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Air Infiltration and Ventilation Centre's Guide to Air Exchange Rate and Airtightness Measurement Techniques

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ABSTRACT

The provision of an adequate supply of uncontaminated air suitable for the needs of the occupants is an important aspect of building design and construction. Ventilation can be promoted by natural or artificial forces and it is necessary to understand this process since it affects both the energy consumption and internal environment of a building.

Ventilation is a complex process which is influenced by a variety of constructional, behavioural and environmental parameters.

Measurement techniques provide the fundamental means of acquiring a greater understanding of air infiltration and ventilation, in that they enable primary data to be obtained from existing structures. In recognition of the importance of measurement techniques the Air Infiltration and Ventilation Centre (AIVC) has produced a document titled:

"Air Exchange Rate and Airtightness Measurement Techniques - An Applications Guide"

The guide primarily examines the measurement of air change rate, interzonal air flow and airtightness. The broad aims of this document are to indicate the variety of techniques which are available, provide detailed information about several techniques and offer advice regarding the selection of techniques for particular applications. This paper describes the scope, structure and content of this guide to air exchange rate and airtightness measurement techniques.

Keywords; air change rate, interzonal air flow, airtightness, measurement techniques

Introduction

The International Energy Agency (IEA) sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is funding various programmes to predict more accurately the energy use of buildings. One such programme is the IEA's annex V; the Air Infiltration and Ventilation Centre (AIVC). This annex has particular responsibility for promoting a greater understanding of infiltration and ventilation in buildings. Ventilation is the general term applied to the transport of air into, through and out of a building. This may be promoted by natural or artificial forces. Infiltration is the fortuitous leakage of air through cracks and gaps in the building fabric.

Infiltration is caused by pressure differences created by the dynamic action of the wind and/or differences in air density due to indoor-outdoor temperature differences. Therefore, infiltration can be viewed as uncontrolled ventilation.

It is necessary to consider ventilation since it affects both the energy consumption and internal environment of a building.

Ventilation is a complex process which is influenced by a variety of constructional, behavioural and environmental parameters. Because of these complexities ventilation is often regarded as one of the least understood aspects of building physics. However, in recent years the development of several specialised measurement techniques has enabled the ventilation behaviour of a large variety of buildings to be quantified.

Now techniques are available which enable the flow rate of air into a building, under normal environmental conditions, to be evaluated.

Methods also exist which allow the air exchange rate between internal spaces to be measured. Evaluation of the overall airtightness of the building shell has become routine and, in some countries, mandatory. The location and distribution of air leakage sites can be determined, and the air leakage characteristics of specific building components or leakage paths can be evaluated.

Measurement techniques provide the fundamental means for acquiring a greater understanding of air infiltration and ventilation, in that they enable primary data to be obtained from the evaluation of existing structures. In recognition of the important role practical methods play in air infiltration and ventilation studies the AIVC has produced a guide to air exchange rate and airtightness measurement techniques. This paper describes the scope, structure, content and use of the guide without presenting details of any specific measurement techniques.

General Scope And Structure Of The Guide

The information in the guide is presented in seven chapters:

- Chapter 1: Selecting a Technique
- Chapter 2: Measurement of Air Exchange Rates
- Chapter 3: Measurement of Airtightness
- Chapter 4: Equipment and Instrumentation
- Chapter 5: Measurement Technique Standards
- Chapter 6: Detailed Description of Measurement Techniques
- Chapter 7: Detailed Description of Instrumentation

A Glossary of terms relevant to air infiltration and ventilation measurements is also included.

The guide has been designed so that the material suited to any user's particular area of interest or current level of expertise, is readily accessible. By examining the flow chart given in Figure 1 (this figure appears at the beginning of the guide) readers can determine which parts of the document will be appropriate to their requirements. For example, readers who are already familiar with measurement techniques may wish only to consult the detailed information presented in Chapters 6 and 7. Whereas readers new to the field will find that the information presented in Chapters 2, 3 and 4 provides a basic introduction to the subject.

The guide is produced in a loose leaf format thus enabling fresh developments in measurement technology to be readily accommodated.

