BSRIA

Specification 10/98

AIR TIGHTNESS SPECIFICATIONS

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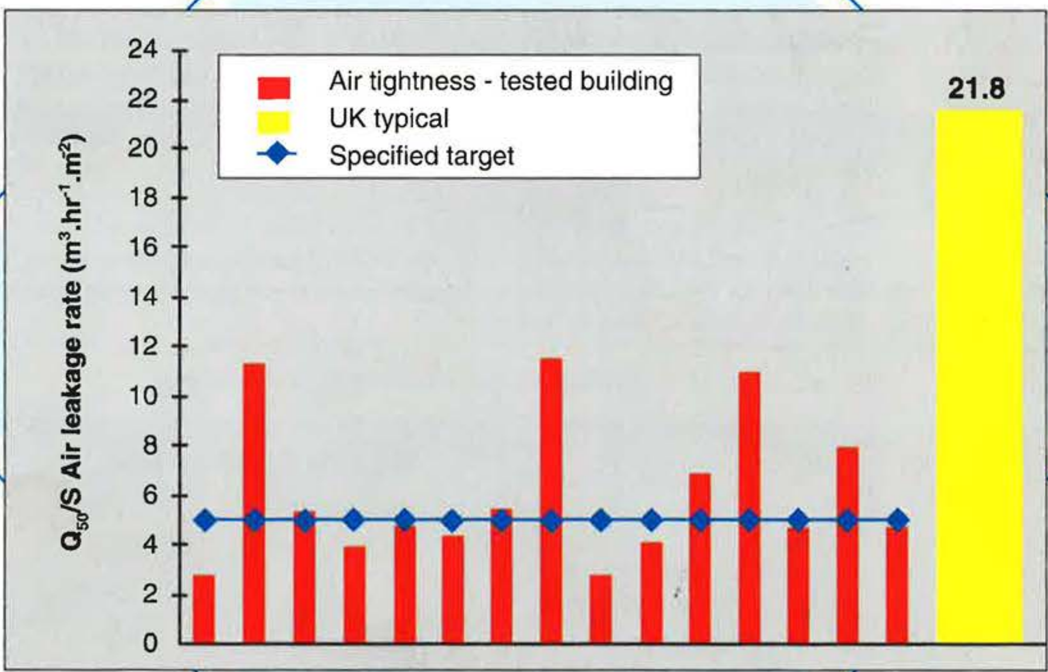
- Offices
- Factories & warehouses
- Cold stores
- Dwellings
- Museum & archival storage
- Retail stores



INTRODUCTION

The air tightness of a structure has a direct impact on the natural ventilation rate and will increase with wind speed and internal/external temperature differences. The unnecessary air leakage of buildings in arbitrary locations leads to occupant discomfort and higher energy consumption. The location of discomfort zones will vary with wind direction and undefined air leakage routes. The magnitude of the discomfort will vary with wind speed and outdoor temperature. No heating or mechanical ventilation system can cope with high infiltration loads which change location with weather conditions. Buildings should be designed and constructed to provide minimal air infiltration except in locations which are part of the building design.

One of the key factors in providing energy efficient, comfortable buildings is specification of an acceptable rate of air leakage and subsequent air tightness testing to ensure compliance. This will help to ensure that clients are provided with buildings which will meet their expected performance.

The air leakage of standard UK buildings is generally poor as revealed by BSRIA Technical Note 7/92, "Ventilation Heat Loss in Factories and Warehouses" and BSRIA Technical Note 8/95, "Air Leakage of Office Buildings." There is considerable scope for improvement and this Specification presents the maximum air leakage rates that should be specified for buildings and enclosures.

Different building types require different air leakage limits. For example, low energy or air-conditioned buildings require a tighter specification than naturally ventilated buildings. Archival stores and museums may require even tighter buildings for close humidity control and prevention of ingress of external pollutants. Cold stores require a particularly stringent specification to maintain food quality and to minimise energy losses.

BSRIA's Ventilation and Special Projects Section has undertaken whole building pressurisation tests on 15 factory/warehouse buildings, 240 superstores, 44 large office buildings, 4 archival storage facilities, 3 schools, 2 cold stores and a variety of pressurised stairwells, builders ventilation shafts, floor voids and fire protected compartments. The majority of the buildings were required to meet various air tightness performance criteria of 1, 2, 5, 7.5 and 10 $m^3.hr^{-1}.m^{-2}$ at a test pressure of 50 Pascals.

The air tightness specifications presented here are based on this extensive accumulation of site test data and each specified level has been bettered in practice by a margin of at least 40%. So there is clear evidence that these maximum air leakage targets can be achieved - and be verified by testing.

