

Chapter 3

Practical Aspects of Pressure Testing Commercial Buildings.

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INTRODUCTION

The airtightness of UK commercial buildings is becoming much more of an important issue than has previously been the case. Several years ago air infiltration represented a smaller percentage of the design heat loss than that through the building fabric. Nowadays with improved insulation standards the heat loss from air infiltration has now become a much more significant factor. Also, with changes in building techniques and materials over recent years, it is not surprising that we end up with buildings in the UK with a wide variability in airtightness.

When a building has been specifically designed and constructed to be airtight there is a need for an independent testing body to measure its air leakage index. This determines whether it meets the airtightness specification as required by the client. This paper describes the practical aspects of pressure testing commercial buildings. Also, to give an indication of the levels of airtightness being achieved in buildings today results will be presented of typical buildings along with good practise air leakage targets.

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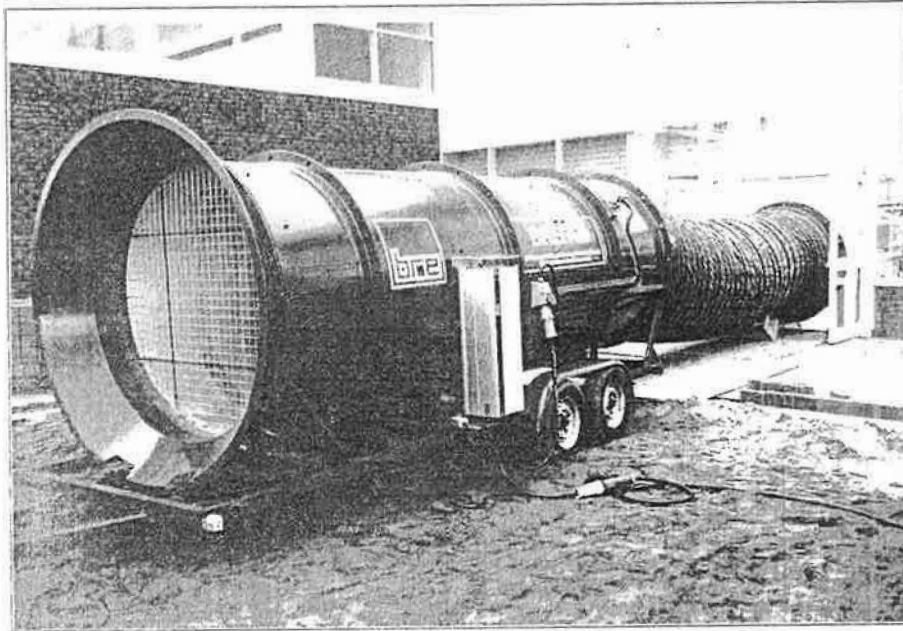


Figure 3.1 Large BREFAN (BRE's Large Fan Pressurisation System)

FAN TESTING METHODS

Building air leakage indices can be measured by one of the following techniques:

1. External fan pressurisation technique.
2. Building (HVAC system) fan pressurisation technique.
3. Using an alternating applied pressure technique.

The external fan pressurisation technique is the most common method used in the UK. The technique of using a buildings supply fan(s) to pressurise the building has been used in the USA and Canada. It is used to measure the air leakage index of large mechanically ventilated buildings. The A/C technique, i.e. using a pulsating pressurising system is thought to be little used in practise, and it will not be discussed any further in this paper.

EXTERNAL FAN PRESSURISATION TECHNIQUE

This is by far the most common method used in the UK for measuring the air leakage index of commercial buildings¹. The technique involves connecting a portable fan (or

fans) to the building under test using flexible ductwork and a temporary wooden panel, which is installed in a suitable external doorframe in the building². The existing doors do not have to be removed they only need to be are opened to 90.

There are two different fan pressurisation systems used by BRE for commercial buildings, Figures 3.1 and 3.2. BRE's large fan pressurisation system (Large BREFAN), shown in Figure 3.1, is testing a large retail store. The smaller system (Medium BREFAN), shown in Figure 3.2, is testing an office building.

Fan capacity

To carry out pressure tests in the size of commercial buildings in the UK requires large-scale equipment. Such systems are costly to build and develop. The fans in these systems need to be of a high capacity and powered from the most convenient and unobtrusive source. BRE's Large BREFAN has a capacity of $32\text{m}^3/\text{s}$ at a building pressure differential of 50Pa and is powered from a stand alone 3-phase generator. The Medium BREFAN