Selecting a Technique

Chapter 1 of the guide describes and discusses the parameters which are important in gaining a greater understanding of the ventilation behaviour of buildings. These are essentially:

Air Change Rate

This is a measure of the bulk movement of air into and out of a space and is defined as the volumetric rate at which air enters (or leaves) a space divided by the volume of the space. Measurements of air change rate enable a building to be assessed in terms of its ability to provide adequate ventilation for its occupants, and allows the actual energy loss due to infiltration and ventilation to be evaluated. The measurement of air change rate is examined in Chapter 2 of the guide.

Interzonal Air Flows

The bulk movement of air into and out of a building causes air to flow between the various internal spaces of that building.

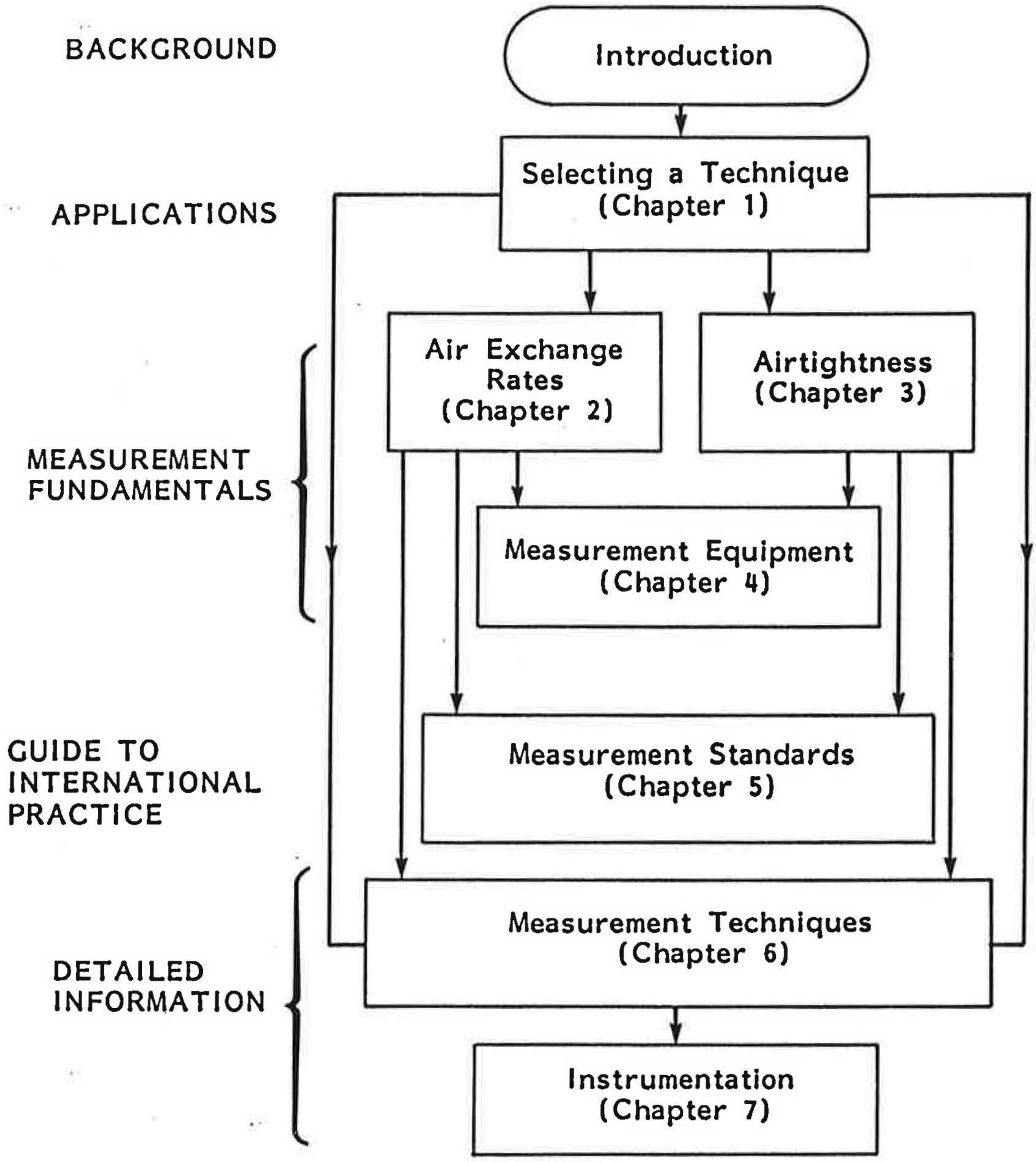
BACKGROUND
Introduction
APPLICATIONS
Selecting a Technique (Chapter 1)
MEASUREMENT FUNDAMENTALS
Air Exchange Rates (Chapter 2)
Airtightness (Chapter 3)
Measurement Equipment (Chapter 4)
GUIDE TO INTERNATIONAL PRACTICE
Measurement Standards (Chapter 5)
DETAILED INFORMATION
Measurement Techniques (Chapter 6)
Instrumentation (Chapter 7)

