the British Institute of Non-destructive Testing (BINDT) at www.bindt.org.

Recommendations for further work

- It is recommended that a more in-depth review should be carried out of requirements for performance testing in emerging regulations in other countries. All EU countries, for example, are in the process of introducing new regulations to comply with the Energy Performance of Buildings Directive, which calls specifically for regular inspection and testing of boilers and air conditioning systems. The advice of building regulations experts in the countries would be sought.

- Further work is needed to determine if the performance tests identified in this study would be cost-effective as requirements in the Building

Regulations. This would involve specifying a standard pre-completion test and carrying out a cost-benefit analysis as part of the Regulatory Impact Assessment associated with a proposed change to the Regulations.

Table 1 Summary of current and possible future test methods

Part	Performance test	Standard method	Application
B	Smoke movement – already carried out on some large buildings	No	PCT
	Fire safety systems – carried out as part of commissioning	Yes	PCT
	Fire barriers – may be able to identify penetration by air-pressure testing	No	PCT
	Pull strength of entrance fire doors	No	PCT
C	Radon – 2-week test	Yes	PCT
	Radon – 12-week test	Yes	ADT
E	Air and impact sound transmission – already specified for dwellings	Yes	PCT
	Sound transmission across hallways and stairs	No	PCT
	Sound transmission across small rooms	No	PCT
	Sound transmission from building services	No	PCT
F	Ventilation – some tests required as part of commissioning	Yes	PCT
	Mechanical ventilation flow rates	No	ADT
	Landfill gas – airtightness test of suspended floors, ambient CO_2/methane	No	PCT
	Equivalent area – airtightness test	No	PCT
G	Water consumption – simple test method could be specified	No	PCT
H	Drains – tests already required	Yes	PCT
J	Combustion appliances – test on flues and chimneys already required	Yes	PCT
	Flue tests in a range of normal weather conditions could be developed	No	ADT
	Seals around fireplaces – airtightness test	Yes	PCT
L	Building airtightness – tests already required	Yes	PCT
	Airtightness of ductwork – test already required	Yes	PCT
	Building services – some tests required as part of commissioning	Yes	PCT
	Hot water run-off times – simple test method could be specified	No	PCT
	Insulation performance – infrared thermography	Yes	PCT
	Insulation performance – borescope surveys combined with thermography	No	ADT
	Insulation performance – U-value testing still a research tool	No	ADT
	Low emissivity glazing – presence of coating already checked	Yes	PCT
	Low emissivity glazing – performance of coating	No	PCT
M	Pull strength of entrance fire doors	No	PCT
N	Laminated safety glazing	No	PCT
P	Electrical installation – tests already required	Yes	PCT

Notes: PCT: Pre-completion testing ADT: Accredited Details testing
All pre-completion tests are also suitable for use as Accredited Construction Details tests

Appendix A

Summary of the research

The project has investigated the scope for extending the range of performance tests carried out on buildings to check for compliance with the Building Regulations. Performance testing can be used before completion ('pre-completion testing') to prove to building control bodies that Building Regulations requirements have been met, or for quality assurance purposes during or after construction as part of a system of 'Accredited Construction Details' (in which performance tests are carried out on a sample of buildings to check workmanship and how well the construction details are working). A range of pre-completion tests is already carried out to check for compliance with Building Regulations. They are either a requirement of the Regulations (for example air pressure testing), called for by guidance in Approved Documents (for example tests on drains), requested by building control bodies (for example tests on fire safety systems), or a part of commissioning building services (for example boilers and controls). Under Part L, commissioning tests are effectively mandatory now that a commissioning certificate must be issued to the local authority to show that building services and controls have been properly set up. The project report describes tests that may be suitable as pre-completion tests or for use in conjunction with Accredited Construction Details. They include:

- Two-week and 12-week measurements of radon gas.
- Measurement of noise transmitted between dwellings across halls and small rooms and from building services.
- Measurements of mechanical ventilation system performance.
- Airtightness testing (as an extension to Part L tests) to determine equivalent areas of trickle vents, identify penetrations in fire barriers, check for leaks into flues around fireplaces, and check for air leakage in sub-floors where there is landfill gas.
- Measurement of ambient carbon dioxide and methane levels.
- Tests on flues under different weather conditions.
- Tests of insulation effectiveness using infrared thermography, borescope surveys and in situ U-value measurement.

