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Techniques and instrumentation for the measurement of air infiltration in buildings – a brief review and annotated bibliography

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Air Infiltration Centre
Old Bracknell Lane West, Bracknell,
Berkshire, Great Britain, RG12 4AH

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Annex V Air Infiltration Centre

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Martin Liddament
and Catriona Thompson

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PREFACE

International Energy Agency

In order to strengthen cooperation in the vital area of energy policy, an Agreement on an International Energy Program was formulated among a number of industrialised countries in November 1974. The International Energy Agency (IEA) was established as an autonomous body within the Organisation for Economic Cooperation and Development (OECD) to administer that agreement. Twenty-one countries are currently members of the IEA, with the Commission of the European Communities participating under a special arrangement.

As one element of the International Energy Program, the Participants undertake cooperative activities in energy research, development, and demonstration. A number of new and improved energy technologies which have the potential of making significant contributions to our energy needs were identified for collaborative efforts. The IEA Committee on Energy Research and Development (CRD), assisted by a small Secretariat staff, coordinates the energy research, development, and demonstration programme.

Energy Conservation in Buildings and Community Systems

The International Energy Agency sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods, etc. The difference and similarities among these comparisons have told us much about the state of the art in building analysis and have led to further IEA sponsored research.

Annex V Air Infiltration Centre

The IEA Executive Committee (Building and Community Systems) has highlighted areas where the level of knowledge is unsatisfactory and there was unanimous agreement that infiltration was the area about which least was known. An infiltration group was formed drawing experts from most progressive countries, their long term aim to encourage joint international research and to increase the world pool of knowledge on infiltration and ventilation. Much valuable but sporadic and uncoordinated research was already taking place and after some initial ground-work the experts group recommended to their executive the formation of an Air Infiltration Centre. This recommendation was accepted and proposals for its establishment were invited internationally.

The aims of the Centre are the standardisation of techniques, the validation of models, the catalogue and transfer of information, and the encouragement of research. It is intended to be a review body for current world research, to ensure full dissemination of this research and based on a knowledge of work already done to give direction and a firm basis for future research in the Participating Countries.

The Participants in this task are Canada, Denmark, Italy, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and the United States.

1. INTRODUCTION

Air infiltration and ventilation heat loss can account for a substantial proportion of a building's space heating demand. Therefore, in the planning of energy conservation measures, the influence of air exchange demands very careful consideration. Unfortunately, air infiltration is particularly difficult to measure. This is because not only is it dependent on building airtightness, and hence the quality of construction, but it is also significantly influenced by prevailing climatic conditions, surrounding terrain and the actions of occupants. Furthermore, the diverse and random distribution of leakage paths generally renders the direct measurement of air flow at each opening impossible. Consequently, the use of infiltration measurement techniques has largely been restricted to research investigations. In other circumstances air change rates are all too frequently based on guesswork or unreliable heat balance estimates. Recently, however, considerable progress has been made in the development of techniques to the point where their more general application has become possible. The objective of this report is to highlight these recent developments by presenting a brief review of measurement methods and a selective bibliography. In addition, this report contains details of manufacturers of instrumentation currently being used in air infiltration investigations.

The first section of the bibliography is devoted to review papers selected to provide a comprehensive background to the theory behind air infiltration measurement techniques. The remaining sections are devoted to tracer gas techniques, pressurization methods and miscellaneous approaches respectively. All references are taken from the Air Infiltration Centre's bibliographic database *AIRBASE* and were selected on the basis that they provide sufficient information to enable the techniques described to be readily adapted by potential users. Details of manufactuers are contained in three appendices; these cover tracer gas analysers, pressurization test equipment and surface pressure measuring instrumentation respectively.

Subject to the usual copyright practices, photocopies of the papers listed in this bibliography are available free-of-charge to organisations in participating countries. To obtain photocopies, users should complete and sign the photocopy request form printed in the back of this report and send it to the Air Infiltration Centre. Reports that are only available on loan are marked with an asterisk (*).

2. BRIEF REVIEW OF TECHNIQUES

2.1 Background

There are two fundamental approaches to the measurement of air infiltration and air leakage in buildings. Ambient air infiltration is measured using tracer gas techniques, while the airtightness of a building is measured by artificially pressurizing the building and measuring the induced air flow rate. Each approach provides substantially different building air loss information and it is not normally possible to directly interchange the results. The tracer gas technique gives a direct measure of air infiltration rate corresponding to the climatic conditions prevailing at the time of the test; many successive measurements over an extended period of time are necessary to determine the relationship between the rate of air infiltration and weather conditions for any particular building. On the otherhand, the pressurization technique is usually performed at pressures in excess of ambient conditions and consequently the results are independent of weather conditions. Frequently smoke tests and thermographic surveys are carried out in conjunction with pressure tests as a method of detecting sources of air leakage. Acoustic methods are also used to detect air leakage in buildings.

Air infiltration instrumentation and measuring techniques formed the subject of the Air Infiltration Centre's first annual conference held in the United Kingdom in 1980[1].The conference proceedings contain a total of 19 papers covering all aspects of current measuring techniques and include a number of comprehensive review papers. In particular, the keynote paper presented by Dick[2] contains an account of his pioneering work in this field and a description of the many problems he encountered. This is followed by a theoretical analysis of tracer gas methods by Sherman et al[3] and a review of pressurization and tracer gas techniques by Alexander et al[4]. The proceedings of the American Society for Testing and Materials conference, held in Washington DC in 1978, also provides a valuable handbook of techniques and begins with a state of the art review paper by Hunt[5]. Many other authoritative reviews are to be found in the literature; these include papers by Hitchin and Wilson[6], Kronvall[7], Stricker[8] and Harrje[9].

2.2 Tracer Gas Methods

If an inert gas that is not normally present in the atmosphere is released and perfectly mixed in a leaky enclosure, its concentration at any instant in time is given by the continuity equation

$$\frac{VdC}{dt} + QC = F \qquad (1)$$

Term I Term II Term III

where V = effective volume of enclosure (m^3).
Q = infiltration/exfiltration rate (m^3s^{-1})
C = concentration of tracer gas in enclosure
F = tracer gas injection rate (m^3s^{-1})
t = time (s)

Hence it is possible to use this method to measure the air infiltration rate.

Ideally a tracer gas should be inert, non toxic and readily detectable at low concentrations. Nitrous oxide has proved very popular for this application because it is readily available, inexpensive and generally regarded as safe at the low concentrations used (typically 100 ppm). Sulphur hexafluoride is also widely used and is particularly useful because it can be detected at concentrations as low as only a few parts per billion. However, the results can be influenced by the presence of other fluoro compounds, for example escaping refrigerant from refrigeration or air conditioning systems. Many other gases and volatile liquids have been successfully used in tracer gas studies and a list of some of the more common substances appears in Table 1. Experimental comparisons between the performances of different tracer gases are described by Grimsrud et al[10], Shaw[11] and Bassett et al[12].

Tracer gas is normally detected by making on-site measurements using an appropriate gas analyser (see Appendix 1). Alternatively, samples may be collected in bags, bottles or adsorption tubes for subsequent laboratory analysis.

Concentration decay

The most straightforward method of conducting a test is to release and thoroughly mix a small quantity of tracer gas in the enclosure. The gas supply is then turned off and after a further period of mixing the decay in concentration over time is measured[13-36]. Following the cessation of gas injection, Term III of the equation (1) becomes zero and by integration the continuity equation reduces to

$$C_{(t)} = C_{(o)}e^{-\frac{Q}{V}t} \qquad (2)$$

where $C_{(o)}$ = tracer gas concentration at start of decay measurement

$C_{(t)}$ = tracer gas concentration at time, t, after start of decay measurement

The air change rate is therefore simply given by the logarithmic gradient of the decay in tracer gas concentration. This method can be readily performed manually although automatic techniques have also been developed[32-36].