FIG 1

This internal air movement plays a vital role in the distribution of pollutants throughout the ventilated space. Therefore, in order to gain a complete understanding of the ventilation behaviour of a building it is desirable to know the rate of air exchange between the various internal spaces of the structure. The measurement of interzonal air flow is examined in Chapter 2 of the guide.

Air Leakage Characteristics

Air change rate and interzonal air flows are parameters which are themselves dependent upon a variety of variable influencing factors. A second basic approach in air infiltration and ventilation measurements is to negate the influence of these variable factors and evaluate the air leakage characteristics of the building fabric only. In any building there are many potential leakage sites. These may be either adventitious or intentional. In order to asses the leakage performance of the building it is necessary to determine quantitatively the relationship between the air flow through, and the pressure differential across, the leakage paths. The evaluation of air leakage characteristics is examined in Chapter 3 of the guide.

The main applications of infiltration and ventilation measurement techniques are also discussed in Chapter 1. The applications are presented in a series of flow charts examining:

Fundamental Data and Research

Standards

Building Diagnostics

Indoor Air Pollution

Ventilation Efficiency

Mathematical Models - Input and Validation

These flow charts provide the reader with a step by step guide to selecting the correct measurement technique for any given application. An example of this type of flow chart, taken from the guide, is shown in Figure 2.

A series of tables provides summaries of the main measurement techniques examined by the guide. Techniques are grouped together according to the parameters which they evaluate i.e.

Air Change Rate Methods

Interzonal Air Flow Methods

Building Envelope Airtightness Methods

Building Component Airtightness Methods

Leakage Location and Qualitative Methods

These tables list the equipment required to perform the measurement, the actual quantities measured and some of the factors affecting the selection of a particular technique. An example of this type of table is shown in Figure 3. The tables and flow charts in Chapter 1 are all cross referenced with the main body of the guide.

Measurement of Air Exchange Rates

The fundamental theory and practice of measuring air exchange rates is presented in Chapter 2. Air exchange between a building and the external environment (air change rate) is examined as is the air exchange between the various internal spaces of a building (interzonal air flows).

