



A practical guide to building airtight dwellings



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FOREWORD

In homes of previous generations, common features were open chimneys and floorboards with gaps in-between and no attention was paid to airtightness at all. In more recent times the trend has been away from these and we have realised just how much energy can be wasted through unwanted air leakage.

Changes to Building Regulations have now made airtightness an issue which cannot be ignored and as we get ever-closer to the zero carbon homes of the future, excellent standards will have to be achieved in all new homes.

Feedback from airtightness testing across the industry is encouraging and demonstrates that considerable improvement has already been made. Key among the lessons already learned by many builders is that airtightness has to be given close attention from the early stages of the design and throughout the construction phase. It is not something that can be sorted out easily when the nearly-completed home fails an air pressure test.

This guide, which has been jointly produced by the NHBC Foundation and the Zero Carbon Hub, brings together the experiences of those who have already got to grips with airtightness for the benefit of designers and builders who have not. It identifies the common air leakage paths in typical constructions and provides practical advice on how these can be addressed. It stresses the importance of designing in an air barrier and ensuring that its integrity is maintained throughout the construction phase.

I hope you will find the guide a useful part of the toolkit for addressing this important feature of homes you are designing and building today, and in the low and zero carbon future.

Neil Jefferson

CEO, Zero Carbon Hub

ABOUT THE NHBC FOUNDATION AND THE ZERO CARBON HUB

The NHBC Foundation was established in 2006 by the NHBC in partnership with the BRE Trust. Its purpose is to deliver high-quality research and practical guidance to help the industry meet its considerable challenges.

Since its inception, the NHBC Foundation's work has focused primarily on the sustainability agenda and the challenges of the government's 2016 zero carbon homes target. Research has included a review of microgeneration and renewable energy techniques and the groundbreaking research on zero carbon and what it means to homeowners and housebuilders.

The NHBC Foundation is also involved in a programme of positive engagement with government, development agencies, academics and other key stakeholders, focusing on current and pressing issues relevant to the industry.

Further details on the latest output from the NHBC Foundation can be found at www.nhbcfoundation.org.

NHBC Foundation Advisory Board

The work of the NHBC Foundation is guided by the NHBC Foundation Advisory Board, which comprises:

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The Zero Carbon Hub

Established in 2008, the Zero Carbon Hub supports and reports to the 2016 Taskforce which is chaired by the Housing Minister and the Executive Chairman of the Home Builders Federation. It is a public/private partnership established to take day-to-day operational responsibility for co-ordinating delivery of low and zero carbon new homes. This purpose will be fulfilled by monitoring, co-ordinating and guiding the zero carbon programme and engaging organisations active in low and zero carbon homes. To do this the Zero Carbon Hub is developing five integrated workstreams – energy efficiency, energy supply, examples and scale up, skills and training and consumer engagement. For more information visit www.zerocarbonhub.org.

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1 Understanding airtightness

This guide is intended for housebuilders and designers. It offers practical advice on how to achieve a reasonable level of airtightness in dwellings.

1.1 Airtightness – why it is important

Achieving a reasonable level of airtightness is important for the energy efficiency of dwellings and the comfort of occupants. The benefits of improved insulation levels and more energy efficient heating systems are lost if warm air can leak out of a building and cold air can leak in. A mandatory requirement for airtightness has been set by the Building Regulations (for England and Wales, and Northern Ireland)¹ to ensure that reasonable standards are being achieved, and it is compulsory to subject samples of newly built dwellings to a pressure test in order to measure and confirm their airtightness on completion.

1.2 Why build airtight dwellings?

Home energy use is responsible for approximately 27% of UK carbon dioxide (CO₂) emissions² and poor airtightness can be responsible for up to 40% of heat loss from buildings.³

The level of airtightness achieved is measured as air permeability:

$$\text{m}^3/\text{h}\cdot\text{m}^2 \text{ at } 50 \text{ Pa}$$

In other words, the quantity of air (in m³) that leaks into or out of the dwelling per hour, divided by the internal area (in m²) of the building fabric at 50 Pa.

Where a lower value is achieved the dwelling is more airtight. For example, a dwelling that achieves 7 m³/h.m² at 50 Pa will have demonstrated a better standard of airtightness, and a dwelling that achieves 3 m³/h.m² at 50 Pa would be even better.

Approved Document L1A of the Building Regulations (England and Wales),⁴ Technical booklet F1 (Northern Ireland)⁵ and Building (Scotland) Regulations 2004 technical handbook section 6: Energy⁶ currently set a reasonable limit for airtightness of 10 m³/h.m² at 50 Pa.

The result of an air permeability test is used in the calculation to confirm that the rate of CO₂ emissions from a dwelling is less than the target needed to comply with the Building Regulations.

Table 1 refers to air permeability standards which are referred to in the Energy Saving Trust publication *Achieving airtightness in new dwellings: case studies*.⁷

	Maximum air permeability (m ³ /h.m ²) at 50 Pa
Approved Document L1A of the Building Regulations (England and Wales), ⁴ Technical booklet F1 (Northern Ireland) ⁵ and Building (Scotland) Regulations 2004 technical handbook section 6: Energy ⁶ – poorest acceptable standard	10
Energy Saving Trust (naturally ventilated)	5
Energy Saving Trust (mechanically ventilated)	3
The Netherlands	6
Germany (air changes per hour at 50 Pa)	1.8–3.8 (n ₅₀ h ⁻¹)
PassivHaus	<1
Super E (Canada) (air changes per hour at 50 Pa)	1.5 (n ₅₀ h ⁻¹)

Proposed revisions to Building Regulations Part L, and the application of the Code for Sustainable Homes, will encourage even lower CO₂ emission rates and hence higher standards of airtightness.

- A target to achieve a 25% reduction in CO₂ emissions from homes from 2010 (Code Level 3) may require an airtightness standard of around 3 m³/h.m² at 50 Pa.
- A target for zero carbon homes (Code Level 6) for 2016 will require dwellings to achieve airtightness levels better than 3 m³/h.m² at 50 Pa and approaching 1 m³/h.m² at 50 Pa.
- Code Level 5 and 6 homes have been built in UK with airtightness levels of 1 m³/h.m² at 50 Pa having been achieved.

As airtightness increases, the energy needed for heating (and cooling) reduces, but the need for controlled ventilation to ensure occupant comfort and safety increases. Therefore, when making a dwelling airtight to prevent air leakage, it is important to also provide adequate ventilation: build tight – ventilate right.

1.3 Understanding the causes of infiltration and exfiltration

Infiltration is when air leaks through cracks and gaps in the dwelling's fabric. The amount of infiltration is affected by design and quality of construction and by wind speed/direction:

Wind: Wind against the dwelling causes pressure differences between the inside and outside. Air is drawn into the dwelling through gaps on the windward face (infiltration) and leaves the dwelling on the leeward face (exfiltration).

Air buoyancy: Warm indoor air is more buoyant than colder outside air (buoyant air rises by convection). This rising effect draws in cooler air from outside (infiltration) which is felt as cold draughts inside. The rising effect increases the pressure inside the dwelling which pushes warm air out of cracks and gaps in the envelope (exfiltration). It is worsened when it is very cold outside and warm inside.

Condensation: Warm moist indoor air that is drawn out through gaps in the envelope may lead to interstitial condensation occurring on cold surfaces in the fabric.



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2 Common air leakage paths

Air leakage paths, which are commonly found in dwellings, can be easily avoided by careful design and good quality construction practice (Fig. 1).