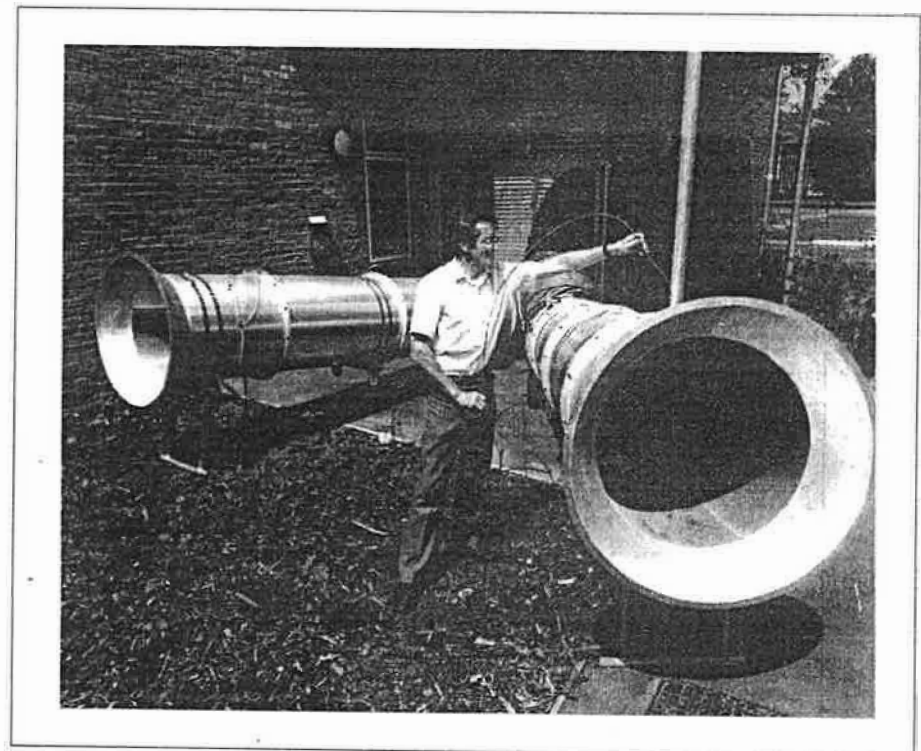


Figure 3.2 Medium BREFAN (BRE's Medium Sized Fan Pressurisation System)

systems (of which there are three) each have a capacity of $5.5\text{m}^3/\text{s}$ at 50Pa and operate from ordinary 13 amp socket outlets. One, two or three fans can be used depending on the size and leakiness of the building being tested.

Principle

The fan(s) is used to supply air, at a constant flow rate, to the building under test. This air subsequently "leaks" out through gaps and cracks in the building envelope. The fan is set to a range of flow rates required to maintain a set of pressure differences across the building envelope. At each setting the airflow rate through the fan(s) and the pressure difference created between the inside and outside of the building are measured. From these parameters, and the building envelope area the air leakage index can be calculated.

Connecting panel

The temporary panel used to connect the ductwork from the fan can be made, for example, from 18mm plywood. It is advisable to have this painted as it provides a good bonding surface for the adhesive tape used to seal the panel/doorframe interface. This is done to ensure an airtight seal. It is important to ensure minimal air leakage around this temporary panel; it should not be a variable air leakage element. Should the building need to be tested again it is important that any air leakage around this temporary panel is small.

Pressure measurements

The pressure difference created by the fan between the inside and outside of the building should be measured with a micromanometer with an operating range of at least 0 to 75Pa and have an accuracy of 2Pa. A small-bore tube (6mm maximum internal diameter) should be extended away from the building to measure the external pressure. If possible the end should be placed about 10 metres from the building. An internal pressure tube should also be placed inside the building and out of direct influence of the pressurisation fan.

Air flow rate measuring system

Whatever device is used to measure the air volume flow rate it should be with an accuracy of 7%. If the flow measurement device does not fully conform to the requirements of BS1042: 1981 and 1984 or BS848: part 1:1980^{3,4} then it must be calibrated after the whole system has been assembled.

The airflow rates measured need to be corrected for air density. This is predominately a correction for the temperature difference when the test was undertaken which would be different from that when the device was calibrated.

The temperature inside and outside the building needs to be measured during the test period. Care should be taken where the external temperature sensor is placed, as it should be out of the influence of direct sunlight or any other influence that may affect its accuracy.

BUILDING FAN PRESSURISATION TECHNIQUE

This technique has been used in Canada⁵ and the USA⁶. It can be the only practical method of measuring the air leakage in large multistorey office buildings. The external fan used, as above, is replaced by using the buildings own HVAC system air supply fan(s) to pressurise the building. This technique is fully described elsewhere⁷.

Fan capacity

The supply fan(s) in the building's air handling unit(s) should have the capacity of creating a pressure difference across the building envelope of at least 60Pa. Also, there should be a method of controlling the air volume flow rate delivered by the air handling units. This can either be by using a fan speed controller (e.g. inverter) or control dampers, in series with the fan(s).

The exhaust fans in the building need to be turned off and the external grille sealed with either board or polythene sheeting and tape.