In summary, BSRIA recommends the following for new buildings:

Type	**Maximum air leakage $m^3.hr^{-1}.m^{-2}$ at 50 Pa**	
	normal	best practice
Offices		
♦ *naturally ventilated*	10	-
♦ *air conditioned/low energy*	5	3
Factories/warehouses	10	-
Superstores	5	3
Museums and archival stores	2	1.4
Cold stores	1	0.5
Dwellings	10	5

COLD STORES

The critical requirement to minimise air leakage into cold stores leads to a very stringent criterion. An air tightness specification of 1.0 $m^3.hr^{-1}.m^{-2}$ is provisionally recommended, with the caveat that 0.5 $m^3.hr^{-1}.m^{-2}$ would be preferred when this has been demonstrated to be routinely practicable.

MISCELLANEOUS

Ventilation / Builders Shafts

The air leakage of builders shafts as ventilation ductwork often runs into difficulties with regard to specification and indeed achievement of a specification.

The HVCA document DW/142 entitled "Specification For Sheet Metal Ductwork" recommends a maximum air leakage for low pressure Class A ductwork of 0.54 $l.s^{-1}.m^{-2}$ (1.94 $m^3.hr^{-1}.m^{-2}$) at a pressure differential of 100 Pa and for medium pressure Class B ductwork of 0.114 $l.s^{-1}.m^{-2}$ (0.41$m^3.hr^{-1}.m^{-2}$) at a pressure differential of 100 Pa.

The following table summarises these specifications for the same test pressures:

	$m^3.h^{-1}.m^{-2}$ at 100 Pa	$m^3.h^{-1}.m^{-2}$ at 50 Pa
HVCA Class A ductwork	0.41	0.29
HVCA Class B ductwork	1.94	1.37
BSRIA very good building	3.54	2.5
BSRIA good building	7.07	5.0
Average UK office building	30.83	21.8

It would be unreasonable to expect a builders shaft to conform to medium pressure ductwork and quite difficult to achieve low pressure ductwork standards. However, they should not exceed the air leakage standard for a good building and preferably not exceed the standard for a very good building.

Museum Display Cases

The current standard is based on a requirement to achieve 0.1 air changes per day and is usually measured using tracer gas techniques. A pressurisation standard has not yet been firmly established by BSRIA but may well be included in any revision to this document. The reason for this is that the volume to surface area ratio changes rapidly with size and the joints (potential air leakage paths) are clearly defined. The air tightness standard is not constant to achieve 0.1 air changes over a wide size range and the distribution/location of the air leakage paths is quite critical.

Floor Voids (Ventilation Plenums)

Where floor voids are used for ventilation plenums as used in displacement ventilation systems, the BSRIA recommended air tightness criteria should remain as 1 litre per second per square metre of floor area.

Pressurised Stairwells

The current British Standard should be used. This is BS 5588 : Part 4 : 1998, "Code of Practice for Smoke Control using Pressure Differentials".

DESCRIPTION OF TEST PROCEDURE

The air leakage characteristics of buildings are determined using an air pressurisation technique. Air is supplied to the building over a range of air flow rates and at each the resulting pressure differential across the building envelope is measured. This pressure differential and measured air flow rate can be related by the equation:

$$Q = k \cdot (\Delta p)^n$$

where: *Q is the air flow rate supplied to the building,* $m^3.s^{-1}$
Δp is the pressure differential across the building, Pa
k is the air leakage coefficient, $m^3.s^{-1}.Pa^{-n}$
n is an exponent normally between 0.5 and 1.0.

BSRIA developed this pressurisation technique to assess the air leakage of larger buildings using a mobile test facility known as the "Fan Rover". This equipment consists of a large fan unit mounted on a trailer, and driven using the rear power take-off of a Land Rover, thus avoiding the need for any intrusion into the electrical system of the building under test. This facility is designed to supply air at flow rates up to 30 $m^3.s^{-1}$, and incorporates a flow grid that enables air flow rates to be measured down to 3 $m^3.s^{-1}$. This built-in flow grid consists of two tubes mounted across the unit incorporating total pressure holes spaced at Log-Chebycheff intervals. The unit is calibrated at BSRIA using standard anemometric and tracer gas techniques. A separate "Wilson" flow grid is used to measure flow rates below 5 $m^3.s^{-1}$ when necessary. The pressure differential across whichever flow grid is in use and across the building envelope are both measured using Furness Controls Type FC014 Micromanometers regularly calibrated by the manufacturers, augmented by regular calibration checks by BSRIA.