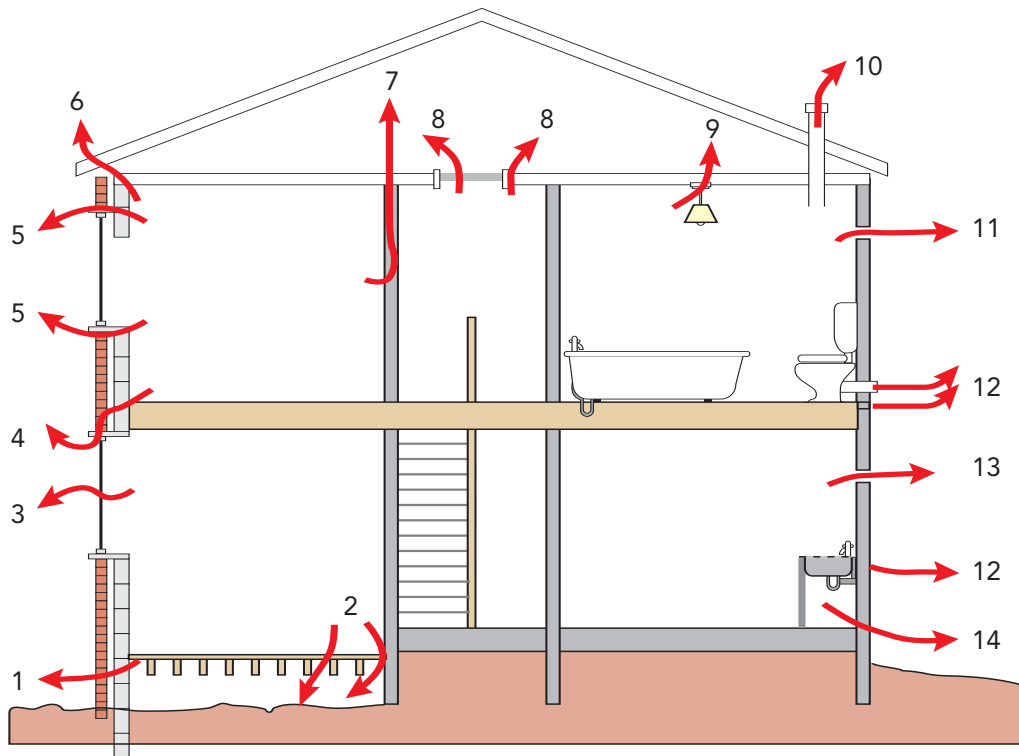


Figure 1 Potential air leakage paths (the numbered points in section 2.1 give a description for each path).

2.1 Descriptions of air leakage paths

- 1 Suspended floors (timber and concrete beam and block):
 - Gaps between floorboards or concrete blocks around the perimeter of the dwelling/junction between floor and walls.
 - Large gaps left around services that penetrate through the floor (eg soil vent pipes).
- 2 Gaps left between floorboards or blocks and also gaps around services (eg pipes and cables).
- 3 Window/door components:
 - Windows and doors that do not close tightly resulting in large air leakage paths.
- 4 Joists that penetrate into wall construction:
 - Masonry walls: Gaps left around joists that penetrate into the inner leaf of external walls. Air leakage from the cavity into the upper floor void leaking into the dwelling through gaps between flooring and through any penetrations in the ceilings, eg recessed lights and ceiling light roses.
 - Timber frame construction: Gaps left around joists, where they penetrate through the air barrier, allowing air leakage into the dwelling through penetrations in the walls and ceilings.
- 5 Window sills and reveals:
 - Air can leak directly to the outside or into the cavity through gaps between the window frame and wall reveals.
 - Gaps around window casements (component air leakage).
 - Gaps between doors and frames.
 - Gap at bottom of door across threshold.
- 6 Gaps between dry lining and ceilings:
 - Gaps and insufficient sealing at the wall to ceiling junction allowing air to leak into, and out of, the unheated loft void.
- 7 Internal partition walls:
 - Air leakage can occur through internal partitions if the detailing or location of the air barrier leaves a pathway between indoors and outdoors. Gaps in the air barrier allowing air into the partition which then leaks through penetrations such as light switches and power sockets.
- 8 Loft hatches:
 - Loft hatches that do not fit properly (prefabricated loft hatches can become twisted as they are installed) (Fig. 2).
 - Inadequate seals between the hatch and the frame.

(Note: condensation can be an issue if the loft hatch does not fit – warm moist air from the dwelling rises into the loft and condenses on cold surfaces, such as roof timbers and roof underlay.)



Figure 2 Air leakage through gaps around a loft hatch.

9 Ceiling roses and recessed ceiling lights:

- Holes made through the upper ceiling for lights creating air leakage paths into the loft space.

10 Gaps around soil and vent pipes and flue stacks:

- Gaps in ceilings around soil vent pipes and passive flue stacks allowing air leakage paths.

11 Gaps around extractor fans and cooker hoods:

- Poorly fitted extractor fans and cooker hoods allowing air leakage through gaps left between the wall and the ventilation duct.

12 Gaps around service pipes (these gaps can often provide the largest air leakage paths in dwellings) (Fig. 3):

- Gaps left around service pipes, cables and ducts that pass through the dwelling's external fabric can be a major contributor to poor airtightness.
- Large holes often created for much smaller diameter pipes to pass through.
- Gaps and holes around service penetrations often hidden from view behind baths, vanity units and kitchen units.
- Cuts and holes in vapour control membranes (used as air barrier for framed construction) made to accommodate pipes, cables and ducts as they penetrate through the dwelling's external walls resulting in large air leakage rates.



Figure 3 Gap around soil pipe at back of toilet.

13 General air leakage through walls (Fig. 4):

- Gaps in mortar joints (or in some cases missing mortar joints) between concrete blocks on the inner leaf allowing significant air leakage from the cavity (Fig. 5).
- Figure 5 shows cold external air being drawn in through gaps and missing mortar joints in the blockwork wall behind the dry lining. Draughts will be felt at the base of the wall (under skirting boards), through electric sockets, around light switches and light roses/recessed light fittings.



Figure 4 Air permeability through gaps in a blockwork wall.

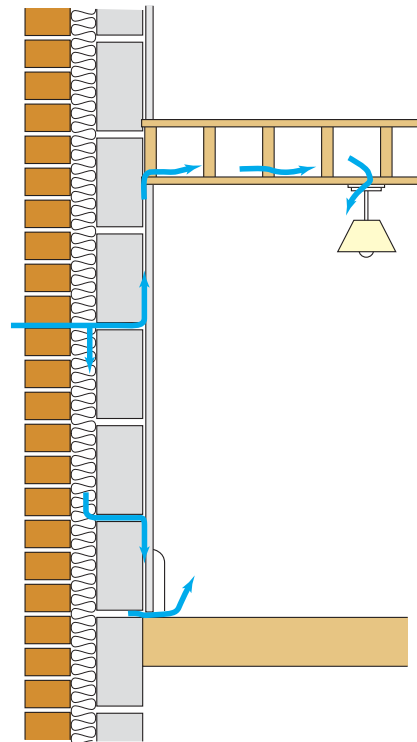


Figure 5 Air leakage through gaps and missing mortar joints in a blockwork wall.

The infrared image in Figure 6 shows the effect of cold air leaking in behind the dry lining. Cold air has been drawn in through missing mortar joints. (Coldness shows up as dark coloured patches in this image). The cold dots that can be seen are the plaster dabs used to fix the plasterboard to the blockwork.

The reasons for the air leakage may be:

- Gaps left around the service pipes.
- Air barriers (vapour control membrane – timber frame or dry lining – steel frame) that have been cut to allow services to penetrate through the wall creating air leakage paths into the dwelling.
- Cuts in membrane are often unnecessarily large for service penetrations making sealing difficult afterwards.
- The wrong tape may have been used to seal the membrane material. Some tapes may not provide a robust seal and could peel off soon after being applied.

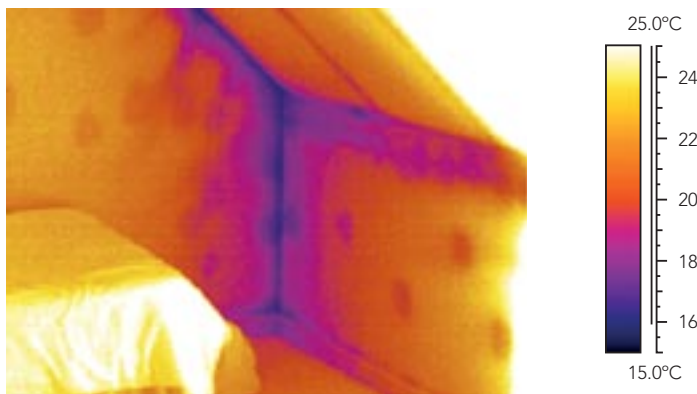


Figure 6 The effects of cold air behind dry lining attributed to air leakage.

14 Gaps between walls and solid ground floors:

- Gaps left between the sole plate of a frame and the ground slab due to undulations in the concrete surface.



3 Ventilation

3.1 Ventilation for occupant comfort

It is important to recognise the difference between planned ventilation and uncontrolled air leakage. Ventilation is designed to provide a controlled amount of fresh air into the dwelling for occupant comfort, and is typically provided using trickle vents, extract vents, mechanical ventilation and other 'designed' openings. It is necessary to dilute stale moist air from the dwelling (caused by cooking, showering and bathing) to reduce odours and to remove excess heat in summer months. Ventilation openings should be carefully sized and located in positions where they will not cause discomfort to occupants. They are controllable so that ventilation rates can be increased or decreased to suit the occupier.