Constant concentration

An alternative approach is to maintain a constant concentration[37-40]. Term I of equation (1) then becomes zero and the continuity equation reduces to

$$Q = \frac{F}{C} \quad (m^3s^{-1}) \qquad (3)$$

Thus the infiltration rate becomes directly proportional to the tracer gas injection rate. A constant concentration can normally only be maintained by using automatic control techniques. Typically, tracer gas is released from a constant pressure vessel and thoroughly mixed until a predetermined

threshold concentration is reached. Small deviations from a predetermined threshold concentration are then automatically rectified by means of additional releases of gas, initiated by means of a computer controlled feedback system.

Constant emission

Air infiltration measurements may also be made by releasing tracer gas at a constant rate of emission[41-46]. If conditions remain constant, a state of equilibrium will eventually be reached at which stage the infiltration rate will be given by equation (3)[41,42]. It is more probable, however, that equilibrium will take too long to achieve or will never be attained at all. In this instance the continuity equation becomes

$$C_{(t)} = \frac{F}{Q} + (C_o - \frac{F}{Q})e^{-\frac{Q}{V}t} \quad (4)$$

The constant emission approach has particularly useful applications in estimating long term 'time averaged' infiltration. In a method described by Sherman et al[43] two sample bags, one empty and the other filled with a known quantity of sulphur hexafluoride, are brought into the building. A two channel pump is used to gradually inflate the initially empty bag with air from the building and to simultaneously evacuate the bag of tracer gas. The test period is generally of one month's duration and at the end of this period the apparatus is brought back to the laboratory for analysis. The total amount of tracer gas discharged and the tracer gas concentration in the initially empty bag is measured and the results are used to calculate the average air infiltration over the sampling period. In a further development of this technique, Dietz[44] has developed a passive dispersion tube and adsorption sampler suitable for perfluorocarbon tracer gases.

The continuous emission of metabolic carbon dioxide has also been used to measure air infiltration in occupied buildings. This method is still very much at the development stage but descriptions of this technique are presented by Turiel et al[45] and Penman et al[46].

Assumptions

The success of the tracer gas techniques is dependent on the validity of three key assumptions; these are that

- the mixing of tracer gas is perfect and instantaneous.
- the effective volume of the enclosure is known (decay and constant emission methods).
- the factors that influence air infiltration remain unchanged throughout the measurement/ integration period (decay and constant emission methods).

Mixing

Imperfect mixing can occur when air movement is impeded by flow resistances or when air is trapped by the effects of stratification. It can also occur when infiltrating air displaces the air present without mixing or when exfiltrating air re-enters the building at another location. The effect is to cause a spatial variation in tracer gas concentration resulting in different parts of the enclosure having apparently different air change rates. A delay in mixing may also create difficulties because the injection and sampling points are normally separated by a short distance, thus there is inevitably a time lag before the effects of tracer gas injection can be detected.

Mixing in dwellings

Adequate mixing is generally achieved in dwellings by placing small mixing fans at each internal doorway[14-16]. In this instance, the building is treated as a 'single-cell'. Alternatively, in dwellings equipped with warm air distribution systems, mixing is often accomplished by injecting the tracer gas directly into the air distribution system[20-23]. Small deficiencies in mixing can be overcome by sampling the air at several locations. This is achieved by linking each sample point via equal length tubes to a manifold[18] or by sequentially sampling the gas concentrations at each location[19]. Other detection methods rely on single point sampling from a central location[14,15,16] or by sampling the tracer gas concentration in the return air duct of warm air systems[20-23]. Grot[17] describes a technique whereby a sample is gradually drawn into a hand held bottle while the operator moves through the building.

Mixing in multi-cell buildings

Mixing difficulties are considerably aggravated by internal partitioning, with the result that tracer gas decay results become difficult to interpret. A rigorous mathematical treatment of this problem is described by Sinden[24]. A simplified approach is to determine the air change rate in each room separately[14]. However, this technique does not distinguish between fresh air exchange and intercellular air movement. Alternatively, tracer gas may be uniformly distributed throughout the entire building and decay measurements made simultaneously in each room[25-27]. The fresh air change rate in each cell may then be determined from the initial part of each decay curve, during the period in which intercellular differences in tracer gas concentration are negligible. This method has also been used by Grot[36] to determine the rate of air infiltration in large air conditioned office buildings. Other tracer gas decay studies in multi-cell buildings have made use of multi-tracer techniques[28,29]. Constant concentration methods are particularly suited to multi-cell environments because, provided a uniform concentration is maintained throughout the building, the fresh air change rate remains directly proportional to the total tracer gas injection rate.

Mixing in large single-cell enclosures

The influence of internal air circulation and stratification in resisting mixing tends to place an upper limit on the size of enclosure in which tracer gas measurements may be made. Measurements in large single-cell buildings such as warehouses and industrial premises are being attempted but results confirming their validity are currently unavailable. Mathematical analyses of tracer gas results in buildings subjected to poor mixing are described by Lidwell[30] (transfer index method) and Sandberg[31] (ventilation efficiency).

Effective volume

The effective volume of the enclosure is the volume in which the tracer gas is mixed and is often assumed to be equivalent to the physical volume of the occupied or heated space. However, the effective volume may be reduced by 'dead spaces' in which air is trapped, such as cupboards, or increased by additional communicating spaces, such as attics and basements. The problem can be minimised by opening all cupboard and internal doors and by ensuring good mixing.

Variations in conditions

Variations in conditions that influence air infiltration during the course of a concentration decay measurement, for example window opening or climatic changes, will result in a departure in tracer gas concentration from the logarithmic decay curve. For this reason, the time interval over which a measurement may be made is usually restricted to no more than one or two hours. This problem also prevents the constant emission approach from reaching equilibrium. Variations in conditions are less of a problem with constant concentration methods because departures in threshold concentration are rapidly detected and restored by automatic adjustment of the tracer gas injection rate.

Main disadvantages

The main disadvantage of the tracer gas method is that single measurements are generally of little value. It is therefore not possible to use this method to make a rapid check on building air change rates under ambient conditions. The effort involved in making many measurements has been alleviated to some extent by the introduction of automatic tracer gas methods. However, these methods involve a substantial increase in the complexity of instrumentation. The second main criticism of tracer gas methods is that the mixing necessary to ensure that the tracer gas is thoroughly distributed creates artificial conditions that may influence the results. Despite these problems, however, the tracer gas technique offers the only real method of measuring the naturally occurring fresh air change rate in a building.

2.3 Pressurization Methods

If a pressure difference is applied across a leakage opening, the induced air flow rate may be approximated by the power law equation

$$Q = k(\Delta P)^n \quad (m^3s^{-1}) \qquad (5)$$

where Q = flow rate (m^3s^{-1})
ΔP = applied pressure difference (Pa)
k = leakage coefficient
n = flow exponent $(.5 < n < 1)$

This principle is widely used to measure the air leakage characteristics of buildings. Three versions of the pressurization test are commonly performed. These are whole building or compartment pressurization[47-70], leakage testing of components in situ[71-76] and laboratory testing of specific components[77-91].

Whole building pressurization

This method provides the main alternative to tracer gas analysis and, because it is a relatively much more straightforward test to undertake, has become very popular. Furthermore leakage measurements are normally made above the ambient pressure regime and therefore the results are independent of weather conditions. The test is further simplified by the ready availability of commercial pressure testing equipment suitable for use in dwellings (Appendix 2). In some countries new residential buildings must conform to specified levels of airtightness, while in others the pressurization technique itself is the subject of national standards[47-50].

Measurements are made by using a suitably rated fan to create incremental pressure differences between the interior and exterior of the building in the ± 10–100 Pa range. For each pressure increment the corresponding air flow rate through the fan is measured.

The instrumentation is frequently built into a door (blower door) which temporarily replaces an existing entrance to the building. Alternatively the fan may be sealed into a window opening[52,53].