Principle

The air supplied by the air handling unit is adjusted to obtain a series of airflow rate and pressure differentials in the same way as the external fan technique. However, accurate measurement of the air volume flow is an important issue, requiring special techniques.

Air volume flow rate measurement

There are two methods commonly used for measuring the air volume flow in the air supply ducts using this technique, tracer gas dilution and direct flow measurement using a calibrated probe. The tracer gas method is described more fully by Grot⁶, and the direct flow measurement method by Shaw⁵.

The tracer gas method involves injecting a tracer gas (100% pure) continuously at a measured rate into the air handling unit and measuring the gas concentration further down the duct after it has fully mixed with the incoming air. Sulphur Hexafluoride (SF_6) is the most widely used tracer gas for this purpose. A calibrated infrared gas analyser is needed to measure the gas concentration in the supply duct. Two lengths of tubing need to be inserted into the duct through convenient or purpose made holes to inject the tracer gas and sample the air from the duct. The rate at which the tracer gas is injected into the duct must be measured accurately. A bubble flow meter is well suited to this task.

The direct flow measurement technique is fully described in the Canadian Standard⁷. It outlines the design of an airflow-measuring device, which basically consists of a set of total pressuring averaging tubes. Two tubes are needed for circular ducts and a grid pattern of tubes for rectangular ducts, see Figure 3.3. A separate static pressure probe needs to be inserted also in the supply duct.

The airflow rate measuring system must be calibrated by normal procedures in a duct specifically constructed for this purpose. There should be adequate clearance of any obstructions before and after the measuring point in the duct.

Pressure measuring apparatus

A micromanometer should be used to measure the pressure differential between the inside and outside of the building. However, in the Canadian Standard there is a description of a pressure averaging and damping system developed for this technique. The purpose of this is to average the pressure differential at the ground floor and roof level, and to damp out any wind effect on these readings. The system recommended in this Standard consists of a 1 litre container with 57.3mm capillary tubes of 0.5mm internal diameter connected to it. If a tube with a different internal diameter tube is used the length will be different. The Standard contains a means of calculating the length of tube required.

BUILDING CONDITIONING PRIOR TO TESTING

Since the purpose of the pressurisation test is to determine the air leakage index of the building envelope accurately, there are certain steps to be undertaken prior to undertaking the test.

Envelope

Construction of the building envelope and any finishes that might affect airtightness must be complete.

Internal doors

All internal doors must be wedged open for the duration of the test. This ensures that there is no restriction to the airflow being delivered by the fan(s). Purpose made wooden wedges is ideal for this purpose. Cupboards inside the building do not need to be opened for the test.

External doors and windows/ventilators

All external doors, windows and ventilators must be closed before the test is carried out. Any smoke ventilators should be closed but not sealed.

Mechanical ventilation systems

All mechanical ventilation systems should be turned off and the inlet and outlet grilles sealed using either boards or polythene sheet and tape. Obviously if the supply fans are being used to pressurise the building these must not be sealed. If the cross-sectional area of any grilles is large the pressure generated by the fans can exert a strong force on the material sealing it. Therefore, this should be sufficiently strong. It is also advisable that this is checked several times during the test, certainly when the pressure differential generated by the fan is at a high setting.