The ventilation target for homes is between 0.5 and 1.5 air changes per hour (ach).⁸

- At $10 \text{ m}^3/\text{h.m}^2$ at 50 Pa approximately 0.5 ach from air infiltration on its own can be achieved (this is uncontrolled and is in addition to purpose-provided ventilation).
- Approved Document F of the Building Regulations gives guidance on how to achieve comfortable ventilation.⁹ It assumes dwellings can have levels of airtightness up to 3 to $4 \text{ m}^3/\text{h.m}^2$ at 50 Pa for naturally ventilated homes.
- Too much air leakage leads to over-ventilation, draughts, heat loss and wasted energy.
- However, too little air infiltration can result in inadequate ventilation and poor air quality.

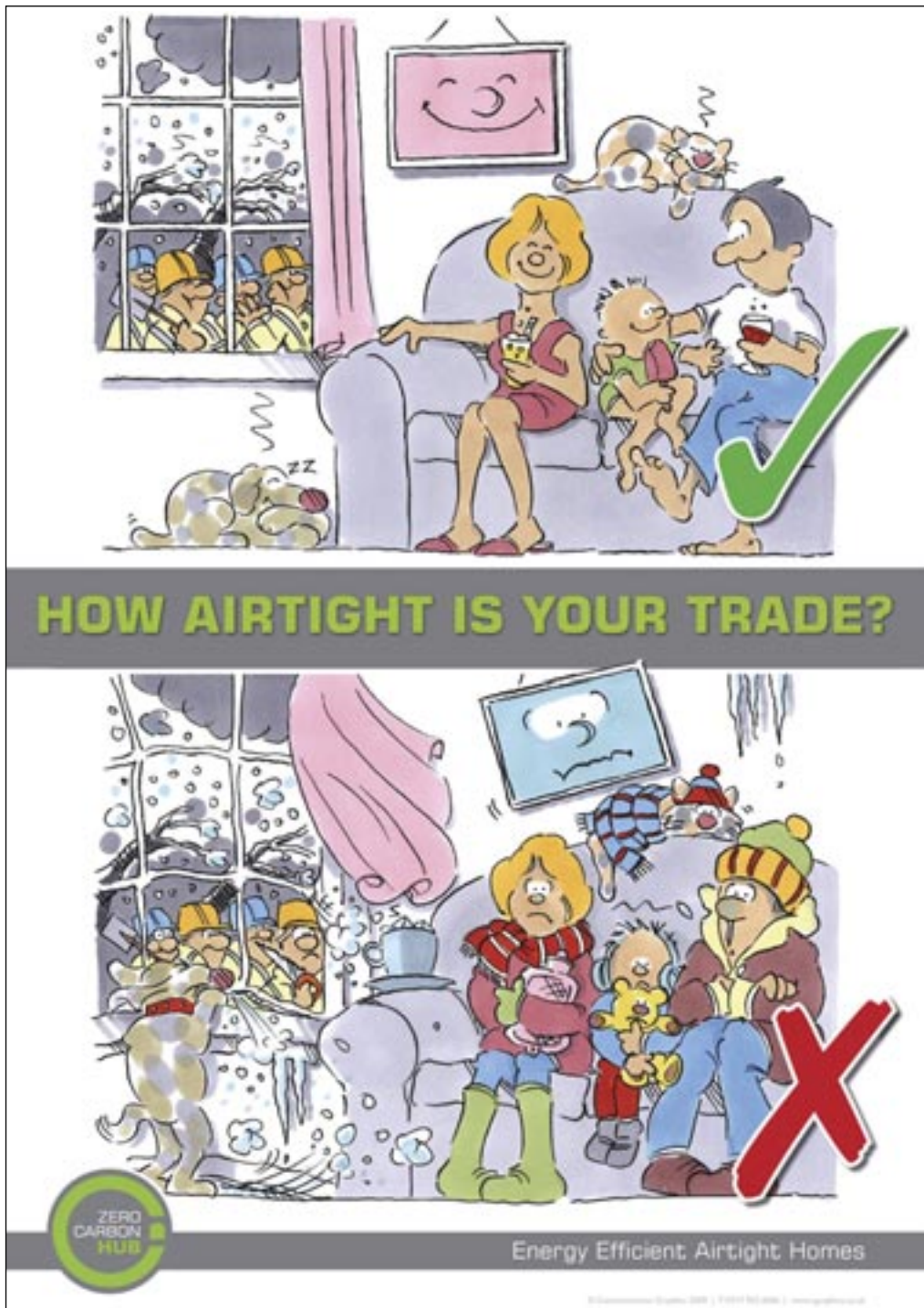
Important note: If the dwelling is required to have an airtightness value tighter than $3 \text{ m}^3/\text{h.m}^2$ at 50 Pa mechanical ventilation should be provided to avoid poor air quality.

While air leakage is not a designed-in facility, a small amount of infiltration can contribute towards background ventilation. If the dwelling's airtightness level is between 7 and $3 \text{ m}^3/\text{h.m}^2$ at 50 Pa there will be sufficient infiltration to provide reasonable air quality. If the dwelling is more airtight than $3 \text{ m}^3/\text{h.m}^2$ at 50 Pa then the contribution of air leakage to background ventilation will be very low and it is likely that the natural ventilation provision will not be adequate and mechanical ventilation will be needed.

3.2 Mechanical ventilation

In cases where dwellings are very airtight, a mechanically operated ventilation system will be necessary to ensure good air quality. Mechanical ventilation systems can be very energy efficient, especially when combined with heat recovery. These systems combine, supply and extract ventilation and are designed to provide adequate ventilation for comfort. Warm, moist air from the dwelling is extracted and passed through a heat exchanger before being exhausted to the outside. Fresh, incoming air is pre-heated via the heat exchanger and ducted to rooms in the home.

Electric power is needed to operate mechanical ventilation with heat recovery. The term 'specific fan power' is used to compare between the electrical energy use of the systems. Specific fan power is defined as the power consumption in Watts (W) divided by the airflow through the system in litres (L) per second (s) Watt (L/s.W). Energy Saving Trust best practice standard⁸ suggests that MVHR must have specific fan power of 1 L/s.W or less at each setting, and heat recovery efficiency of 85% (ie 85% of heat is reused).





4 Building Regulations compliance route

Since 2006, the Building Regulations for England and Wales, and Northern Ireland have included a mandatory requirement to undertake an air pressure test on a sample of newly built dwellings on completion (as stated in Approved Document L1A [2006] for England and Wales⁴ and Technical booklet F1 [2006] for Northern Ireland).⁵ Air pressure testing is only required in Scotland if a target figure better than $10 \text{ m}^3/\text{h.m}^2$ at 50 Pa has been set. Airtightness is one of the factors that has to be considered when calculating both the Target CO₂ Emission Rate (TER) and Dwelling CO₂ Emission Rate (DER) as part of the government's Standard Assessment Procedure (SAP) calculation to demonstrate compliance with the Building Regulations. It should be noted that to achieve the TER, the design airtightness for most dwellings will need to be significantly better than the reasonable limit of $10 \text{ m}^3/\text{h.m}^2$ at 50 Pa.

4.1 CO₂ emission from dwellings

During the design stage, as part of Building Regulations compliance, the SAP assessor is required to input data on the dwelling's envelope insulation and boiler efficiency as well as predicting the dwelling's airtightness performance. The SAP model will be used to calculate the DER based on data relevant to the dwelling. The SAP model compares the DER against the TER that is automatically generated. The dwelling will only be compliant with Building Regulations if the DER is lower than the TER. It is not necessarily acceptable to use the least acceptable airtightness rate of $10 \text{ m}^3/\text{h.m}^2$ at 50 Pa and achieve compliance unless the designer compensates in some way, eg by specifying higher insulation values for the envelope and/or specifies a high efficiency boiler or perhaps includes a renewable energy source. An easier way to achieve compliance would be to set good envelope insulation properties, good boiler efficiency and a reasonable airtightness performance value of $7 \text{ m}^3/\text{h.m}^2$ at 50 Pa (or better).

On completion a sample of dwellings will need to be airtightness tested. The SAP assessor will use this result in the SAP model to generate the dwelling's final DER. Once again this DER must be equal to or below the TER to achieve Building Regulations

compliance. For example: if you set a target airtightness value of 5 m³/hour/m² at 50 Pa at design stage, but only achieve 9 m³/h.m² at 50 Pa on completion you will find this excess amount of air leakage will increase the CO₂ emissions and the dwelling may not comply.