The air flow rate through the fan is most accurately determined by measuring the pressure drop across a calibrated orifice plate or nozzle situated within the fan ducting[51,54,55,57]. Alternatively a vane anemometer or pitot static tube may be used[53,56,58]. With some commercial units, the rate of air flow may be calibrated against fan speed. The internal/external pressure difference is measured using a manometer, which is normally connected via a tapping in the blower door.

To minimise the influence of ambient pressures, measurements should only be made during periods of low wind speed and negligible internal/external temperature differences. To further minimise the influence of ambient conditions, the proposed Canadian Testing Standard[49] stipulates that exterior pressure taps should be located on each face of the building and connected to the manometer via a pressure averaging box.

Building pressurization (large buildings)

The maximum volume of enclosure that may be pressurized is governed by the overall airtightness of the building and the size of the available fan. Shaw, for example, has used fans of capacity up to 24 m^3s^{-1} to measure air leakage in schools and supermarkets[59,60] of volumes up to approximately 40,000 m^3. More generally, however, other techniques are used to measure air leakage in large buildings. One such method that has been successfully developed is to pressurize the building using the building's existing mechanical ventilation installation[61,62]. Another method is to pressurize each room or compartment in turn. Adjacent rooms are similarly pressurized to minimise internal flow[63-65].

Building leakage at 50 Pa

It has become common practice to use the measured air leakage at a pressure difference of 50 Pa as a datum against which the airtightness performance of buildings may be compared. Unfortunately, however, there is little international uniformity governing testing methods and therefore it is difficult to use this approach to make valid comparisons between the air leakage performance of buildings in different countries. In Sweden, for example, all ventilators, fireplaces and other openings are sealed prior to the test while in other countries tests are often performed with the building in its 'operating' state.

Alternating (infra-sonic) method

A disadvantage of the pressurization method is that it is only possible to obtain leakage data at pressures in excess of those that occur naturally. These results can be unrepresentative because excessive pressures can alter the size of leakage openings. To overcome this problem, an alternating pressurization technique has been developed[66-70]. This involves using a large piston assembly to alternately enlarge and decrease the effective volume of the building at frequencies in the range of 0.1 – 10 Hz. The pressure response due to this variation is measured and the results are used to determine the 'low pressure' leakage characteristics of the building.

In situ testing of components

An alternative to whole building pressurization is to pressure test individual openings within the building. This technique enables the leakage characteristics of specific components, the component wall interface and even entire facades to be determined.

The test is performed by fitting a framework to one side of the component to form an airtight enclosure[71-76]. The enclosure is then pressurized and the resultant air leakage measured. In some instances the room in which the component is situated is also pressurized by an equivalent amount to minimise leakage into the room[74,75].

Laboratory testing of components

This is a long established method used by manufacturers and others to ensure that component leakages comply with specific airtightness standards. Laboratory methods are widely reported and essentially involve placing the component in an appropriately constructed framework across which a suitable pressure difference can be applied[77-81].

Laboratory methods have only limited applications in building airtightness studies because specific component leakages generally only account for a small proportion of total air leakage from a building. However, the results of component leakage tests are important for design purposes.

2.4 Miscellaneous Methods

There are a number of miscellaneous techniques that are primarily used to locate sources of air leakage in buildings. None of these methods provides a quantitative measure of air infiltration or air leakage but they have important retrofit applications. These methods include:

Smoke tests

This technique simply involves pressurizing a building to induce air leakage through openings and to use a smoke source to trace the paths followed by the leaking air[82].

Thermographic (infra-red) scanning

This test is best performed when there is a temperature difference between the inside and outside of the building of several degrees. The building is depressurized and an infra-red scan is performed to locate the ingress of the cooler external air[83-99]. It is also possible to detect air leakage from the heated space to the roof space by pressurizing the building and observing the flow of warm air into the attic[86].

Acoustic testing

This method is used to locate sources of air leakage by placing a high pitched sound source within the building and using a microphone outside as a detector. Leaks correspond to an increase in volume of the transmitted sound[100-104].

TABLE 1 – Selected List of Tracer Gases

Gas	Measurement method	Advantages	Disadvantages	Comments
Hydrogen H_2	Katharometer	Non toxic. Detectable at 0.5% in air. Readily available.	Explosive at concentrations greater than 4% in air. Absorbed into porous material.	An early tracer gas not now in common use.
Helium H_e	Katharometer or acoustic analyser	Non toxic. Stable. Detectable at less than 0.5% in air.	Low molecular weight. Low density. Tendency for small molecules to be absorbed into porous material or diffused through the fabric of thin partitions.	Not now in common use.
Carbon dioxide CO_2	Non dispersive infra-red analyser, also acoustic analyser	Readily available. Non toxic. Detectable in low ppm.	High background concentrations. Spurious sources. Building must be unoccupied during course of test.	Despite its disadvantages, this gas is fairly popular.
Methane CH_4 Ethane C_2H_6	Flame ionisation detector with or without gas chromatograph	Readily available. Easily detectable (20–40ppm). Inexpensive monitoring equipment.	Background concentrations. Explosive.	Not widely used.
Argon Ar^{41} Krypton Kr^{85}	Geiger counter	–	Radio-active. Safe levels of radiation exposure must not be exceeded.	No longer in general use.
Nitrous oxide N_2O	Infra-red absorption analyser	Readily available. Detectable at concentrations under 100ppm. Well suited to automatic monitoring systems.	Anaesthetic. May be a health risk. Continuous exposure not recommended.	Widely used tracer gas.
Sulphur hexafluoride SF_6	Gas chromatographic separation with electron capture	Inert. Non toxic (when pure). Non flammable. Detectable in ppb.	Detection difficult. Results may be upset by the presence of other halogenated compounds.	Widely used tracer gas.
Perfluorocarbons PFT	Samples collected in adsorption tubes for subsequent analysis using electron capture gas chromatography	Used in passive samplers. Several of these compounds can be used simultaneously to determine air movement.	As above.	Recently introduced tracer.

BIBLIOGRAPHY

3.1 Review Papers

(1) Air Infiltration Centre
1st AIC Conference "Air Infiltration Instrumentation and Measuring Techniques" Windsor 6-8 October 1980.

(2) Dick J.B.
Instrumentation and measuring techniques AIC Conference "Instrumentation and measuring techniques" Windsor 6-8 October 1980 p.1-8 #DATE 07:10:1980 in English AIC
ABSTRACT
Presents a review based on the early experience of the Building Research Station team engaged in ventilation research in the fifties. Briefly describes infiltration measurements made using the tracer gas decay technique in unoccupied houses.
KEYWORDS
tracer gas, decay method, residential building, review,

(3) Sherman M.H. Grimsrud D.T. Condon P.E. Smith B.V.
#NO 611 Air infiltration measurement techniques. A.I.C. Conference "Instrumentation and measuring techniques" Windsor 6-8 October 1980. 31p. 3 figs. #DATE 07:10:1980 in english AIC.
ABSTRACT
Presents a survey of tracer gas techniques for measuring air infiltration and includes a theoretical derivation of the equations, a description of each method, and a short description of the experimental procedure. Derives a qualitative error analysis which concentrates on mixing problems and uses it to compare the strengths and weaknesses of each method. Derives the theory of multi-chamber infiltration measurements in situations involving many interconnected spaces (network type models). Discusses a set of measurement techniques analogous to the single chamber techniques along with qualitative error analysis. Examines the question of effective volume and mixing for both the single and multi-chamber cases. Discusses in general terms non-tracer techniques for measuring infiltration.
KEYWORDS
tracer gas, air infiltration, multi-chamber, theoretical modelling, instrumentation,