- Measurements of water consumption and hot water run-off times.
- Measurement of the pull-strength of doors to show that they meet Part B requirements while not being too difficult to open.
- Checks for the presence of laminated safety glass.

Generally the study suggested that there is little enthusiasm in the construction industry for further mandatory pre-completion testing owing to the cost and likelihood of delays to occupation. For a given test, identifying whether it will be suitable as a pre-completion test or for use with Accredited Construction Details will call for a cost-benefit analysis when the relevant Part of the Building Regulations is next reviewed.

Appendix B

Questionnaire

Part 1 – Background

Introduction

- BRE is carrying out a research project for the Government department responsible for the Building Regulations – the Buildings Division of the Department for Communities and Local Government.

- We are investigating the scope for extending the range of pre-completion **performance** tests carried out on buildings – as opposed to inspections and calculations – to check for compliance with Building Regulations, both when new buildings are constructed and when existing buildings are refurbished.

- Examples of performance testing are:

  - Air pressure testing.

  - Infrared thermography.

  - U-value testing.

  - Acoustic testing.

  - Radon testing.

Purpose of questionnaire

- To seek your views on:

  - The impact of workmanship and conflicts between different requirements in the Building Regulations on compliance with all Parts of the Building Regulations.

  - The scope for carrying out more performance testing to check for compliance with Building Regulations.

Note: BRE recognises that you may have expertise and opinions on only some Parts of the Building Regulations – please respond for the Parts you are familiar with. The boxes will expand as you type your answers.

Part 2 – Questions

Workmanship

Question 1 **Considering the requirements in all Parts of the Building Regulations, and guidance in the Approved Documents, what are the key areas where performance is likely to be strongly linked to workmanship?** *Note: workmanship includes the influence of designers and procurers on the end result.*

Answer 1 *Please insert comments against each Part as appropriate*
A Structure:
B Fire safety:
C Site preparation and resistance to contaminants and moisture:
D Toxic substances:
E Resistance to the passage of sound:
F Ventilation:
G Hygiene:
H Drainage and waste disposal:
J Combustion appliances and fuel storage systems:
K Protection from falling:
L1A Conservation of fuel and power in new dwellings:
L1B Conservation of fuel and power in existing dwellings:
L2A Conservation of fuel and power in new buildings other than dwellings:
L2B Conservation of fuel and power in existing buildings other than dwellings:
M Access to and use of buildings:
N Glazing:
P Electrical safety in dwellings:

Conflicts between requirements

Question 2
In your experience, can conflicts between different Parts of the Building Regulations lead to poor compliance?
Examples of where conflicts may arise are between:
• *airtightness and ventilation (maintaining adequate ventilation)*
• *thermal insulation and sound insulation (acoustic bridging)*
• *ventilation effectiveness and fire safety (fire spread)*
• *insulation and fire safety (overheating of electrical cables and equipment)*

Answer 2

Performance testing

Question 3
What performance tests (as opposed to calculations and inspections) are carried out at the moment to check for compliance with Building Regulations, and in what circumstances?
Examples are testing for: airtightness, sound transmission, radon, drains

Answer 3 *Please answer for each Part of the Building Regulations as appropriate*
A Structure:
B Fire safety:
C Site preparation and resistance to contaminants and moisture:
D Toxic substances:
E Resistance to the passage of sound:
F Ventilation:
G Hygiene:
H Drainage and waste disposal:

Answer 3 (continued) *Please answer for each Part of the Building Regulations as appropriate*
J Combustion appliances and fuel storage systems:
K Protection from falling:
L1A Conservation of fuel and power in new dwellings:
L1B Conservation of fuel and power in existing dwellings:
L2A Conservation of fuel and power in new buildings other than dwellings:
L2B Conservation of fuel and power in existing buildings other than dwellings:
M Access to and use of buildings:
N Glazing:
P Electrical safety in dwellings:

Question 4

What other tests exist that could be used to check for compliance with Parts of the Building Regulations?