Table 2 uses SAP generated data to show the effect of air permeability on a DER. The examples shown are based on a gas centrally heated semi-detached house with floor area of 80 m². In the first three examples, an airtightness target value of 7 m³/h.m² at 50 Pa has been set at design stage; the final example is an energy efficient home with an airtightness target figure of 3 m³/h.m² at 50 Pa. On completion, it shows four different outcomes with the dwelling achieving actual airtightness test results of 7, 10, 15 and 3 m³/h.m² at 50 Pa. Note the changes in the DER and how in two cases the dwelling does not comply with Building Regulations; in one case the dwelling only just complies.

TABLE 2

SAP assessments for a semi-detached house with a 80 m² floor area

Target Emission Rate	23.19 kg/m ² floor area per annum			
Design air permeability value (m ³ /h.m ² at 50 Pa)	7	7	7	7
Measured air permeability value (m ³ /h.m ² at 50 Pa)	7	10	15	3
Design Emission Rate (kg/m ² floor area per annum)	23.14	23.70	25.01	22.65
CO ₂ emissions increase from design	-	Increased by over 90 kg/annum	Increased by over 100 kg/annum	Saving over 90 kg/annum
Pass/fail	Pass	Fail	Fail	Pass
Remedial action required?	None: No need for any further action	Improve: airtightness and/or improve insulation of envelope. Install higher efficiency boiler or install renewable energy source	Improve: airtightness	None: No need for any further actions (check ventilation is adequate)



5 Achieving an airtight dwelling

KEY POINTS

Communication

- Inform everyone of the importance of the air barrier and where it is located within the construction.
- Everyone needs to know about airtightness. The design team, site management, trades and site labourers must be made aware of the importance of airtightness and their roles in achieving an airtight dwelling. Toolbox talks are useful.
- Refer to airtightness in subcontracts.

Keep it simple

- Refer to the Communities and Local Government's accredited construction details.¹⁰
- Refer to the Energy Saving Trust's (EST's) enhanced construction details.¹¹
- Remember to carefully sequence work so that details are sealed as the work progresses.

5.1 Ground floors

The air barrier has to separate conditioned (heated) spaces from unconditioned (unheated) spaces. For most dwellings the air barrier will be located within the external envelope (outer walls), the ground floor, separating walls and either the line of the roof (in the case of a warm roof) or the line of the upper most ceiling (if it is a cold roof).

5.1.1 Ground-bearing slab

Lay damp proof membrane with adequate laps to achieve robust seals and joints. Seal around services penetrations through barrier.

Figure 7 shows an example of a damp proof membrane providing an air barrier located under a ground-bearing slab.

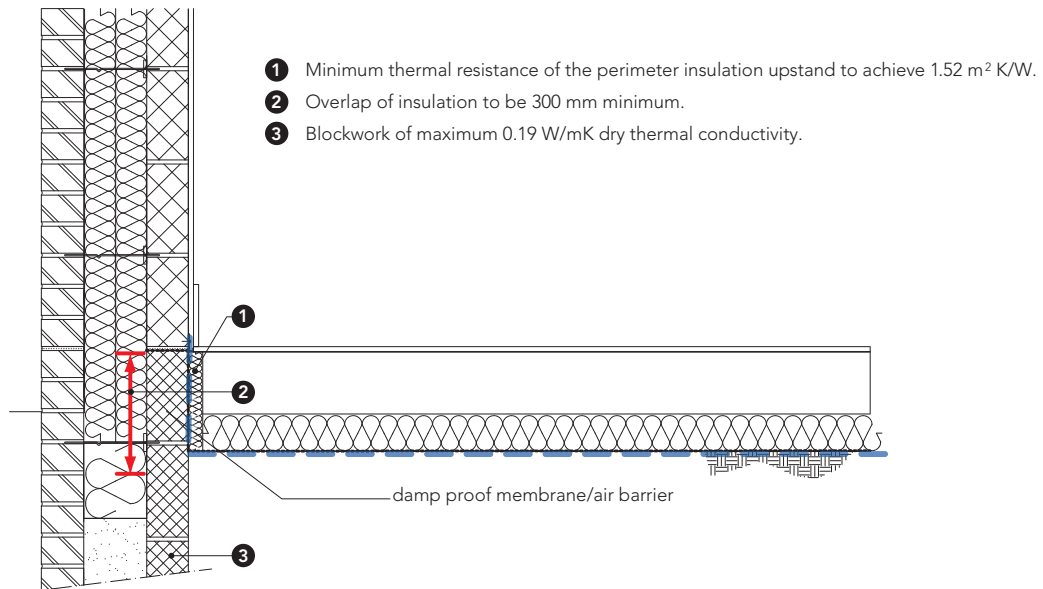


Figure 7 Air barrier formed by damp proof membrane laid under the ground-bearing slab (Energy Saving Trust enhanced construction detail MV01-F01 [A]).

Care should be taken to protect membranes from being damaged after they have been laid. Make sure any tears or punctures are repaired.

5.1.2 Beam and block floor

Grout/cement-wash the surface of beam and block floor to seal joints between blocks.

While not a regulatory requirement, a membrane can be laid over the beam and block floor to provide airtightness. Seal the air barrier in the wall, laps and joints. As with all membranes, repair any tears or punctures. Seal around any services penetrations through barrier (section 5.1.3).

Figure 8 shows an example of an air barrier located over a beam and block floor.

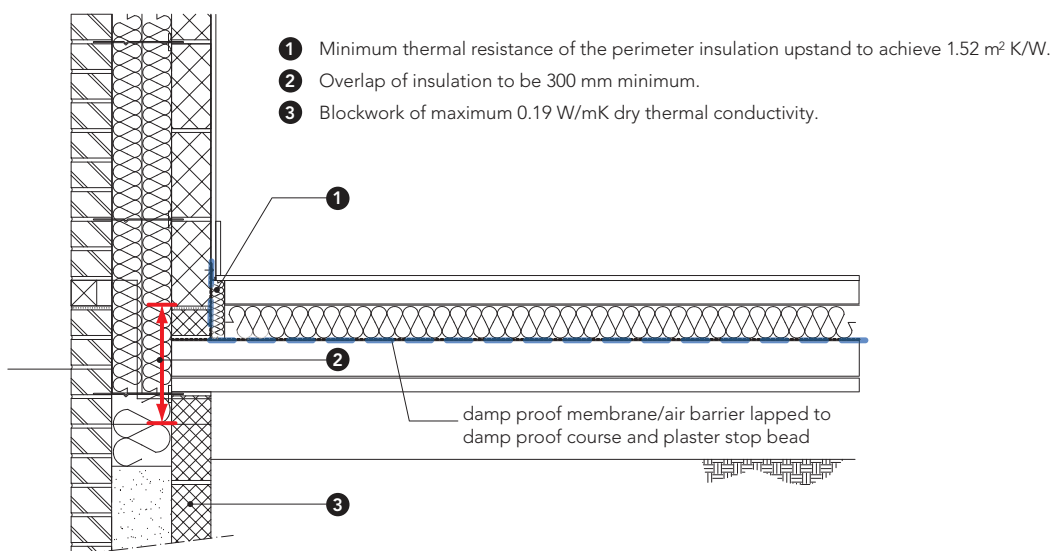


Figure 8 Air barrier formed by damp proof membrane laid over the beam and block floor (Energy Saving Trust enhanced construction detail MV01-F01).

5.1.3 Sealing gaps around services penetrations through the ground floor

Seal around services (eg water, gas and cables) using proprietary seals such as top hat details or collars (Figs 9 and 10). If services are tight up against a wall or corner it may be difficult to fit a top hat seal. It may be prudent to have services penetrations located slightly away from the wall/corner to allow sealing. Seal penetrations prior to installing kitchen units, baths or other fittings otherwise it may be difficult to access gaps and holes.



Figure 9 Good sealing between the soil vent pipe and the floor structure.

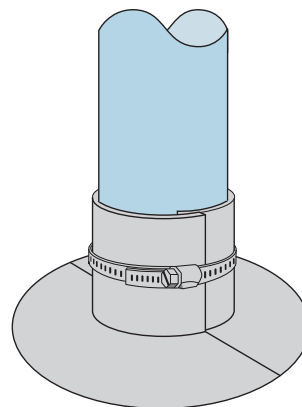


Figure 10 An example of a top hat detail. A seal is achieved around the pipe and the flange is sealed to the air barrier.

5.2 Walls

5.2.1 Masonry

KEY POINTS

- Fill mortar joints.
- Use parging layer or wet plaster finish to seal blockwork.