BUILDING DIAGNOSTICS

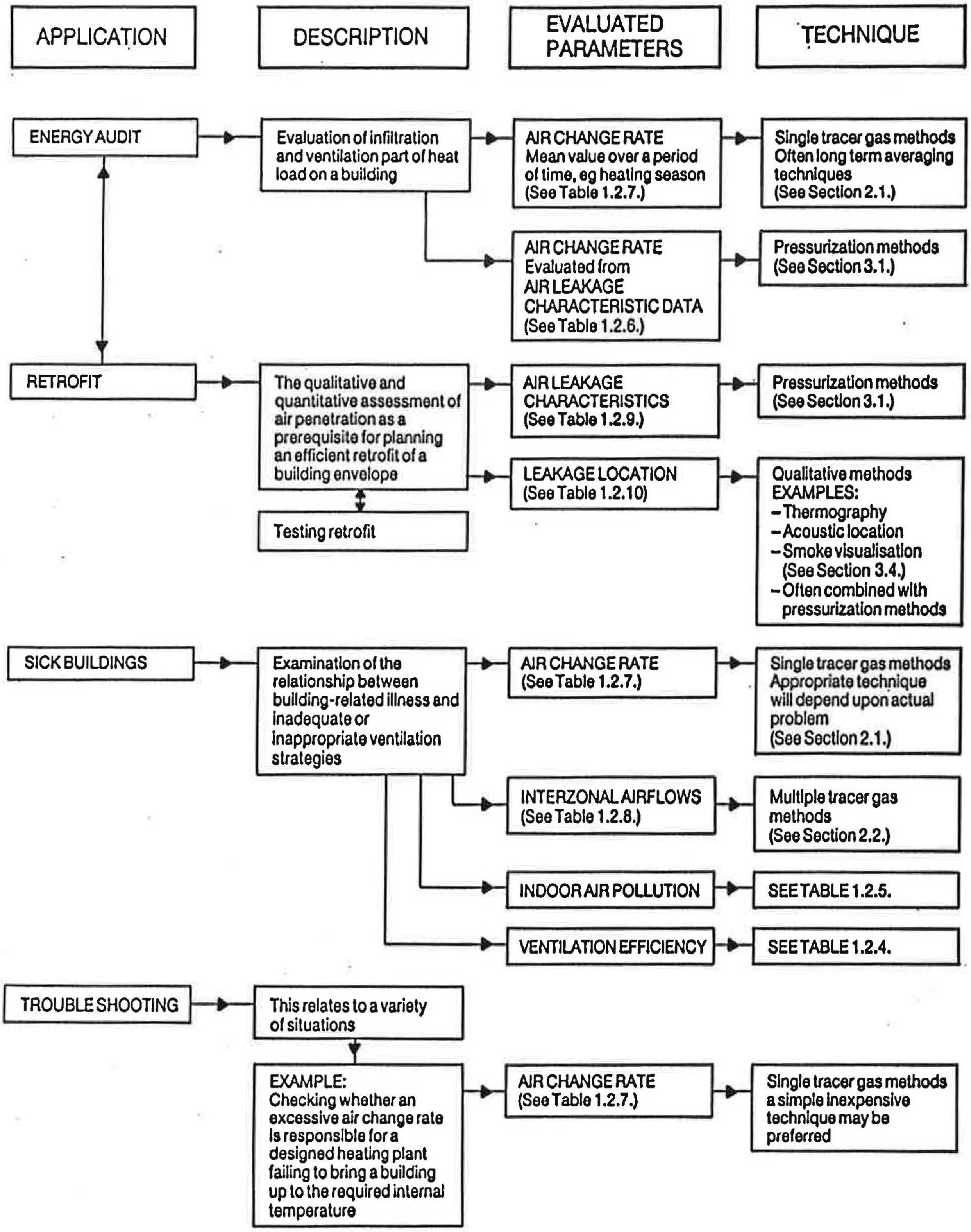

FIG 2

BUILDING COMPONENT AIRTIGHTNESS METHODS

TECHNIQUE	EQUIPMENT	MEASURED QUANTITIES	FACTORS AFFECTING SELECTION
DC PRESSURIZATION COLLECTOR CHAMBER (Further details in Section 3.2.)	*ESSENTIAL* Collector chamber (Sealing box) Fan Flow rate measurement device Differential pressure measurement device *OPTIONAL* Second fan to balance pressure between collection chamber and room	Airflow rate through component Pressure difference across component Component dimensions	Relatively low cost method Ideal for examination of buildings which have a large number of replicated components Time and skill is required to adjust the collector chamber to a given component
DC PRESSURIZATION LABORATORY TESTING (Further details in Section 3.2.)	Test chamber Fan Flow rate measurement device Pressure differential measurement device	Airflow rate through component Pressure differential across component Component dimensions	High initial cost to build facility Good design allows many types of components to be tested Results may be 'better' than site measurements due to controlled workmanship
DC PRESSURIZATION REDUCTIVE SEALING (Further details in Section 3.1.1.)	Pressurization equipment (See Table 1.2.9.) Sealing products For example: plastic sheet Sticky tape	Air flow rate through envelope Pressure difference across envelope Building volume Degree of sealing (Type, number and location of sealed components)	Low cost method Patience and skill are required to seal components effectively Does not apply to components which cannot be isolated Similar work can be performed with AC pressurization
DC PRESSURIZATION Balanced fan (Further details in Section 3.2.)	Two or more sets of pressurization equipment (See Table 1.2.9.) Pressure differential measurement and control devices	Air flow rate through main test fan Pressure difference across test component Pressure difference across other partitions (Should be maintained at zero) Building volume	Increase cost due to more equipment Skill required to balance pressure differentials In complex buildings several sets of equipment (more than three) may be required or several sets of measurements must be made More susceptible to wind effect errors than single fan method
FLOW RATE METER (Further details in Section 3.2.)	*ESSENTIAL* Pressure compensating flow rate meter Flow collection chamber *OPTIONAL* DC pressurization equipment (See Table 1.2.9.)	Airflow rate through measured component Component dimensions	Can measure natural air flow rate through facade components Flow collection chamber does not have to provide an air tight seal Limited flow rate range Large leaks in facade cannot be evaluated Large internal leaks make pressure compensation difficult