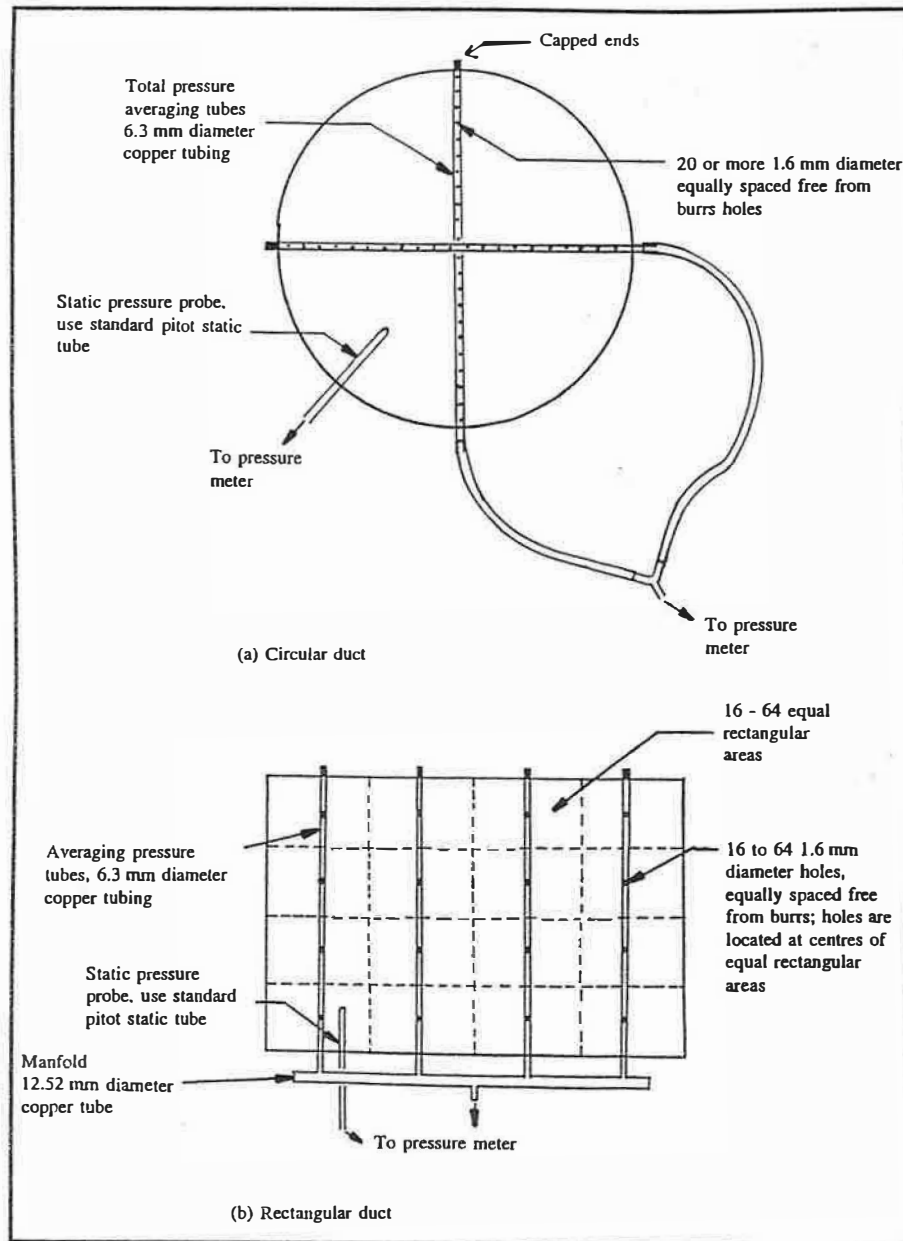


Figure 3.3 Construction and Installation of Averaging Total Pressure Airflow Measuring Device.

Plant rooms

Since plant rooms are outside the conditioned space of a building and they usually contain ventilation grilles they should be eliminated from the test. This is achieved by sealing any doors linking them to the main part of the building.

Other areas to check

If the building is new check that there is water in the U-bends of all the sinks and WC's. If there are any loft/ceiling hatches a weight should be placed on top of them to ensure that they do not lift up when the building is pressurised. Any combustion appliances in the test area should be turned off. Also, any flue or chimney should be sealed either by taping over the appliance or flue outlet, or even inflating a football bladder inside the flue/chimney.

RESTRICTIONS ON CARRYING OUT A TEST

A test should not be undertaken if the mean wind speed as measured at the test site is greater than 3m/s.

The draft CEN Standard⁸ deals with restrictions on carrying out tests due to the difference between the internal and external temperatures and also building height. With the fan aperture temporarily sealed a test should not be carried out if the stack induced pressure difference is greater than 5Pa. The Standard also states that if the product of this temperature difference and building height (in metres) exceeds 500 mK it is unlikely that a satisfactory zero flow pressure difference (i.e. < 5 Pa) will be obtained. However, it is possible to compensate for this in the data processing.

ENVELOPE AREA.

The calculation of the building envelope area is an important element in determining the air leakage index. Therefore, this should be carried out with great care using accurately scaled A0 plans and elevations, and if necessary backed up by photographs. The envelope area is calculated using the gross internal dimensions of the building, i.e. the dimensions bordering the interior volume of the building under test. This means the external walls, upper ceiling or roof, and the ground floor area, but only if it is a suspended floor with a direct access to the external air. No deductions are to be made for any internal partitions, floors, ceilings or fittings etc.

EXTERNAL FAN TEST PROCEDURE

1. Check that all the instruments have warmed up, stabilised, and have been levelled and zeroed as necessary. The micromanometer should be zeroed with the external pressure tube temporarily disconnected.

2. Set up an air temperature sensor and datalogger outside to record the external temperature during the test. Ideally it should be set to record once a minute. Also, set up a number of air temperature sensors and dataloggers inside the building, e.g. one per floor in a multistorey building, or several in a single-storey building to record the internal temperature, also once a minute.
3. Check that the average wind speed is below 3m/s.
4. Check that the building is ready for the test (i.e. internal doors open, external doors and windows closed and mechanical ventilation systems sealed).
5. Temporarily cover up the fan using polythene sheet and tape and measure the zero flow rate pressure difference.
6. Uncover the fan and start it operating at a relatively slow speed so as not to over pressurise a tight building. Adjust the airflow rate such that a pressure difference of between 55 to 60 Pa is obtained. Check that no temporary sealed components have started to leak. If so, reseal them. When the readings have stabilised take at least ten pairs of values of the pressures difference and airflow rate. Calculate the average of these readings. Record the time each set of readings is taken. If a pressure difference greater than 50 Pa cannot be obtained with the equipment, readings should be taken at the maximum pressure difference possible. If 25 Pa can be obtained with the equipment the test will be valid
7. Adjust the fan speed to obtain a lower pressure difference, and take another set of readings. Repeat this sequence so as to obtain at least eight equally spaced sets of measurements. If possible avoid measurements below 10 Pa. Further checks should be made during the test to see if there have been any changes to the building openings, e.g. doors or windows opened or any sealed component leaking. Sometimes it is obvious from the measurements that something has "gone wrong" with the test. If this happens the problem should be dealt with and the set of readings repeated.