To prevent air leakage into the cavity, seal the internal block wall by filling mortar joints and by sealing gaps around penetrations through the blockwork. For best results use a wet plaster finish or a parging layer (thin rough coat of plaster) to cover the blockwork. The rough parging layer can be covered by dry lining to provide the finish. Figure 11 shows the air barrier within a masonry wall.

Masonry separating walls

Make sure the separating wall between dwellings (if semi-detached or terraced) is well sealed to provide an adequate air barrier. Treat the separating wall for airtightness as if it is an external wall by sealing mortar joints – for best results use a wet plaster finish or parging layer.

Internal studwork partition walls

Ensure blockwork is sealed and parging layer/plaster finish is applied to external walls before erecting studwork for internal partitions.

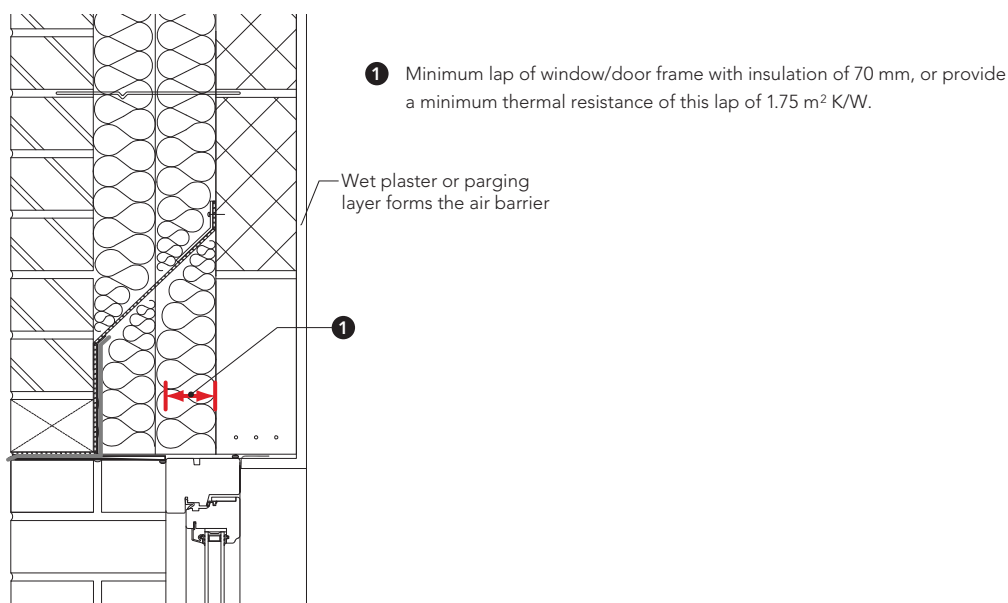


Figure 11 Energy Saving Trust enhanced construction detail MV01 lintel A (showing masonry wall detail and lintel detail).

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It is essential to close the cavity at window/door openings. Use proprietary cavity closers for best results, make sure the closer strip is fixed flat and robustly sealed to the wall. Any undulations in the cavity closer will result in air leakage.

Check the seal between cavity closer and wall before fixing dry lining to the window reveals (Fig. 12).



Figure 12 Proprietary cavity seal at the window reveals.

HELP US TACKLE AIR LEAKAGE



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ALL CABLE HOLES
THROUGH THE WALLS

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Intermediate floor joists

Floor joists can either be supported by the use of joist hangers or by building them into the inner leaf of the blockwork using the methods described below. Joist hangers should not compromise the air barrier as the extent of their penetration into the wall is limited.

Where joists penetrate the inner leaf of a cavity wall (built-in joists) they should be sealed in position using a flexible sealant or by using a proprietary joist sealing box (Figs 13 and 14).

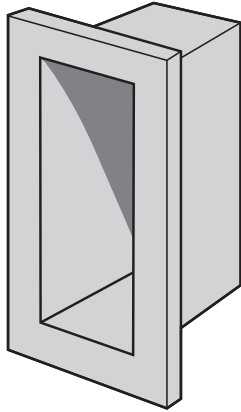


Figure 13 (above) Proprietary joist sealing box.

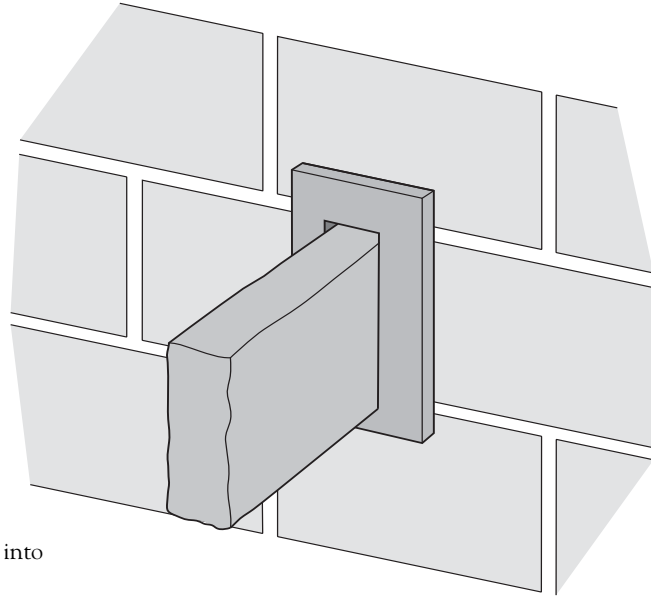


Figure 14 (right) Joist box built into inner leaf of masonry wall.

Services penetrations

Services penetrations are unavoidable, eg water pipes (supply and waste), gas pipes, electrical cables and ventilation ducts. Where services penetrate through the air barrier it is essential to achieve a robust seal around them (Fig.15).

Avoid excessively oversized openings for services through walls. While it may be easier for the service engineer to install pipes and cables through large gaps, these will be more difficult to seal afterwards.



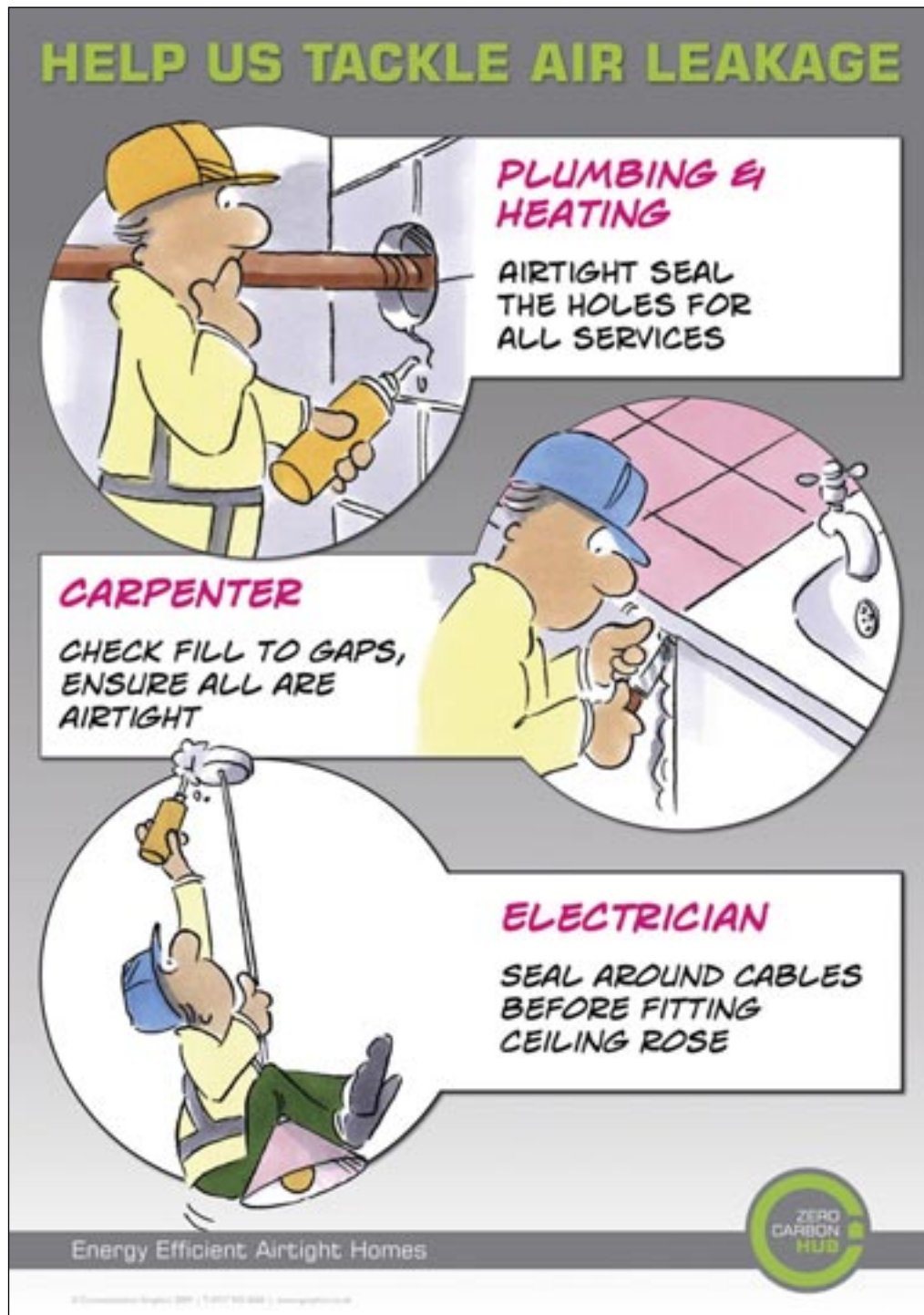
Figure 15 (a) and (b) Good sealing around services penetrations.