Answer 4

Question 5

How practical are the above tests when applied to dwellings and other buildings?

For each test mentioned above, please add a comment on:

- *cost*
- *duration*
- *reliability and consistency of results*
- *ease of interpreting results*
- *how clearly compliance with requirements is established*
- *the failure rate*
- *potential for delaying occupancy, taking account of the need for remedial action*

Answer 5							
Test	Cost (£)	Duration (hours)	Reliability	Interpreting results	Establishing compliance	Failure rate (%)	Delay (days)
Other comments?							

Question 6

What other tests would be worth developing to check for compliance with the Building Regulations?

Answer 6

Consequences of failing a performance test

Question 7

In your experience, when a test failure occurs do building control bodies always insist on improvements being made, and then a repeat test?

Answer 7

Question 8

How easy is it to carry out remedial treatment following a test failure?

Answer 8

Question 9

Do building control bodies allow trade-offs if remedial treatment is costly or would fail to rectify the problem?

Trade-offs are improvements elsewhere to compensate for poor performance.

Answer 9

Availability of qualified testers

Question 10

What testing organisations do you know of that can provide competent persons for performance tests?

Answer 10

Approved design and construction details

Question 11

Do you believe that the use of approved design and construction details when combined with on-site inspection is a good alternative to pre-completion testing?

Answer 11

Other comments

Question 12

Do you have any other comments?

Answer 12

Appendix C

Acknowledgements

BRE would like to thank the following for their help in preparing this report:

- David Baker, Robust Details Ltd (ex Technical Director, Home Builders Federation)
- Steve Blackmore, Swansea City & County Council, Building Control
- Andrew Ford/Claire Wildfire, Fulcrum Consulting
- Bill Wright, John Lewis
- Neil Smith, NHBC
- Dave Mitchell, Home Builders Federation
- Linda Stewart, SBSA
- Pierre Lopez, Aerco

The BRE specialists were:

- Dr Gerard Canisius, Part A, Structure
- Tom Lennon, Part B, Fire safety
- Chris Scivyer, Part C, Radon and landfill gas
- Dr Robin Hall, Part E, Sound
- Dr David Ross, Part F, Ventilation
- Martin White and John Griggs, Part G, Hygiene, Part H, Drainage and waste disposal
- Peter Guy, Part J, Combustion appliances
- Dr Sean Doran and Jose Ortiz, Part L, Conservation of fuel and power
- Ken Bromley, Part P, Electrical safety – dwellings

Appendix D

Organisations contacted

(a) National governments

- Sweden at www.sweden.gov.se
- Denmark at www.denmark.dk
- Finland at www.government.fi
- Norway at www.odin.dep.no
- France at www.premier-ministre.gouv.fr
- Germany at www.deutschland.de
- Switzerland at www.swissworld.org
- Austria at www.austria.gv.at

(b) Other bodies

- European Organisation for Technical Approvals (EOTA) at www.eota.be
- Energy Performance Regulations for Buildings in European Countries at www.enper.org
- International Council for Research and Innovation in Building, email secretariat@cobworld.nl
- European Network of Building Research Institutes (ENBRI): 20 members via website at http://enbri.cstb.fr/members.asp
- British Institute of Non-destructive Testing (BINDT) at www.bindt.org
- Passivhaus: 21 stakeholders. Web address www.passivhaus-vauban.de