BUILDING FAN TEST PROCEDURE

1. Carry out the first 4 items listed above.
2. Install the pre-calibrated averaging total pressure tubes and static pressure tube, or tracer gas injection and sampling tubing into each supply duct. The total averaging tubes should be installed at least five duct diameters downstream or upstream of any fan and two diameters upstream or downstream of any elbow or damper. The tracer gas injection tube should be inserted in the duct before the fan, and the sample tube after the fan.
3. Turn off the exhaust fan(s) and seal the grilles.
4. Install a reference pressure tapping at the centre of a typical floor, located near

the mid-height of the building.

5. Install an exterior pressure tapping at both ground floor and roof levels, using identical lengths of tubing. Connect both tubes to the pressure averaging/damping vessel.
6. Switch on the supply fans and adjust the air volume flow rates using the speed controllers or dampers to obtain a pressure difference between 55 and 60Pa. If this pressure difference cannot be reached record the maximum pressure difference obtained from the buildings air handling units.
7. Take a set of readings at least at five different air low rates, as before.

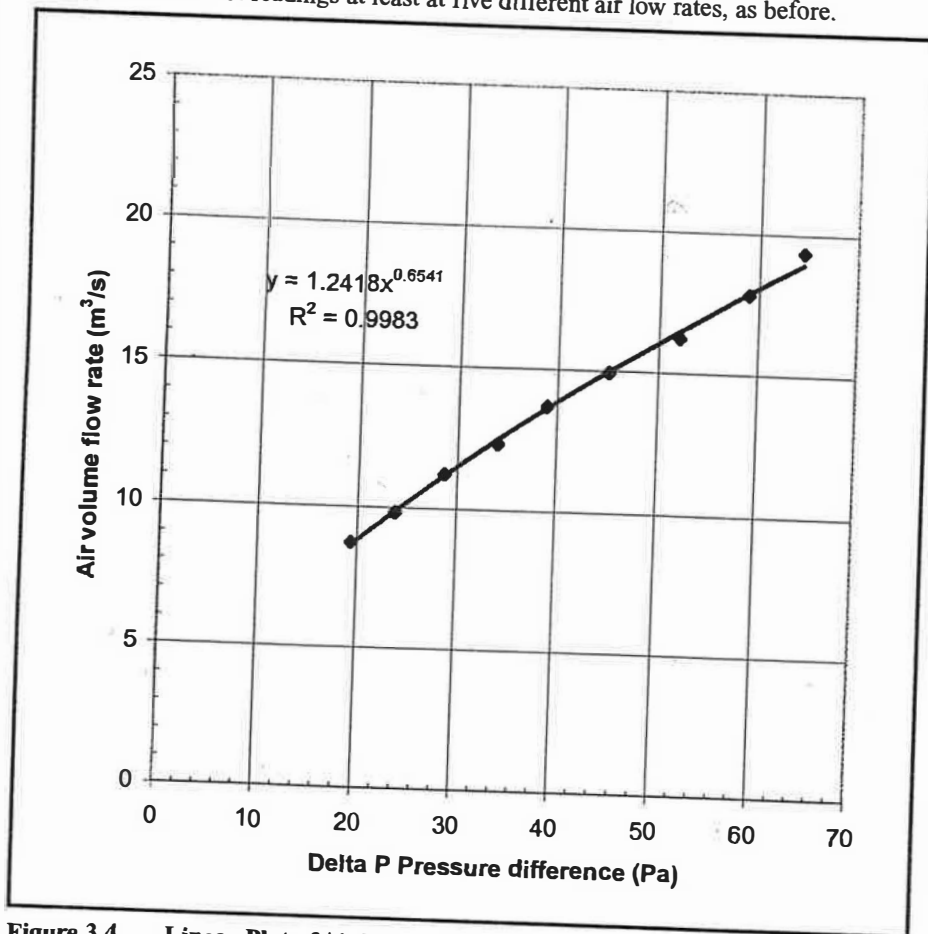


Figure 3.4 Linear Plot of Air Volume Flow Rate against Pressure Difference for the sales area of a retail store