Fig 3

Air change rate is usually measured by injecting a single tracer gas into a building and measuring its concentration with time. There are three main variations of single tracer gas measurements:

Decay Rate Method

With this method a one-time injection of tracer gas is made. The gas is allowed to mix with the internal air; this may be promoted by small electric fans or the building air handling system. The concentration of gas, over a given time interval, is then monitored with a suitable detector. The decay of the tracer gas in the building can be related to the air change rate.

Constant Emission Rate Method

With this method tracer gas is injected at constant rate into the building and its concentration with time monitored. The air change rate is inversely proportional to the measured concentration.

Constant Concentration Method

For this method the concentration of tracer gas is held at a constant level within the building. This is achieved by providing a controllable variable flow rate of tracer into the building. The air change rate is proportional to the amount of tracer injected to maintain the concentration.

The detailed theory of each technique is presented and the practical solutions to the theory are discussed.

For interzonal air flow measurements multiple tracer gas methods are most often used. The multi-tracer gas versions of the three basic techniques shown above are examined.

Measurement of Airtightness

Chapter 3 presents the fundamental theory and practice of evaluating the air leakage characteristics of buildings and building components. There are two basic approaches to building envelope airtightness measurement:

DC Pressurisation

With this method a uniform static under or over pressure is created within the building. The flow rate required to produce this pressure is measured, as is the pressure difference across the envelope. From a knowledge or these two parameters the air leakage characteristics of the building can be evaluated.

AC Pressurisation

In this technique a small varying pressure difference is created across the building envelope, which can be distinguished from naturally occurring pressures. Because of this distinction the air flow through the envelope, due to the applied pressure differential, can be evaluated.

These two techniques are discussed in some detail. This chapter also contains a section describing the techniques used to locate leakage sites in the building envelope.

Equipment and Instrumentation

Chapter 4 describes in general terms some of the specialist equipment and instrumentation used to perform ventilation measurements. Four specific topics are addressed:

Tracer Gases

Tracer gases are used in the measurement of air exchange rates. The guide discusses the characteristics of an ideal tracer gas, and provides information about gases which have been used in practice.

Tracer Gas Analysers

The role of the gas analyser is to determine, as accurately as possible, the concentration of tracer gas in a sample of air from the measured space. The guide provides information about commonly used analysis methods and offers advice regarding choosing an analyser to make tracer gas measurements.

Commercial DC Pressurization Equipment

Measurements of building envelope airtightness can be performed by using a fan which is temporarily installed in the building envelope. This type of equipment was initially developed as a research tool. Versions of this type of equipment are now available from several commercial organisations. This equipment is often known as a blower door. The guide discusses blower door design and provides detailed information about several commercially available door fans.

Instruments for Measuring Climatic Parameters

Many different climatic parameters can be measured. However only those of most relevance to infiltration and ventilation studies are considered by the guide. These are wind speed wind direction and air temperature.

This chapter is cross-referenced with Chapter 7 which contains detailed descriptions of several instruments.

Measurement Technique Standards

Several standards have been developed which relate to ventilation measurements. Chapter 5 discusses 11 selected standards from around the world. The criteria for selection being that they relate to site measurements of buildings or building components.

Two main groups of standards are examined:

Air Change Rate Measurement Technique Standards

The guide examines four standards in this category. Three deal with the decay rate method and one with the constant concentration method.

Airtightness Measurement Technique Standards

The guide examines seven standards in this category. Five deal with whole envelope airtightness measurement and two with building component airtightness measurement.

Brief summaries of the all the standards are presented and a comparison of similar standards is made (see, for example, Figure 4).