Figure 16 Poor sealing around a service pipe.

Important tips for sealing around service penetrations:

- For small to medium sized gaps and holes use a suitable sealant that will accommodate expansion and compression movement between the wall and service pipe/duct/cable.
- **Warning:** Insulating coatings around electrical cables may be affected by the use of some sealant materials. Some sealants can increase the insulation around the cable leading to overheating and potential fire risks. BS 6213 *Guide to the selection of constructional sealants*¹² advises that compatibility between sealants and adjacent materials should be ascertained. The sealant manufacturer should be consulted.
- The use of spray-applied foam can be used to stop air leakage through large gaps and holes in the structure. Care must be taken to ensure that the foam is applied deep into the hole rather than around the surface (see Fig. 16 for an example of poor sealing which should be avoided). For best results use an applicator (thin tube attached to the nozzle).



Dry lining

Warning: It is not recommended to use the dry lining as an air barrier. Sealing between boards can be difficult onsite because of services penetrations.

As an added precaution when using dry lining as a wall finish, it is advisable to consider the following good practice advice:

- Do not fix dry lining until you are sure blockwork behind has been sealed.
- Seal around each plasterboard sheet with a continuous ribbon of sealant. The practice of 'dot and dab' should be avoided.
- Make sure that a continuous ribbon of sealant runs along the bottom of the sheet.
- Apply a continuous ribbon of sealant around any penetrations through the sheet (eg light switches, wall mounted sockets).
- Seal the edge of the plasterboard even in areas that will be hidden from view – this includes wall areas behind baths and kitchen units.

Figure 17 shows the blockwork wall which is providing the air barrier. The mortar joints have been sealed and the dry lining can now be fixed to the wall.



Figure 17 Blockwork wall providing air barrier: dry lining can now be fixed.

5.2.2 Timber and steel frame construction

KEY POINTS

- Seal gap between sole plate and slab.
- Use vapour control membrane as the air barrier (for timber frame).
- Use dry lining layer as the air barrier (for steel frame).
- Ensure membrane is lapped and sealed using tape or sealing strip.
- Repair any tears or punctures as they occur.

Sole plate to floor slab junction

Use a gun-applied flexible sealant or foam tape to fill the gap between the sole plate and the floor slab. It is essential to make sure this seal is applied prior to any follow-on work that will restrict access. The seal will need to accommodate differential movement between the slab and wall structure.

Timber frame external walls

The vapour control membrane will offer a good level of airtightness and already forms part of the fabric. The key areas to watch are:

- Ensure laps and joins in the barrier are well sealed and avoid folds and ripples in the sheets. If folds are unavoidable, make sure the seal will accommodate this. It is also essential that the sealant material used (eg adhesive tape and gun-applied sealants) are compatible with the membrane. It is critical to check the manufacturer's instructions as these will recommend compatible sealing products and correct methods of applying them.
- Seals to be applied to dry and dust-free surfaces.

Figure 18 shows location of air barrier in a timber frame dwelling.

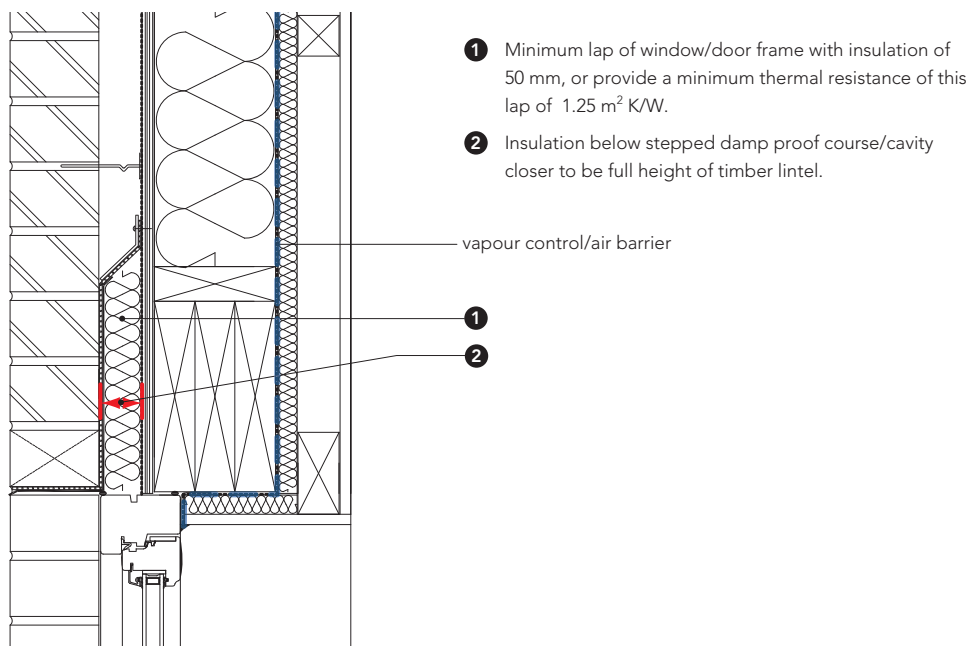


Figure 18 Energy Saving Trust enhanced construction detail TF01.

Steel frame external walls

The air barrier for a light steel frame dwelling can be achieved by fixing plasterboard dry lining to the frame, appropriately sealed at the edges and junctions or by a continuous membrane behind the plasterboard integrated within the wall construction. Note: in a 'warm' frame construction, a vapour barrier is generally not required as interstitial condensation should not occur on the frame. Where a significant amount of inter-stud insulation is included within the light steel structure, a vapour control layer or vapour resistant plasterboard may be necessary on the warm side of the steel (Fig. 19).

In modular construction an external sheathing board often acts as an air barrier.

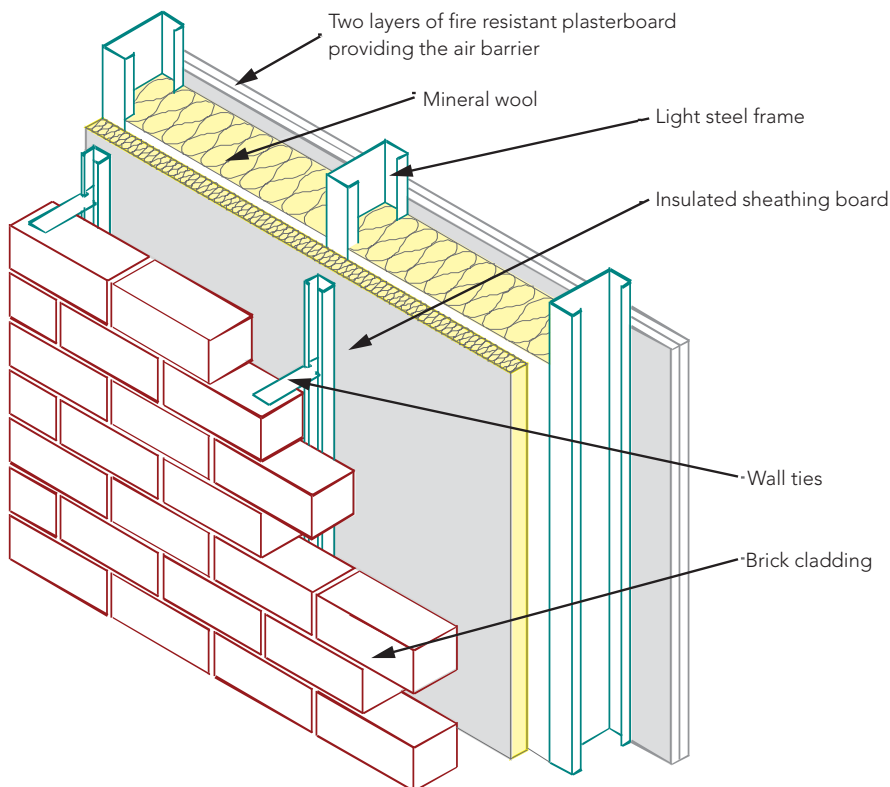


Figure 19 Air barrier achieved using two layers of plasterboard on the inside face.¹³

Separating walls

The separating wall between dwellings must be treated as an external wall to provide a continuous air barrier around each dwelling. Make sure that joints between membrane or sheet materials are robustly sealed and an airtight barrier is achieved.