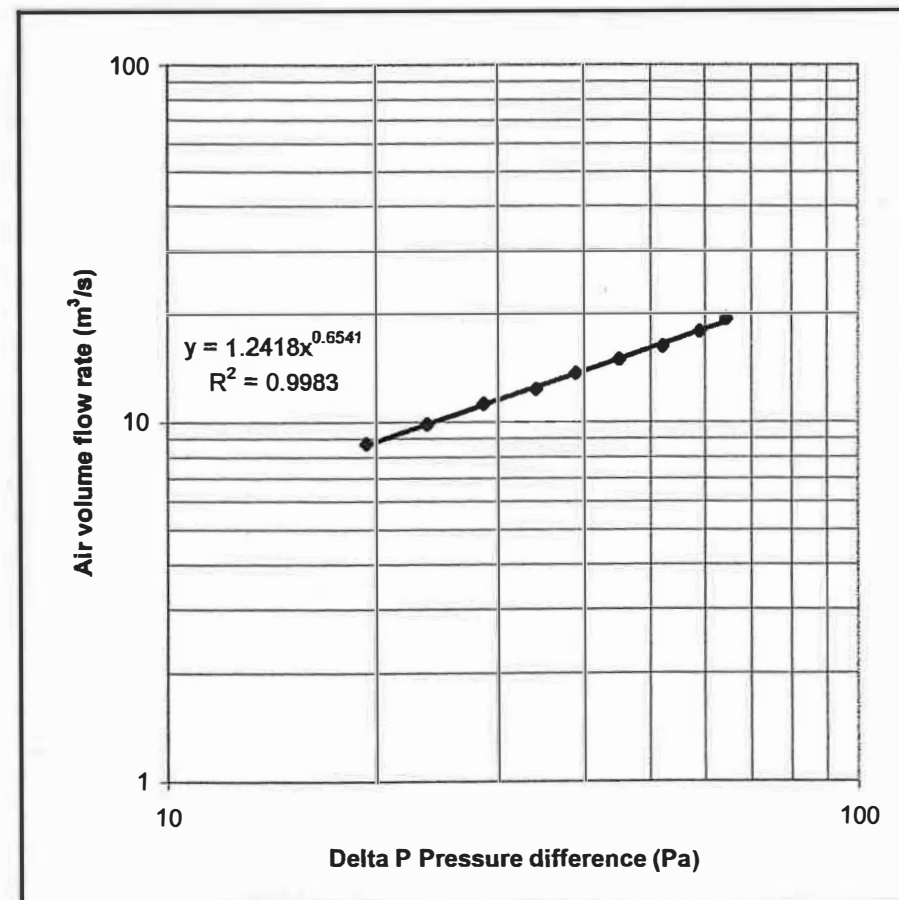


Figure 3.5 Log-log Plot of Air Volume Flow Rate against Pressure Difference for the sales area of a retail store

DATA ANALYSIS

1. Subtract the average zero-flow pressure difference from the pressure differences measured at each setting. Note, for the majority of cases this value will be negative, therefore it is an addition to the readings.
2. Convert the readings of the air flow rate measuring system to the measured air flow rate at the temperature and pressure the system was calibrated.
3. Also, to account for the difference between the outdoor and indoor temperature convert the airflow rate to the true flow rate through the building envelope.

4. Plot the airflow rate through the building envelope against the corresponding pressure differences on a linear/linear plot and a log-log plot; see Figures 3.4 and 3.5.
5. Carry out a least squares power-law curve fit on the data in accordance with the equation

$$Q = KP^n$$

Where

Q = Air volume flow rate through the building envelope (m^3/s)
 K = air leakage coefficient ($m^3/s Pa^n$)
 n = exponent {value between 0.5 and 1}

6. Determine the correlation coefficient of the curve fit.
7. Calculate either the Q_{50} or Q_{25} value and using the envelope area (S) calculate the air leakage index Q_{50}/S or Q_{25}/S . These have units of $m^3/h m^2$ of envelope area.

AIR AUDITS/SMOKE TESTS

If following a fan pressurisation test a building does not meet its air leakage specification there may be a requirement to carry out a brief or detailed air leakage audit to identify the air leakage paths. A smoke tracer or even an infrared camera can be used to identify the areas of air leakage.

There are two methods of using smoke as an identifier of air leakage paths. The first is where the whole building or a part of it is filled with smoke from multiple smoke machines. With the building pressurised using a pressurisation fan points where air leaks through the envelope can be observed from the outside. This method however, suffers from the fact that where the air leaks out from the inner leaf, may not be in close proximity to where it leaks out from the building. Therefore, there would be some confusion on how to deal with the areas identified.