(4) Alexander D.K. Etheridge D.W. Gale R.
#NO 614 Experimental techniques for ventilation research. A.I.C. Conference "Instrumentation and Measuring Techniques" Windsor 6-8 October 1980 #DATE 07:10:1980 in english AIC = in ,Ventilation of Domestic Buildings' #AIC 492
ABSTRACT
Reviews experimental techniques for determining the infiltration characteristics of buildings. Discusses the use of wind tunnel models to determine surface pressure distributions and ventilation rates. Reviews the measurement of open areas and leakages. Discusses correlation of measured leakage and ventilation. Describes the British Gas method of measuring ventilation rates using tracer gas. The system, known as "Autovent" provides a constant concentration of tracer gas and can be used for the continuous monitoring of ventilation rates.
KEYWORDS
tracer gas, constant concentration,

(5) Hunt C.M.
#NO 712 Air infiltration: A review of some existing measurement techniques and data. In "Building Air Change Rate and Infiltration Measurements" Proceedings, ASTM Conference Gaithersburg 13 March 1978 C.M.Hunt J.C.King H.R.Trechsel eds. ASTM 1980 p.3-23 5 figs. 51 refs. #DATE 13:03:1978 in English AIC.
ABSTRACT
Reviews the state of the art in the measurement of ventilation and air infiltration. Considers tracer gas techniques and discusses some of the tracer gases used as well as some of the potential sources of error. Also discusses fan pressurization-evacuation procedures for measuring building tightness and compares fan and tracer measurements. Discusses the ASHRAE crack method. Considers factors influencing infiltration rate and finally reviews a few of the empirical equations that have been developed to correlate infiltration rate with wind velocity and inside-outside temperature difference.
KEYWORDS
tracer gas, review, pressurization, measurement technique,

(6) Hitchen E.R. Wilson C.B.
#NO 66 A review of experimental techniques for the investigation of natural ventilation in buildings. Bldg. Sci. March 1967, 2, 1, 59-82, 1 graph, 10 tabs, 91 refs. #DATE 01:03:1967 in English #AIC 520.
ABSTRACT
After discussing briefly the principles of natural ventilation, goes on to describe tracer gas techniques, air movement measurements, and various model techniques including analogues. Advantages and disadvantages of each method are indicated, and their suitability for particular applications.
KEYWORDS
air change rates, natural ventilation, tracer gas, modelling, instrumentation,

(7) Kronvall J.
#NO 418 Airtightness - measurement and measurement methods Matningar och matmetoder for lufttathet Swedish Council for Building Research, Stockholm 64p. 10 refs. D8:1980 ISBN 91-540-3201-6 in English T6: ISBN 91-540-2967-8 in Swedish #DATE 01:01:1979 #AIC 58
ABSTRACT
Describes methods of measuring the air tightness of whole buildings. Outlines three tracer gas methods; constant concentration; decreasing concentration and constant emission. Describes pressurisation method. Describes measuring equipment and test procedure and discusses calculation of ventilation rate and error magnitudes. Gives brief summary of measured results and an appendix contains a print-out of data on the air tightness of houses.
KEYWORDS
air infiltration, tracer gas, pressurization, instrumentation,

(8) Stricker S.
#NO 739 Ventilation, State-of-the-art review. Report for the Canadian Electrical Association, prepared by Ontario Hydro Ltd., Canada. June 11 1980 34p. 22 refs. #DATE 11:06:1980 in English #AICR CA1
ABSTRACT
Reviews the ventilation requirements for residential buildings and the recently discovered contaminants of indoor air which will have an influence on the required ventilation rates. Describes methods of measuring air leakage and the rate of air infiltration. Cites work aimed at finding the

correlation between air leakage and air infiltration. Outlines the role of heat recovery devices and recommends areas of further research. An appendix reports on a Canadian Mortgage and Housing Association seminar "Controlled ventilation with exhaust air heat recovery for Canadian housing".
KEYWORDS
ventilation needs, review, air leakage, air infiltration, measurement technique,

(9) Harrje D.T. Dutt G.S.
#NO 973 House doctors program - retrofits in existing buildings. 2nd AIC Conference ,Building design for minimum air infiltration' Sweden 21-23 September 1981 p.61-72 1 fig. 1 tab. 14 refs. #DATE 21:09:1981 in English AIC
ABSTRACT
Outlines the needs, history, procedures and past case studies for the ,house doctor' approach to energy auditing and retrofitting. The beginnings of this method started with the Twin Rivers Project, where it was realised that inexpensive and portable instrumentation and streamlined analysis procedures were necessary. Methods include using a ,blower door' in combination with infrared scanning equipment to determine air leakage in dwellings. Describes audits and retrofitting carried out in four older houses (two ranch-style and two colonial-style) along with an estimate of energy saved. Also reports on a statewide experiment carried out by the four gas utilities of New Jersey and Princeton University to conduct a large scale test of the house doctor concept. House doctor teams were specially trained, and 18 house modules were covered to include 6 controls, 6 house doctor visits, and 6 houses to receive retrofitting after a house doctor visit. Discusses the results of this experiment.
KEYWORDS
retrofitting, energy audit, pressurization, air leakage, house,

3.2 Tracer Gas Methods

3.2.1 Comparison of Tracer Gases

(10) Grimsrud D.T. Sherman M.H. Janssen J.E. Pearman A.N. Harrje D.T.
#NO 200 An intercomparison of tracer gases used for air infiltration measurements. Lawrence Berkeley Laboratory. University of California paper LBL-8394 2 figs 10 =ASHRAE trans. 1980. vol 86 no 1. #DATE 19:04:1979 in English #AIC 18.
ABSTRACT
Reviews ideal characteristics of a tracer gas and gives literature review of the subject. Reports tests made on a house in California giving a direct intercomparison between common tracer gases used to measure air infiltration rates in buildings. Results indicate that air exchange rates measured using sulphur hexafluoride are slightly larger than those measured using methane or nitrous oxide. The ratio of air change rates measured using sulphur hexafluoride to air change rates measured concurrently using a lighter tracer gas was found to be 1.10 +- 0.10
KEYWORDS
tracer gas, air change rate, sulphur hexafluoride, methane nitrous oxide,

(11) Shaw C.Y.
#NO 1005 The effect of tracer gas on the accuracy of air change measurements in buildings. Preprint for ASHRAE Atlantic Meeting January 23-27 1983 30pp. 10 figs. 5 tabs. 6 refs. #DATE 23:01:1983 in English #AIC 606
ABSTRACT
Compares the air change rates measured using the decay method with several different tracer gases. Tracer gas measurements were conducted in a tightly sealed room where constant air leakage rates were maintained using an exhaust fan. Tracer gases investigated were CH4, CO, CO2, N2O and SF6. Agreement between tracer gas measurements and measured flow rates of the exhaust fan was very good for CH4, CO and N2O. The agreement was also satisfactory for CO2 and SF6, but the scatter in tracer gas data was much greater then it was for the other three gases.
KEYWORDS
tracer gas, decay rate, methane, carbon monoxide, carbon dioxide, nitrous oxide, sulphur hexafluoride,

(12) Bassett M.R. Shaw C. Evans R.
#NO 991 An appraisal of the sulphur hexafluoride decay technique for measuring air infiltration rates in buildings. ASHRAE Transactions 1981 vol.87 no.2 11pp. 13 figs. 4 refs. #DATE 01:01:1981 in English #AIC 593
ABSTRACT
Compares the air change rates measured with SF6 and CO2 using the tracer gas decay technique and the fan extraction method over a wide variety of test chamber sizes and mixing systems. Shows that the conventional air handling or portable floor fans can provide adequate mixing for SF6 tracer gas decay measurements of infiltration. Warns that the mixing operation may become the dominant driving force of infiltration during calm climatic conditions. Finds that +-0.08 ach/h is a reasonable measure of experimental error at the 95% confidence level using SF6 as the tracer gas. There is a small difference between the behaviour of CO2 and SF6 that leads to relatively high SF6 results above 0.5 ach/h and relatively low results below.
KEYWORDS
carbon dioxide, sulphur hexafluoride, decay rate, mixing, tracer gas, air change rate, pressurization correlation,