Internal partition walls

Where internal partition walls abut external walls they must not penetrate the air barrier. Therefore the external walls should be completed before erecting internal partitioning.

Services penetrations

Seal gaps around services penetrations as they penetrate the air barrier. When the vapour control layer is cut to allow pipes, cables and ducts to enter the dwelling make sure the cuts are immediately sealed prior to any dry lining being fixed. Seal gaps in the membrane using either tape or a proprietary sealing system like a top hat detail that fits over the pipe like a sleeve with a flat end flange that is sealed to the membrane.

Repairs

If the air barrier is damaged (punctured or torn) then it must be repaired. It is important to regularly inspect the work to check for any damage that may have occurred.

5.3 Roofs and ceilings

KEY POINTS

- Fit and seal around ceiling boards to provide continuous air barrier.
- Use suitable proprietary airtight backing cups when fitting recessed lighting.
- Seal around services penetrations.

Fit ceilings in place and seal between the ceiling boards and the external wall. Seal around penetrations through ceiling. For recessed spot-lighting, airtight backing caps should be used to create an air seal. Caution: only use caps that are recommended for this purpose by the light fitting manufacturer as the wrong use of caps in this location may result in the light fitting overheating with the risk of fire.

5.4 Components

KEY POINTS

- Ensure an airtight seal has been created between loft hatch and frame.
- Adjust window closers to achieve an airtight seal when windows are closed.
- Fit draught excluders to seal any gaps around external doors.

5.4.1 Loft hatches

The hatch must fit the frame without gaps around the edges and close securely with an integrated draught seal. Take care when installing prefabricated loft hatches as they can twist when fitting, resulting in a gap being created between the hatch and the frame. If this occurs the hatch may need some adjustment to avoid air leakage.

5.4.2 Windows and external doors

Make sure windows and doors are specified to provide an airtight seal when closed. Window closing mechanisms may need to be adjusted to ensure a tight seal is achieved. Draught excluders should be fitted around external doors to avoid air leakage (Fig. 20).

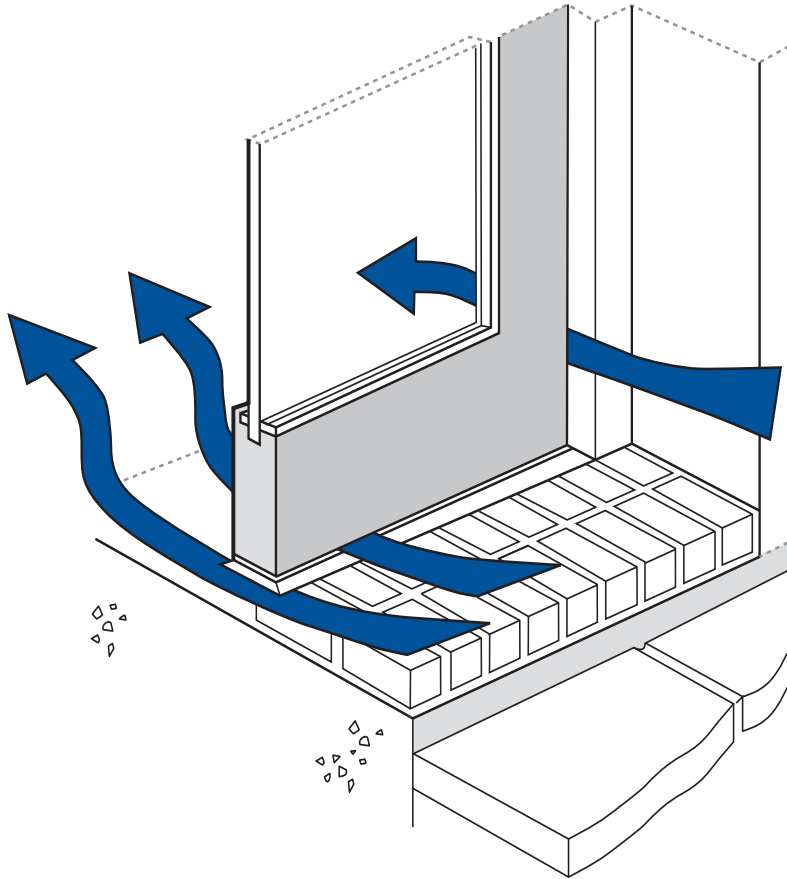


Figure 20 Air leakage through gaps around an external door.



6 Key tips to achieve an airtight dwelling

6.1 Responsibility

One person needs to take responsibility for checking the continuity of the overall air barrier. This could be someone from the design team as they are involved in the project at an early stage. With larger sites it may be more appropriate for the developer to appoint someone from their team. It is important that airtightness is considered throughout the design and construction stages.

6.2 Design

- Identify the line of the air barrier on drawings to make site operatives aware of its location.
- Ensure the continuity of the air barrier.
- Ensure the air barrier is correctly located within the fabric to avoid cold air breaching the insulation layer.
- Avoid complex detailing which is difficult to build, resulting in ad hoc air leakage pathways.
- Specify airtight barrier materials that can be adequately lapped and sealed.
- Mark up details showing how penetrations through the air barrier will be sealed, eg structural elements (floor joists, beams etc) and services (water/gas pipes, cables, ducts etc).

6.3 Construction

- It is important to make site operatives aware of the location of the air barrier and its importance.
- Work should be sequenced to allow sealing to be carried out as the dwelling is built.

Key stages where inspection of seals is advised:

6.3.1 Foundation/ground floor level

- Check that the wall damp proof course and floor damp proof membrane form an adequate air barrier. Make sure any laps and joints are well sealed and any tears or punctures are repaired.
- Check that the gap between sole plate of timber/steel frame structure and floor slab has been sealed. Make sure the seals accommodate movement and any uneven surfaces of the concrete slab.
- If beam and block floors are being used check that a seal has been applied between blocks and around the perimeter edge. Do not leave blocks out to accommodate services.
- Check that any gaps around ground floor supports (eg joists and beams), where they penetrate into the wall, have been sealed. Make sure the seal is robust and will accommodate differential movement (use joist hangers or joist shoes).
- Check seals between timber flooring and wall structure. Also check seals between individual floor boarding.

6.3.2 Walls

Brick/block masonry construction

- Use the inner leaf of the block wall as air barrier.
- Continually check the quality of construction as the work proceeds. Make sure mortar joints are fully filled.
- Check no gaps have been left around any services that penetrate through blockwork walls.
- Close and seal cavities around windows and external doors.
- Wet plaster or parging will provide an effective and robust seal to masonry walls.

Timber and steel frame construction

- Use the vapour control layer to provide a continuous air barrier (timber frame).
- Use dry lining to provide continuous air barrier (steel frame).
- Ensure laps and joints are well sealed.
- Seal around services penetrations.

6.3.3 Dry lining

- Dry lining should not be used as an air barrier in masonry and timber frame construction, but it can be used as a finish.

6.3.4 First floor and intermediate floor levels

- Check floor joists built into the wall or frame are sealed to prevent air leakage into the intermediate floor void (use joist hangers or joist shoes).

6.3.5 Eaves level

- Check air barrier between the wall and the ceiling/roof is continuous. Apply sealant between ceiling board and wall.