The second method uses small hand-held smoke tubes. Ideally a building should be under depressurisation for an air leakage audit. This can be achieved by operating the pressurisation fan in reverse. The smoke tubes are ideal for identifying air leakage paths in a building envelope. The use of ladders or a lifting platform may be required to reach the ceiling/roof areas. To carry out the air leakage audit thoroughly floor tiles will probably need to be taken up and drop ceiling tiles removed. It is worth pointing out that this type of survey; especially a detailed air leakage audit is best undertaken outside of normal working hours.

Infrared cameras can also be used to detect air leakage paths. Using a fan to depressurise the building is required with this method so that colder outside air is drawn in through

the air leakage paths. The "colder" image colours or shades of grey show up localised cooling adjacent to these areas on the video display. If the building was pressurised you would have the same problem with whole building smoke tests in trying to correlate external leakage points to internal ones. This technique is quite successful in the winter but less so during the summer months.

CURRENT LEVELS OF AIR LEAKAGE INDEX

To give an indication of the range of the air leakage index in UK commercial buildings (i.e. offices/educational/retail) I have included a cumulative frequency plot of the results from buildings measured both by BRE and BSRIA, see Figure 3.6. For convenience I have plotted out the data for two reference pressures 25 and 50 Pa. There are both new build and existing buildings included in this data set. As can be seen very few of the buildings meet BRE's designated tight building criteria of $5m^3/hm^2$ of envelope area at 25 Pa. The average value is of the order of $10m^3/hm^2$ and leaky is $20m^3/hm^2$. The comparable values at 50 Pa are 7.5, 15, and $34m^3/hm^2$.

BSRIA have published a leaflet on air tightness specification⁹ which contains a table of the maximum and best practise air leakage values for various types of new buildings. The industry leaders in requiring their buildings to have a high air tightness specification are the main superstore chains. Their normal specification is for the buildings to have an air leakage index of $5m^3/hm^2$ at 50 Pa, but in several cases they have achieved $3m^3/hm^2$. Both these values also apply to air conditioned/low energy offices. For naturally ventilated offices and factories/warehouses the normal air leakage index specification would be $10m^3/hm^2$.

MINIMISING AIR INFILTRATION

One of the current driving forces motivating some UK designers, builders and clients to address the airtightness issue in commercial buildings is the Approved Document Part L (1995 edition)¹⁰ which supports the Building Regulations in England and Wales. The AD states that it is desirable to limit air leakage by reducing unintentional air paths as far as practicable, but does not specify an air leakage index limit. However, this AD is to undergo revision and air leakage is likely to be much more of a feature in the revised document.

It is important that the issue of airtightness is approached at the building design stage. Specialist advice should be sought if necessary. BRE have produced a 34 page report BR 265 "Minimising Air Infiltration in Office Buildings": 1994¹¹. This guidance document covers all aspects of minimising air infiltration in commercial buildings, especially offices. Examples are presented in the document on designing for a tight envelope and the materials to use in achieving this. The important issue of construction phase inspections is also discussed along with the fan testing method.