3.2.2 Concentration decay

Manual methods

(13) ASTM
#NO E741-80 Measuring air leakage rate by the tracer dilution method. 1980. 1982 Annual Book of ASTM Standards Part 18 p.1426-1435

(14) Warren P.R.
#NO 262 Natural infiltration routes and their magnitude in houses-part 1. Proceedings of Aston University/Electricity Council Research Establishment Conference on Controlled Ventilation;held at University of Aston:24 September 1975 8p 8 figs, 3 tabs, 21 refs, #DATE 24:09:1975 in English. #AICR UK1
ABSTRACT
A supply of fresh air is necessary in any dwelling to ensure a comfortable,

safe and hygienic environment, but the heat loss to this air, during the heating season, may represent a substantial proportion of the total heat loss. This points to the need for greater control of domestic ventilation, either by using a mechanical system or by better design for natural ventilation. This paper touches upon both of these possibilities. Gives simple method for assessing approximately the possible reduction in heat loss achieved by the use of a mechanical ventilation system. Describes the first results of field measurements of natural ventilation in six unoccupied houses.
KEYWORDS
natural ventilation, ventilation needs, mechanical ventilation, heat loss, tracer gas, nitrous oxide, house, air change rate,

(15) Guillaume M. et, al,
#NO 116 Measurements of ventilation rates in houses with natural and mechanical ventilation systems In "Ventilation and infiltration in dwellings" proceedings of C.I.B. steering group S17 meeting "Heating and climatisation" Holzkirchen September 1977, 68-93 12 figs, 5 refs, #DATE 01:09:1977 in English #AIC 281
ABSTRACT
Describes measurements made to compare ventilation rates in six Belgian houses with both natural and mechanical ventilation systems using 02 and N20 as tracer gases. Ventilation rates were correlated with wind speed. Air leakage across individual components of the house was measured and from this the distribution of leakage areas calculated.
KEYWORDS
component, leakage, oxygen, nitrous oxide, tracer gas, wind speed, house, mechanical ventilation, natural ventilation,,

(16) Kronvall J.
#NO 418 Airtightness - measurement and measurement methods Matningar och matmetoder for lufttathet Swedish Council for Building Research, Stockholm 64p. 10 refs. D8:1980 ISBN 91-540-3201-6 in English T6: ISBN 91-540-2967-8 in Swedish #DATE 01:01:1979 #AIC 58
See Reference (7)

(17) Grot R.A.
#NO 227 A low-cost method for measuring air infiltration rates in a large sample of dwellings. In "Building Air Change Rate and Infiltration Measurements" Proceedings ASTM Conference, Gaithersburg 13 March 1978 C.M.Hunt J.C.King H.R.Trechsel eds. ASTM 1980 p.50-59 AIC = National Bureau of Standards report no. NBSIR 79-1728 10p 1 tabs, 7 refs. #DATE 13:03:1978 in English #AIC 19
ABSTRACT
Presents method for collecting air infiltration data in a large sample of dwellings. The method consists of a tracer gas dilution technique using sulphur hexafluoride and employing air sample bags which are analyzed in a central laboratory. The method is easy to perform and inexpensive and will be used in approximately 300 dwellings on 16 sites to give air exchange rates under typical heating season conditions. Presents preliminary data on air infiltration rates in low-income housing in Portland, Maine.
KEYWORDS
air infiltration, tracer gas, sulphur hexafluoride, air change rate, house,

(18) Dickson D.J.
#NO 763 Methods of measuring ventilation rates and leakage of houses. Electricity Council Research Centre report ECRC/M1419 April 1981 13p. 12

figs. #DATE 01:04:1981 in English #AIC 406
ABSTRACT
Describes methods used at ECRC for measuring the ventilation rate in houses. Two tracer gas methods are used, the decay method and the constant concentration method. Measurements have been made using both nitrous oxide and carbon dioxide as tracer gases. Also describes test of air leakage made by pressurizing the entire house. Gives for each method a detailed description of the measurement technique.
KEYWORDS
tracer gas, pressurization, measurement technique, decay rate, constant concentration, nitrous oxide, carbon dioxide,

(19) Bargetzi S.P. Hartmann P. Pfiffner I.
#NO 400 Measurement of air-change-rate in rooms without air-conditioning. Messung des naturlichen Luftwechsels in nichtklimatisieren Wohnraumen. Schweiz. Bauzig. vol.95 no.14 p.3-7 5 figs, 23 refs #DATE 01:01:1977 in German #AIC 91
ABSTRACT
Describes the importance and purpose of measurements of air infiltration. Discusses methods of measuring air-change-rate and the range of measurements. Describes test method and gives preliminary results of practical tests made in living rooms during the winter of 1975/76. Results indicate that more detailed and comprehensive tests are necessary to obtain valid data for heat loss due to air infiltration in rooms and buildings and dependence of air-change-rates on year of construction and type of building.
KEYWORDS
air change rate, tracer gas,

(20) Hunt C.M. Burch D.
#NO 41 Air infiltration measurements in a four-bedroom townhouse using sulphur hexafluoride as a tracer gas. ASHRAE transactions 1975, 81, part 1. 186-201, 5 figs, 4 tabs, 18 refs. #DATE 01:01:1975 in English #AIC 229
ABSTRACT
Reports measurements in title. House was contained in environmental chamber with control over inside and outside temperature with essentially no wind velocity. Observes familiar correlation between inside-outside temperature difference and infiltration rate, and effect of sealing doors and ducts under conditions of negligible wind velocity. Compares different methods of collecting air samples for analysis and compares SF6 measurements with air exchange rates imposed on the house by means of a centrifugal blower.
KEYWORDS
air infiltration, tracer gas, sulphur hexafluoride, house, component leakage,

(21) Shaw C.Y. Tamura G.T.
#NO 706 Mark XI energy research project, Air tightness and air infiltration measurements. Division of Building Research, National Research Council of Canada. Building Research Note no.162, Ottawa June 1980 7p. 14 figs. 1 tab. 12 refs. #DATE 01:06:1980 in English BSRIA sp.
ABSTRACT
Reports measurements of air leakage rates in the four energy-conservation research houses using the fan pressurization method. One of the houses is standard for the area and the other three houses have added insulation and vapour barriers. One house has a heat pump and one an air-to-air solar heating system. Air infiltration rates were measured in two of the houses

using CO2 as a tracer gas. Discusses results and compares tracer gas with pressurization tests. Finds that air infiltration accounts for about 20% of the total energy purchased for the standard and heat-pump houses in the 1978-79 heating season.
KEYWORDS
pressurization correlation, tracer gas, carbon dioxide, house, decay rate, solar heating, heat pump, air infiltration, air leakage,

(22) Harrje D.T. Gadsby K. Linteris G.
#NO 1060 Sampling for air exchange rates in a variety of buildings. Preprint ASHRAE Transactions vol.88 no.1 1982 11pp. 5 figs. 12 refs. #DATE 01:01:1982 in English #AIC 645
ABSTRACT
Outlines a method for measuring air infiltration using the tracer gas decay technique. SF6 is introduced into a building, and once it is well mixed, container samples of air (in this case plastic bottles) taken over a period of time are analyzed for gas concentration. Describes the use of this measurement technique in 14 houses in NJ, where the occupants undertook the sampling. Further tests in large multi-storey buildings were undertaken and the results were used to 1. Calculate and compare infiltration rates for individual floors. 2. To check tracer gas distribution problems due to stratification. 3. To find the time taken for tracer gas concentration to reach equilibrium throughout the building. SF6 gas was injected into the exhaust/return duct of the ventilation system, and a sampling probe in the duct was used to monitor SF6 concentration decay, in parallel with the sampling technique. Finds close agreement between the duct technique and sample technique infiltration rates.
KEYWORDS
air infiltration, sample bottle, tracer gas, decay rate, sulphur hexafluoride, measurement technique, high rise building,

(23) Janssen J.E. Glatzel J.J. Torborg R.H. Bonne U.
#NO 353 Infiltration in residential structures In "Heat transfer in energy conservation" ed. Goldstein R.J. p33-38, 3 figs, 2 tabs. 9 refs. #DATE 01:01:1977 in English #AIC 136.
ABSTRACT
Briefly reviews methods of estimating infiltration rates in dwellings. Describes tracer gas method using methane. Gives results of measurements of air change rate made in houses in Minneapolis, Kansas and Denver. Concludes that technique works well for measuring residential infiltration.
KEYWORDS
tracer gas, methane, air change rate, house.