Detailed Description of Measurement Techniques

Chapter 6 currently contains detailed descriptions of 9 measurement techniques. Because the guide is presented in a loose leaf format updates of current techniques or information about new techniques can be easily added. Information about each technique is presented in a standard format thus aiding comparison and selection. The information in the standard format is presented in the following main sections.

Type of Technique

Range of Application

Equipment and Instrumentation

Setting Up and Operating Details

Presentation of Results

Measurement Accuracy

Availability of Measurement System

COMPARISON OF AIRTIGHTNESS MEASUREMENT STANDARDS

Standard	Recommended Fan Flow Capacity	Pressure Tap Location	Differential Pressure Range	Limiting Conditions	Expression of Results	Accuracy
CAN/CGSB –149.10-M86	Maximum 1.5–2.5 m^3s^{-1}	At least four taps around building leading to an averaging container	0 – 50 Pa underpressure	Windspeed < 5.6 ms^{-1}	Equivalent leakage area	Air flow ± 5% Δ P ± 2 Pa
NEN 2686	Maximum 1.2 m^3s^{-1}	One tap at building facade	15–100 Pa overpressure or underpressure	Natural Δ P across envelope < 5Pa usually windspeed < 6 ms^{-1}	Flow coefficients Flow rate at 1 and 10 Pa in m^3s^{-1}	Airflow ± 5% Δ P ± 5%
SS 02 15 51	Sufficient to produce Δ P of 55 Pa	One tap 10 m from building ending in a T-piece	0–55 Pa over pressure and underpressure	Windspeed < 6 ms^{-1} 10 m from building	Air change rate at 50 Pa	Airflow ± 6% Δ P ± 3 Pa overall ± 10%
E779-87	Not stated	One tap location not stated	12.5 – 75 Pa overpressure or underpressure	Ideal windspeed < 2 ms^{-1} temperature 5–35°C	Plot of flow against Δ P Equivalent leakage area	Airflow ± 6% Δ P ± 2.5 Pa
DP9972	Sufficient to produce Δ P of 60 Pa	Ideally near neutral plane	10 – 60 Pa overpressure or underpressure	Natural Δ P across envelope < 3 Pa	Flow coefficients	Airflow ± 5% Δ P ± 5%

FIG 4

The guide currently contains detailed descriptions of the following techniques

Tracer Gas Decay Rate - Site Analysis

Tracer Gas Decay Rate - Grab Sampling (Bottles)

Tracer Gas Decay Rate - Grab Sampling (Detector Tubes)

Tracer Gas Constant Emission Rate - Passive Sampling

Tracer Gas Constant Concentration

Multiple Tracer Gas Decay Rate

DC Pressurization - External Fan

DC Pressurization - Internal Fan

AC Pressurization

Detailed Description of Instrumentation

Chapter 7 contains descriptions of instruments which have been used in making some types of air exchange rate or airtightness measurements. The description is presented in a standard format and issues such as measurement method, precision, response time, input requirements and possible applications are addressed. Information about 3 instruments is currently presented in this chapter.

Infra-red Gas Analyser

Electron Capture Gas Detector

Electronic Micromanometer

Due to the loose leaf nature of the guide, information about other instruments may be easily added.

Role of the Measurement Techniques Guide

The role of this guide is to increase general awareness of air exchange rate measurement techniques and their application. By providing the fundamental theory and practice of making measurements and detailed information about several techniques it is hoped to meet the needs of a wide range of readers. However the following groups of people are specifically provided for by the guide.

Research and Academic

The guide will act as a directory of current techniques and will promote discussion about measurement techniques by research workers.

Specialist Consultants

The guide will encourage specialist consultants, operating in the field of building physics, to consider using air exchange rate and airtightness measurement techniques in their work.

Non-specialist Consultants

The guide will introduce measurement techniques to non-specialist consultants, indicate the variety of methods available and give advice as to where further information may be obtained.

The guide to air exchange rates and airtightness measurement techniques is available from the Air Infiltration and Ventilation Centre at:

Barclays Venture Centre
University of Warwick Science Park
Sir William Lyons Road
Coventry
CV4 7EZ
United Kingdom

Figure 1 Scope and Structure of the Guide

Figure 2 Example of an Application and Selection Flow Chart

Figure 3 Example of a Measurement Techniques Summary Table

Figure 4 Example of Comparison of Measurement Standards