Throughout the test periods, air temperatures are measured using PRT probes connected to panel counters or a data logger. The accuracy of these probes is better than 0.2°C. The internal temperature is averaged for the period of each test to provide a mean internal air temperature. Similarly, the external temperature is averaged throughout the period of each test.

Buildings are tested with all external doors and windows closed and with all internal doors wedged open. Any natural and mechanical ventilation openings are also sealed with polythene sheet and self-adhesive tape. Smoke extract fans or vents are left closed but are **not** sealed and other integral openings such as lift shafts are left unsealed.

TERMINOLOGY

The rate of air infiltration into a building is often expressed as air changes per hour with typical values of ¼, ½ or 1 air change per hour. The heating and cooling systems in buildings are sized to cater for the loads imposed by air infiltration under design external and internal conditions.

The design external conditions are usually taken at fairly extreme temperature values. However, for assessing air infiltration rates it is also necessary to take relatively high wind speeds to be sure that the systems will meet the loads under all but exceptional conditions. The average air leakage of UK office buildings is 21.8 $m^3.hr^{-1}.m^{-2}$, from BSRIA Technical Note 8/95, "Air Leakage of Office Buildings". It is quite clear that a design infiltration load based on 1 air change per hour would have been exceeded in nine out of twelve typical buildings when the wind speeds were 12.6 $m.s^{-1}$ (strong breeze) or above.

Air tightness testing involves the measurement of the airflow rate, Q_{50}, required to pressurise the enclosure to 50 Pascals. This pressure is low enough not to cause any damage to the building and high enough to overcome moderate wind speeds. To relate the measured airflow rate to an air tightness standard, the flow rate is normalised by the envelope area of the building, S. This is defined as the area of walls and roof, wherever the airtight surface has been established, which is usually at the inner surfaces of the building fabric. This yields a value for Q_{50}/S, the main parameter used in this Specification. This normalised flow rate is also useful for assessing the suitability of cladding, the air tightness of which is usually expressed per unit area.

The measured airflow rate can also be used to approximately estimate the area of gaps in the building envelope through which the air would leak. This gives building designers and contractors a better 'feel' for the required target. For example, a gap area of 3 m^2 is much easier to envisage than a Q_{50} value of 16 $m^3 s^{-1}$.

Air tightness standards are sometimes expressed as air changes per hour at test pressures of 25 and 50 Pascals. For a single storey building of moderate size, the following table compares such standards in terms of Q_{50}/S values:

Test pressures	**Q_{50}/S $m^3.hr^{-1}.m^{-2}$**
1 air change at 50 Pascals	4.57
0.5 air changes at 50 Pascals	2.29
0.25 air changes at 50 Pascals	1.14
0.5 air changes at 25 Pascals	3.24
0.25 air changes at 25 Pascals	1.62

PERFORMANCE SPECIFICATIONS

OFFICE BUILDINGS

Naturally Ventilated Offices

The air infiltration rate for a naturally ventilated office building should not greatly exceed the rate of ventilation required for the occupants during high wind speed conditions. During less than high wind speed conditions, the occupants should be able to open ventilators or windows to provide adequate ventilation. The ventilation design for naturally ventilated buildings is actually quite complex, especially during periods of low wind speeds and moderate internal/external temperature differences. However, the openings in the structure should be purpose made and mostly limited to occupant control or fixed trickle ventilator openings in accordance with the selected ventilation strategy. The air leakage of the structure should be at a sufficiently low level to avoid causing draughts and discomfort, and increased space heating requirements.

A moderate air tightness specification of 10 $m^3.hr^{-1}.m^{-2}$ is recommended for this building type with all windows and trickle ventilators closed. During average wind speeds the air change rate would be approximately 0.3 - 0.4 air changes per hour but windows or ventilators could be opened, if required. The air change rate will rise to > 1 air change during windy weather conditions.

If a high surface area to volume ratio is inherent in the design of a building, for example by the inclusion of courtyards, then a tighter specification may well be required. Buildings in exposed locations will require a more stringent specification.

Air-Conditioned and Low Energy Offices

Ventilation air required for the occupants and cooling to combat internal heat gains are provided by air-conditioning systems and no natural air infiltration is required. Indeed all natural air infiltration in such buildings is an additional energy load and can cause local discomfort.

It is impractical to demand a perfectly sealed building but, based on test data, an air tightness specification of 5 $m^3.hr^{-1}.m^{-2}$ is clearly achievable and is recommended as the maximum limit for air-conditioned and low energy buildings. For moderate to large office buildings this would result in infiltration rates of approximately 0.15 - 0.2 air changes per hour during average wind speeds and temperatures, rising to approximately 0.5 air changes per hour during high wind speeds.