6.3.6 Ceiling level below the roof space

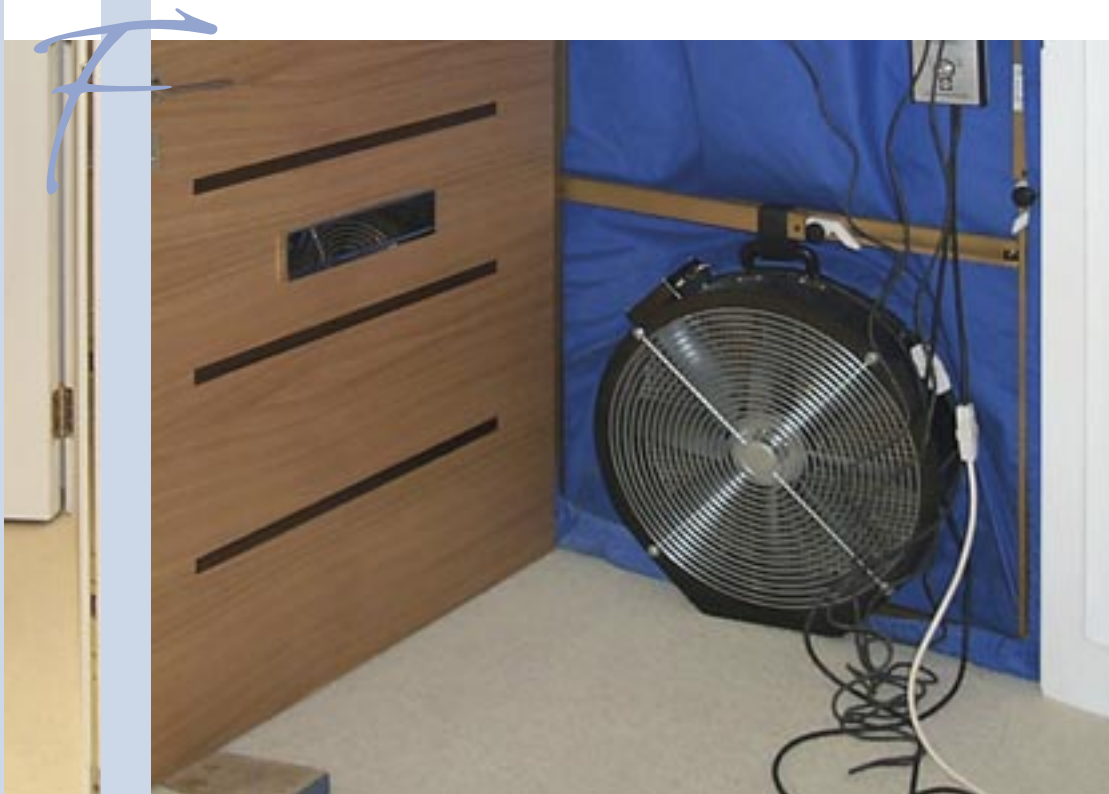
- Check air barrier separates the heated rooms from unheated loft above.
- Check services penetrations and loft hatches are well sealed.

6.3.7 Windows and doors

- Check that the window/door frame to wall junction is well sealed. Make sure a cavity closer has been used to effectively seal the cavity at wall reveals and sills.
- Check that windows and doors have an appropriate weather seal between the opening unit and frame.

6.3.8 Services penetrations

- Check for robust seals at services entry points (eg gas pipes, water pipes, drainage pipes, electric and telecommunications/computer cables). Checks must be made prior to services being covered or boxed in.
- Sealing work around service entry points should not compromise fire safety (eg over insulate cables). Please refer to sealing manufacturers' information.



7 Airtightness testing of dwellings

Testing the dwellings at different stages of construction can be useful to highlight air leakage paths and defects. This is particularly useful if you are trying to achieve a very airtight dwelling. Remedial sealing can then be carried out in good time (Table 3).

TABLE 3

Suggested stages when airtightness testing can be carried out

Stages to test	Phase
Initial airtightness test	On completion of the structural frame when the dwelling is weathertight (air barrier complete), with windows and external doors installed
Second airtightness test	After services have been installed
Final airtightness test	On final completion

Airtightness testing of a sample of newly completed dwellings is a requirement of Building Regulations in England and Wales, and Northern Ireland (and only a requirement in Scotland if a target better than $10 \text{ m}^3/\text{h.m}^2$ at 50 Pa has been set). Guidance on the number of dwellings needed to be tested on each site to demonstrate compliance is provided in Approved Document L1A for England and Wales⁴ and Technical booklet F1 for Northern Ireland.⁵

7.1 Testing requirements to satisfy the Building Regulations

If approved construction details have been used, testing of one of each dwelling type will be expected (building control body would make the selection).

Table 4 lists the number of tests required where accredited construction details¹⁰ have not been used.

TABLE 4**Number of tests required to demonstrate compliance with the Building Regulations**

Dwelling type	Number of tests
4 dwellings or fewer	One of each type
4–40	Two tests of each dwelling type
More than 40	At least 5% of dwelling type, unless the first 5 tested achieve design air permeability when sampling frequency can be reduced to 2%

The test should conform to BS EN:13829 *Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method*¹⁴ and the Air Tightness Testing and Measurement Association (ATTMA) technical standard 1: *Measuring air permeability of building envelopes*.¹⁵ This testing procedure can be downloaded from www.attma.org. Competent domestic airtightness testers will belong to either ATTMA or the British Institute of Non-Destructive Testing (BINDT: www.bindt.org), or be accredited by UKAS for airtightness testing. A list of competent testers can be found on ATTMA's or BINDT's websites.

7.2 Informing site operatives

Let site operatives know when airtightness testing will be carried out so that they can plan their work around this. An airtightness test should take no longer than half an hour per dwelling. It is safe for site operatives to remain inside the dwelling during the test, providing they do not open windows or external doors.

Avoid painting in dwellings immediately before and during a test as the fan may blow dust onto wet surfaces.

7.3 Test procedure

A temporary airtight screen is fitted into the entrance door of the dwelling, water traps should be filled or temporarily blocked, trickle vents closed and extract vents sealed. A fan is then mounted in the screen (Fig. 21) and operated to blow air into or out of the dwelling to create a pressure difference between inside and outside of approximately 50 Pa. The air permeability (or airtightness) of the dwelling is quantified by measuring the rate of airflow through the fan while a range of pressure differences between the inside and outside of the dwelling are maintained.



Figure 21 Air tightness testing equipment.

7.4 If the dwelling fails its airtightness target

If the dwelling does not meet its airtightness target then remedial sealing will be required. The dwelling will need to be re-tested to demonstrate that it has met its airtightness target. Additional dwellings on the site will also need to be tested (the building control officer will notify you of their requirements).

7.4.1 Air leakage audit

Most air leakage paths are difficult to see and so commonly smoke is used as a visual aid (smoke pencils or a smoke machine). Smoke will be drawn through air gaps allowing targeted remedial sealing.



8 Conclusions

This guide should lead to achieving a reasonable level of airtightness in new dwellings. Considering airtightness at all stages – from initial design, through construction onsite to final completion – will ensure that a good airtight result is achieved.

Airtightness is everyone's concern and design and construction teams need to work together. Communication is vital to make sure that simple, workable details are produced and provided to the site in a timely manner. It is crucial to sequence work in such a way to allow the air barrier to be achieved as the work progresses – this will avoid having to carry out remedial measures late in the project. It is also important to carry out regular checks on the air barrier so that any problems can be rectified and attended to.

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Zero carbon homes – an introductory guide for housebuilders

The guide is designed to help builders understand the issues associated with the definition of zero carbon and help them engage in the consultation process. It provides an overview of CO₂ emissions from homes, how these can be reduced and how zero carbon standards can be set through the Building Regulations, the Code for Sustainable Homes and stamp duty tax relief.

NF14, February 2009

The Code for Sustainable Homes simply explained

This guide will help developers to get to grips with the Code for Sustainable Homes by distilling the experience gained from a large number of Code assessments that have already been carried out. It advises designers and builders on a strategic way through, by highlighting the interaction between the various issues and suggesting how they can be addressed in the most practical and cost-effective way. It includes numerous useful tips and other further information.

NF15, June 2009



NHBC Foundation publications in preparation

- Assessing life safety of open plan flat layouts
- Water efficiency guidelines
- Sustainable drainage systems for housing

A practical guide to building airtight dwellings

In homes of previous generations, open chimneys and floorboards with gaps between were common, and airtightness was given little attention. Recently we have realised how much energy can be wasted through unwanted air leakage and changes to Building Regulations have made airtightness an issue that cannot be ignored. As we get closer to the zero carbon homes of the future, excellent standards will have to be achieved in all new homes.

This guide has been jointly produced by the NHBC Foundation and the Zero Carbon Hub to bring together the experiences of those who have already got to grips with airtightness, for the benefit of designers and builders who have not. It identifies the common air leakage paths and the importance of designing in an air barrier and ensuring that its integrity is maintained throughout the construction phase.

The guide is a useful part of the toolkit for addressing this important feature of homes we are designing and building today and in the low and zero carbon future.



The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the country's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.