Multi-cell buildings

(24) Sinden F.W.
#NO 5 Multi-chamber theory of air infiltration Building Environ. 1978, 13, (1), 21-28, 7 figs, 6 refs. #DATE 01:01:1978 in English BSRIA j.
ABSTRACT
Estimates of air infiltration in houses based on tracer gas measurements have usually assumed house is a single perfect mixing chamber with incoming air instantaneously and uniformly diffused to all parts of the interior. Points out that in reality some parts of the house - basement or rooms with doors closed - exchange air only very slowly with other parts so that actual mixing is far from instantaneous. Presents theory and mathematics

necessary to apply tracer gas method to buildings of many chambers.
KEYWORDS
mixing, multi chamber, tracer gas, theoretical modelling

(25) Etheridge D.W. Martin L. Gale R. Gell M.A.
#NO 764 Natural and mechanical ventilation rates in a detached house : measurements. Applied Energy vol.8 no.1 March 1981 p.1-18 9 figs. 8 refs. #DATE 01:03:1981 in English #AIC 407
ABSTRACT
Presents results of measurements of ventilation rates in the SEGAS test house. Describes the house and its heating and mechanical ventilation systems. Measurements of ventilation rates were made using helium as a tracer gas. Tests were made both with the house sealed to block obvious paths of infiltration and with it unsealed. Tests were also made with the house mechanically ventilated and with supply and extract systems working. Presents results of tests and examines the effect of variation in mean wind speed on ventilation rates. Discusses results and concludes that sealing the external windows and weatherstripping external doors reduces the air change rate by about a third. Finds that the mechanical ventilation systems exceed the design air change rate when the house is unsealed.
KEYWORDS
house, air change rate, tracer gas, helium, decay rate, mechanical ventilation, wind speed,

(26) Blomsterberg A.
#NO 916 Tracer gas measurements in low leakage houses. 2nd AIC Conference ,Building Design for Minimum Air Infiltration' Stockholm 21-23 September 1981 1 fig. 1 tab. 4 refs. #DATE 21:09:1981 in English AIC
ABSTRACT
Measures the air infiltration in individual rooms of a one-storey airtight house, using a special tracer gas measurement technique. Concludes that the overall ventilation rate was very low for the test house, although it had mechanical ventilation (exhaust fan). States that the best way of getting adequate ventilation is to install a ventilation system with built-in routes where fresh air can enter the building. This should either be balanced ventilation system or an exhaust fan system with special vents to the outside for supplying fresh air.
KEYWORDS
house, tracer gas, decay rate, constant concentration, air change rate, mechanical ventilation, ventilation efficiency, air infiltration,

(27) Saunders C.H.
#NO 969 Air movement in houses: a new approach. Building Research and Practice May/June 1982 vol.10 no.3 p.160-174 5 figs. 3 refs. #DATE 01:05:1982 in English #AIC 583
ABSTRACT
Uses a multi-channel infra-red gas analyser to measure nitrous oxide tracer gas concentration at six points round a house. Combines concentrations to give overall house ventilation rates and to estimate the air exchange between individual rooms. The gas analyser is also used to measure air movement between the house and its roof (with 5 sampling points in the house and one in the roof). Results show that typically 20-30% of the air that enters a house leaves via the roof space through gaps in the ceiling. Shows, by means of heat and moisture balance in the roof space, that the air flow through these gaps is the major mode of transport of water vapour from the house to the roof, but the air movement is less important for heat

transport. Blocking gaps in the ceiling will significantly reduce the relative humidity in roof spaces.
KEYWORDS
tracer gas, nitrous oxide, air flow, roof, house, water vapour, decay rate, mixing,

Multi-tracer methods

(28) I'Anson S.J. Irwin C. Howarth T.
#NO 947 A multiple tracer gas technique for measuring air-flow in houses. Proceedings of CIB W67 3rd International Symposium ,Energy Conservation in the Built Environment' March 30-April 1 1982 vol.VI p.A21-A30 7 figs. 4 refs. #DATE 30:03:1982 in English #AICR UK9
ABSTRACT
Describes a technique developed for measuring air flows between internal spaces of houses. Involves using a portable gas chromatograph to monitor the concentrations of three tracer gases released in three distinct zones within the building envelope. Using the results of each measurement, which takes approximately two hours, the ventilation rate of each zone can be calculated along with the interconnecting air flow. Presents the tracer gas equations involved, and includes an account of the experimental method and the practical difficulties encountered. Describes a programme of field work just started with the objective of investigating the magnitudes of air movement in a wide range of houses and conditions. Shows two of the early results which have been obtained by use of the multiple tracer gas technique.
KEYWORDS
air flow, chromatograph, tracer gas, measurement technique, decay rate,

(29) Prior J. Littler J. Adlard M.
Development of a multi-tracer gas technique for observing air movement in buildings. AIR vol.4 no.3 1983 p.9-11 5 figs.
ABSTRACT
Describes a mrthod for following air movement within buildings, using several different tracer gases simultaneously. Uses a series of perfluoro hexanes and decalins. Up to 4 tracer gases are released at various points in the building, the mixture of gases is sampled at a number of positions as a function of time since release, samples are chemically analysed to produce curves showing gas concentration through time and space,and the variation in gas concentrations is used to evaluate air movement through space.

Imperfect mixing

(30) Lidwell, O. M.;
#NO 2044 The Evaluation of Ventilation; LOCATION = Europe; RESEARCH.LOC = Air Hygiene Labs, Central Public Health Labs, Colindale, London; TYPE = JOURNAL; #DATE 19:05:1960; VOLUME.TITLE = J. Hyg. Camb.; VOLUME.no = 58; PAGES = 297-305; in English #AIC 359
ABSTRACT
The problem of describing quantitatively the effective ventilation in a room when the air within the room is imperfectly mixed is discussed. It is suggested that the protection afforded by the ventilation to any given

position against airborne contamination liberated at any other position can be best expressed in terms of the integrated exposure at the first point following liberation of a tracer substance at the second. This quantity is called the transfer index, and its reciprocal, the equivalent ventilation, approaches numerically the rate of supply of ventilating air as the mixing of air within the room approaches completeness. Nitrous oxide is a convenient tracer gas for making such measurements. A method is also described whereby estimates of the transfer index can be made employing only such apparatus as is easily available in a reasonably well-equipped laboratory. This method employs acetone vapour as a tracer substance. The concentration of this vapour in the air is measured by the pH change produced in a dilute solution of hydroxylamine hydrochloride as it flows down a cotton wick exposed to the atmosphere.;
KEYWORDS
= VENTILATION; TRACER GAS; INSTRUMENTATION, transfer index, nitrous oxide, AIR INFILTRATION; MIXING;

(31) Sandberg M.
#NO 1048 Definition of ventilation efficiency and the efficiency of mechanical ventilation systems. 3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.13.1 - 13.22 10 figs. 5 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Discusses air quality and the related definitions of ventilation efficiency. Suggests a definition of efficiency for ventilation systems in residential buildings that takes into consideration how ventilation air spreads within a dwelling. Measurements of the efficiency for exhaust, supply and combined systems show that for combined and supply systems the highest efficiency occurs in those parts where the air is supplied. For these systems efficiency is sensitive to ventilation flow rate, while for the exhaust system the relative efficiency is more or less independent of ventilation flow rate. Finds that in warm-air systems the ventilation efficiency is affected by the positioning of the supply and exhaust registers, the ventilation flow rate and the relative difference between supply air temperature and room air temperature.
KEYWORDS
ventilation efficiency, residential building, mechanical ventilation,