Factories/ Warehouses

The average air leakage of UK factory/warehouse buildings exceeds 30 $m^3.hr^{-1}.m^{-2}$, which is excessive. At this value the heat loss resulting from the air leakage is likely to be at least double the amount predicted using the data in the CIBSE Guide.

An air tightness specification of at the most 15 and preferably 10 $m^3.hr^{-1}.m^{-2}$ is suggested as a cost effective compromise. However, the purpose of the building should, more appropriately, dictate the envelope integrity specification. For instance, some warehouse buildings incorporate dehumidification for stock preservation and these buildings would require a very much tighter specification to ensure that the required internal conditions could be maintained. Similarly, air curtains designed to protect building openings will not be effective unless the air leakage through the building envelope is minimised.

Superstores

These are air-conditioned buildings and should be built to an air tightness specification of 5 $m^3.hr^{-1}.m^{-2}$, or to comply with best practice, 3 $m^3.hr^{-1}.m^{-2}$. The use of open entrances for ease of customer access requires, among other design considerations, that these structures strictly comply to this specification.

Museum & Archival Storage Buildings

Many of these buildings incorporate items which require very close control over temperature and humidity, and the exclusion of pollutants. Where small-tolerance control and high-grade air filtration and is required, an effective air tightness performance specification will also be necessary. An air tightness specification of 2 $m^3.hr^{-1}.m^{-2}$ is recommended and will be essential for such installations.

Dwellings

There are a number of schemes which have been recommended for a number of years. The Medallion 2000 scheme recommends an air tightness test requiring the structure to meet a maximum air leakage of 7 air changes per hour when subject to an internal/external pressure difference of 50 Pascals.

The above is quite a good standard, except that the standard of construction will need to be better for small dwellings compared with larger dwellings. BSRIA would therefore recommend an air tightness performance of 10 $m^3.hr^{-1}.m^{-2}$, except for mechanically ventilated dwellings which should achieve 5 $m^3.hr^{-1}.m^{-2}$.

DATA PROCESSING

The results of measurements directly associated with air leakage tests are initially verified on-site. This consists of converting the pressure differences across the flow grid into air flow rates using the calibration data. The pressure difference across the building envelope versus the measured air flow rate is plotted on a log-log graph, and the slope determined using a portable PC and printer. This immediate analysis provides confirmation that the relationship between these parameters was generally as expected and that nothing extraneous, such as a door or window left open, had occurred during the tests.

The air flow test data is further processed to take account of two factors. First, an air density correction is applied. This is determined from the air temperature and barometric pressure at the flow grid. The second correction applied is a change in the air volume flow rate that occurs if there is any difference in the temperature of the supply air and that within the building. For example, during the pressurisation test, outside air passes through the apparatus into the building and mixes with the inside air. If the indoor air temperature is higher, the supply air expands so that the volume rate of flow out of the building envelope is slightly greater than the measured air flow rate.

Following these corrections, a regression analysis is carried out on the pressure differentials across the building envelope and the corrected air flow rate to calculate values of 'k' and 'n' (see the equation on page 6). The correlation coefficient is also calculated to indicate the 'closeness of the fit' of the data to the calculated relationship.

Using the calculated relationship, the air flow rate required to pressurise the building to 50 Pa is determined and then normalised with respect to the surface area (S) of the building to yield values for Q_{50}/S ($m^3.hr^{-1}.m^{-2}$).

SMOKE TESTS

If the air leakage of a building under test is greater than specified, a smoke test can be carried out to help identify the air leakage routes. The fluid from which the smoke is generated is a food-grade polyglycol mixture often used in theatre and disco applications. The building is pressurised by the "Fan Rover" while smoke is released in all or part of the interior. Visual observations outside, as well as photographs and/or video recordings, are made of the smoke egress from the building.

For large office buildings, it is usually more appropriate to undertake localised smoke tests. This involves the use of a smoke generator with a ducted outlet which can be directed at particular areas of the structure.

ABOUT BSRIA

Founded over 40 years ago BSRIA is a member based organisation and the UK's leading centre for building services research. Operating from two well equipped laboratory and office premises in Berkshire BSRIA provides a focus for co-operative research, offering a partnership between industry and government.

Among BSRIA's extensive client list are consulting engineers, contractors, building operators, government bodies and utility companies. We work closely with these clients utilising our specialist knowledge in performance testing, consultancy and trouble shooting to complement their existing skills.

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