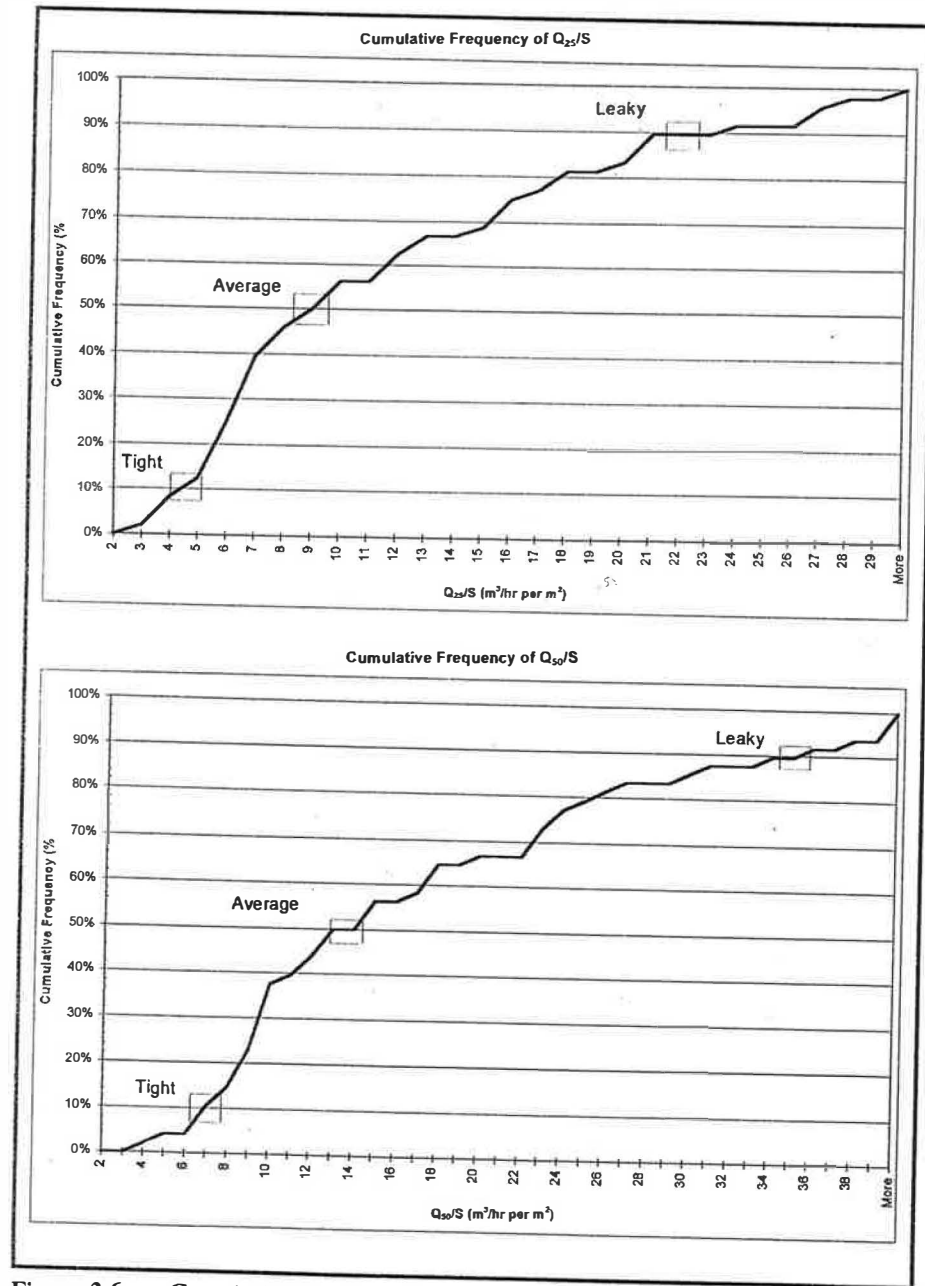


Figure 3.6 Cumulative Frequency Diagrams of Air Leakage Index at 25 and 50Pa

PROVISION OF ADEQUATE VENTILATION/IAQ

Good building design needs to separate the air supply mechanisms from the adverse and unpredictable effects of air infiltration. Therefore, attention should not only be paid to minimising air infiltration but also to providing good ventilation design. Obviously ventilation can be supplied by natural or mechanical means or a combination of both i.e. mixed mode ventilation. Guidance on the design can be found in several publications, BRE Digest 399 Natural Ventilation in Non-Domestic buildings¹², DETR Good Practise Guide 237 Natural Ventilation in Non-Domestic Buildings¹³, AIVC Guide to Energy Efficient Ventilation¹⁴ and CIBSE Applications Manual AM10 Natural Ventilation in Non-domestic Buildings¹⁵.

The benefits from minimising air infiltration in buildings can be grouped into three main groups: occupants, building and environment.

Occupants will benefit from the avoidance of discomfort from draughts. In severe cases a leaky building may not reach comfort temperatures in the winter. It is likely that productivity will improve since staff feeling comfortable in their working environment will get on with their work. With a well-designed ventilation system contaminants from outdoor air will be suitably filtered etc.

Air infiltration through the building envelope can lead to potential problems with condensation within the structure and affect the performance of the thermal insulation in the outer leaf.

Energy costs will be much higher than necessary with high air infiltration rates. The reduction of air infiltration in a building will allow designers of HVAC systems to reduce the size of the plant and plant room.

With about 50% of UK CO₂ emissions being attributed to delivered energy use in buildings any energy efficiency measures targeted at buildings will represent a major contribution towards achieving the desired reductions.

CONCLUSIONS

The minimisation of air infiltration in new and existing commercial buildings has benefits not only for the occupants but also in the reduction in energy costs and CO₂ emissions. The common methods of carrying out pressure tests in buildings have been described along with the practical aspects of undertaking them. Typical values of air leakage index for commercial buildings have been presented and best practise values listed for various types of buildings.

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Chapter 4**Guidelines for Minimising the Ingress of Urban Pollution****Paul Ajiboye*****INTRODUCTION**

The aim of this Chapter is to breakdown barriers to concepts of natural ventilation. The study is part of a Pan European project titled NatVent, that involves seven countries in the north of Europe. The project leaders are the UK Building Research establishment. Urban pollution is a major barrier to the adoption of natural ventilation, so successful ways of avoiding these problems need to be found.

The traditional approach to ventilating non domestic buildings located in urban areas is to specify mechanical ventilation. This strategy can seal buildings from pollution along facades, and where necessary draw air via cleaning filters to remove contaminants; the pressure drop associated with this process is not a practical option for passive ventilation. The draw back in relying upon air conditioning systems is in the amount of energy required to run them, hence the negative environmental impact. If natural ventilation systems are not adversely affected by external pollution then it offers an ideal alternative.

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