Automatic methods

(32) Harrje D.T. Hunt C.M. Treado S.J. Malik N.J.
#NO 209 Automated instrumentation for air infiltration measurements in buildings. Princeton University, Centre for Environmental Studies, report no. 13 16 figs, 4 tabs, 15 refs, #DATE 01:04:1975 in English #AIC 63
ABSTRACT
Describes automated instrumentation using sulphur hexafluoride as a tracer gas in residential housing to determine rates of air infiltration in houses. Discusses in detail the principles of operation, necessary calibration procedures and early field data. Concentration levels of SF6 are maintained at the parts per million level in the buildings and are measured by sensitive electron capture detectors in conJunction with a gas chromatograph.
KEYWORDS
air infiltration, tracer gas, sulphur hexafluoride, residential buildings. instrumentation, automatic equipment,

(33) Kumar R. Ireson A.D. Orr H.W.
#NO 284 An automated air infiltration measuring system using SF6 tracer gas in constant concentration and decay methods ASHRAE trans. vol 85 part2 p385-395 9 figs, 5 refs. ,#DATE 01:06:1979 in English #AIC 57.
ABSTRACT
Describes a system which measures the rate of air infiltration in buildings using sulphur hexafluoride as a tracer gas. Discusses two methods for evaluating the infiltration rate,the decay method and the constant concentration method. The system automatically operates a portable electron capture detector /chromatograph and samples air on a one-minute cycle. In the decay method the slope of concentration vs time on a semilogarithmic plot can be used to compute infiltration rate. In the second method the infiltration rate is proportional to the rate at which tracer gas must be injected to maintain a constant concentration.
KEYWORDS
tracer gas, sulphur hexafluoride, instrumentation, air infiltration, automatic equipment,

(34) Condon, P.E.. Grimsrud, D.T. Sherman, M.H.. Kammerud, R.C.
#NO 95 An automated controlled-flow air infiltration measurement system. Symposium on Air Infiltration and Air Change Rate Measurements, ASTM Washington D.C.. March 13 1978 #DATE 13:03:1978 in English #AIC 25
ABSTRACT
Presents description of an automated, controlled-flow air infiltration measurement system. This system measures total air flow, a volume per unit time, due to infiltration in a test space. Data analysis is discussed and the mixing problem analysed. Different modes of operating the system are considered : (1) concentration decay, (2) continuous flow in a single chamber and (3) continuous flow in a multichamber enclosure. Problems associated with the use of nitrous oxide as a tracer gas are described.
KEYWORDS
tracer gas, nitrous oxide, air infiltration, air flow. instrumentation, automatic equipment,

(35) Grot R.A. Hunt C.M. Harrje D.T.
#NO 653 Automated air infiltration measurements in large buildings. A.I.C. Conference "Instrumentation and measuring techniques." Windsor 6-8 October 1980, 22p. 9 figs. #DATE 07:10:1980 in English AIC
ABSTRACT
Describes an automated air infiltration measurement system for large buildings. The system consists of a micro-computer, electron capture gas chromatograph, a ten port sampling manifold, and five tracer gas injection units. The system controls the injection and sampling of tracer gas in a multi-zone building, calculates the air infiltration rates of each zone, and measures the duration of events such as HVAC fan operation, exhaust fan operation and door/window openings. The measurements also include such analog variables as interior and exterior temperatures, wind speed, wind direction and pressure differentials across the building envelope. The data collected by the system will allow the determination of the relative importance of air leakage and forced ventilation to the energy requirements of the building as well as evaluating the influence of meteorological conditions, HVAC fan operation, exhaust fan operation and exterior building pressure on the air leakage.
KEYWORDS
tracer gas, automatic equipment, sulphur hexafluoride, constant concentration, instrumentation,

(36) Hartmann P. Muehlbach H.
#NO 612 Automatic measurements of air change rates (decay method) in a small residential building without any forced air-heating system. A.I.C. Conference "Instrumentation and Measuring Techniques" Windsor 6-8 October 1980 7 figs. 12 refs. #DATE 07:10:1980 in english AIC
ABSTRACT
Describes an automatic measurement system for air infiltration and discusses factors influencing the measurements in single rooms or in a group of connected rooms. The system works on the decay rate method and is controlled by a purpose-designed controller. The test data are evaluated off-line by computer. Discusses in detail the instrumentation and test procedure Gives results of measurements made in a detached house and correlations of the test data with wind and temperature difference data. Gives a comparison with pressurization data.
KEYWORDS
automatic equipment, tracer gas, air infiltration, decay rate, instrumentation, detached house, pressurization, natural ventilation,

3.2.3 Tracer Gas (Constant Concentration)

Automatic

(37) Kumar R. Ireson A.D. Orr H.W.
#NO 284 An automated air infiltration measuring system using SF6 tracer gas in constant concentration and decay methods ASHRAE trans. vol 85 part2 p385-395 9 figs, 5 refs. ,#DATE 01:06:1979 in English #AIC 57.
See Reference (33)

(38) Alexander D.K. Etheridge D.W. Gale R.
#NO 614 Experimental techniques for ventilation research. A.I.C. Conference "Instrumentation and Measuring Techniques" Windsor 6-8 October 1980 #DATE 07:10:1980 in english AIC = in ,Ventilation of Domestic Buildings' #AIC 492
See Reference (4)

(39) Collet P.F.
#NO 977 Continuous measurements of air infiltration in occupied dwellings. 2nd AIC Conference ,Building design for minimum air infiltration' Sweden 21-23 September 1981 p.147-160 7 figs. 1 tab. #DATE 21:09:1981 in English AIC
ABSTRACT
Reports on a measurement system developed by the Institute of Technology at Tastrup Denmark, involving a microcomputer- controlled system for registering air change rates using tracer gas (nitrous oxide) according to the constant concentration method. The system is designed for measuring and metering tracer gas in up to 10 separate rooms (using an infrared gas absorption detector). It operates through automatic data logging on a floppy disc and can run without supervision for extended periods (up to six days). This means that the building's true air change rate over a long period can be measured, taking into account factors such as occupancy effects. Gives the results of one day's measurements in a house, and describes the difficulties encountered in maintaining a constant concentration of tracer gas.
KEYWORDS

computer, tracer gas, nitrous oxide, constant concentration, automatic equipment,

(40) Lundin L. Blomsterberg A.
An automated air infiltration measurement system - its design and capabilities - preliminary experimental results. AIR vol.4 no.1 1983 p.8-10 7 figs.
ABSTRACT
Describes a completely automated concentration technique developed by the Swedish National Testing Institute. Tracer gas is injected into 9 rooms simultaneously, and the concentration is measured in each room, with a target concentration being maintained. The result of the measurements is the supply of fresh air to each room, in m3/h.

3.2.4 Tracer Gas (Constant Emission)

Equilibrium

(41) Condon, P.E.. Grimsrud, D.T. Sherman, M.H.. Kammerud, R.C.
#NO 95 An automated controlled-flow air infiltration measurement system. Symposium on Air Infiltration and Air Change Rate Measurements, ASTM Washington D.C.. March 13 1978 #DATE 13:03:1978 in English #AIC 25
See Reference (34)

(42) Dickson D.J.
#NO 763 Methods of measuring ventilation rates and leakage of houses. Electricity Council Research Centre report ECRC/M1419 April 1981 13p. 12 figs. #DATE 01:04:1981 in English #AIC 406
See Reference (18)

Long-term averaging method

(43) Sherman M.H. Grimsrud D.T. Condon P.E. Smith B.V.
#NO 611 Air infiltration measurement techniques. A.I.C. Conference "Instrumentation and measuring techniques" Windsor 6-8 October 1980. 31p. 3 figs. #DATE 07:10:1980 in english AIC.
ABSTRACT
(see reference 3)

(44) Dietz R.N. Cote E.A.
#NO 1129 Air infiltration measurements in a home using a convenient perfluorocarbon tracer technique. Proceedings of the International Symposium on indoor air pollution, health and energy conservation Amherst Mass. USA 13-16 October 1981 Environmental International Special Issue "Indoor Air Pollution" vol.8 no.1 1982 p.419-433 9 tabs. 11 figs. 22 refs. #DATE 01:01:1982 in English #AICR US25
ABSTRACT
Using miniature perfluorocarbon tracer (PFT) sources and miniature passive samplers, tests conducted in the lab and in a typical home successfully demonstrate the utility of the PFT kit as a means for implementing wide-scale infiltration measurements in homes. Shows that the PFT diffusion plug source provides steady-state concentrations in a home of

about 1-10 pL/L when one source is deployed for each 28-46 m2 of living space. Together with a programmable tracer sampler, deploys miniature diffusion sources and samplers in a typical home; uses 6 PFT sources, 3 on each level of a two-storey house. Shows that even in a house without forced-air circulation, a well-mixed modelling approach is justified. Analyses tracer samples using a gas chromatograph. Comparison with SF6 tracer decay approach shows the results of the 2 methods to be similar. With the PFT kit,infiltration rates in the range 0.2-0.5 ac/hr can be measured over time-averaged periods of as little as one day up to several years.
KEYWORDS
air infiltration, tracer gas, decay rate, perfluorocarbon, instrumentation, measurement technique,

Metabolic carbon dioxide method

(45) Turiel I. Rudy J.
#NO 1020 Occupant-generated CO2 as an indicator of ventilation rate. Report No. LBL-10496 April 1980 20pp. 11 refs. 4 figs. 1 tab. #DATE 01:04:1980 in English #AIC 619
ABSTRACT
Uses occupant-generated CO2 as an indicator of the actual ventilation rate in a San Francisco office building. Employs two techniques, a decay method and an integral method, and measurements are conducted simultaneously at several locations. The decay method compares favourably with the conventional measurement methods in both the all-outside-air and recirculation modes, whereas the integral method shows a considerable deviation from the other methods in the recirculation mode. Both techniques show promise of being suitable methods for measuring ventilation rates in commercial and institutional buildings.
KEYWORDS
tracer gas, carbon dioxide, commercial building,

(46) Penman J.M. Rashid A.A.M.
#NO 1115 Experimental determination of air flow in a naturally ventilated room using metabolic carbon dioxide. Building and Environment vol.17 no.4 1982 p.253-256 7 figs. 6 refs. #DATE 01:12:1982 in English #AIC 685
ABSTRACT
Reports on an extension of the metabolic CO2 method for ventilation measurement to a naturally ventilated room having air flow connections with other internal spaces as well as the outside. Uses an infra-red gas analyser to monitor CO2 concentrations in the fresh air outside and also within the room, the corridor and the ceiling space. An automatic unit switches the analyser between 6 sampling points. Comparison of the data with results from SF6 tracer gas decay methods gives close agreement.
KEYWORDS
air flow, natural ventilation, carbon dioxide, tracer gas, measurement technique,

3.3 Pressurization Methods

3.3.1 Whole Building Pressurization

(47) SS
Thermal insulation - determination of airtightness of buildings. Swedish Standard 02 15 51 1980.

(48) NSF
Airtightness of buildings. Test method. Norwegian Standard NS 8200 1981.

(49) CGSB
Determination of airtightness of buildings by the fan depressurisation method. Canadian Standard 149-GP-10M (draft) 1983

(50) ASTM
E779-81 Standard practice for measuring air leakage by the fan-pressurization method 1981. 1982 Annual Book of ASTM Standards part 18 p.1484-1493

(51) McIntyre I.S. Newman C.J.
#NO 175 The testing of whole houses for air leakage. Building Research Establishment note. 21/75. 5 figs. 1 ref. #DATE 01:02:1975 in English. #AIC 69.
ABSTRACT
Describes portable air leakage apparatus capable of measuring the air infiltration of whole dwellings directly on site by the pressure method. Main assembly consists of a flow measurement duct and electric fan. Describes test procedure and gives air leakage curves for an ordinary semi-detached house and an experimental house. Finds that doors and windows account for a surprisingly small proportion of total leakage.
KEYWORDS
air infiltration, fan, component leakage, pressurization, house.

(52) Stricker S.
#NO 42 Measurement of air tightness of houses. ASHRAE Trans. 1975 vol.81 part 1 p.148-167 9 figs. 1 tab. 3 refs. #DATE 01:01:1975 in English BSRIA J.
ABSTRACT
Describes pressurization method of measuring air leakage using a fan installed through an open window. Gives results of survey of 24 houses. Humidity, meteorological parameters, indoor particulate levels, measured equivalent leakage areas and other information were recorded. Finds that tight houses tend to have higher humidity, that leaky houses require more heating energy and that houses where smoking takes place have higher air pollution levels than others.
KEYWORDS
house, air infiltration, humidity, air leakage, pressurization, tobacco smoke, particulate, air quality,

(53) Tamura G.
#NO 40 Measurement of air leakage characteristics of house enclosures. ASHRAE transactions 1975, 81, part 1. 202-208, 1 fig, 5 tabs. #DATE 01:01:1975 in English BSRIA j.
ABSTRACT
Reports results of series of tests on 6 single-family houses to determine rates of overall leakage through windows, doors, walls and ceilings. Uses vane- axial fan to reduce pressures inside house and measure flowrate and

resultant pressure differences across house enclosure. Purpose of tests was to assist in eliminating rates of air infiltration in houses.
KEYWORDS
air leakage, window, door, walls, ceiling, house, pressurization,

(54) Kronvall J.
#NO 185 Testing of houses for air-leakage using a pressure method. ASHRAE trans. vol 84 no 1 p 72-79 5 figs, 13 refs. #DATE 01:01:1978 in English #AIC 26
ABSTRACT
Describes pressure method for testing whole houses for air leakage. States main advantages compared to tracer gas technique are that equipment is inexpensive, easy to handle and so well adapted to routine tests. The house is pressurized using a powerful fan and the flow through the fan is equivalent to the leakage through the building envelope at given pressure. Summarizes measurements made on test houses. and shows use of thermography to detect leaks. suggests use of pressure test to estimate the natural ventilation of a house. Gives brief extract from new directions for air-tightness of houses according to the Swedish building code (SBN 1975).
KEYWORDS
fan, pressurization, air infiltration, air leakage, thermography, instrumentation, houses, building code,

(55) Kronvall J.
#NO 418 Airtightness - measurement and measurement methods Matningar och matmetoder for lufttathet Swedish Council for Building Research, Stockholm 64p. 10 refs. D8:1980 ISBN 91-540-3201-6 in English T6: ISBN 91-540-2967-8 in Swedish #DATE 01:01:1979 #AIC 58
See Reference (7)

(56) Caffey, G.E.
#NO 92 Residential air infiltration ASHRAE Trans. 1979, 85, (1), 41-57, 12 figs, 5 tabs, 1 ref. #DATE 01:01:1979 in English #AIC 2
ABSTRACT
When attempting to determine heating/cooling requirement of a home a difference in infiltration can drastically affect heating/cooling requirement imposed on air conditioning system. Describes "the super sucker" machine designed to depressurise homes so that infiltration can be measured under simulated wind conditions and each area of leakage isolated. Illustrates machine photographically. Gives method of determining air change rates. Summarises test data for several homes which indicate that infiltration could be effectively reduced by use of various caulking compounds. Finds average air change rate for 50 homes tested is 1.5 per hour.
KEYWORDS
air infiltration, pressurization, air change rates.

(57) Orr H.W. Figley D.A.
#NO 450 An exhaust fan apparatus for assessing the air leakage characteristics of houses. Prairie regional station, Division of Building Research, National Research CounCil of Canada B.R. note no.156 . 5figs. 7refs. #DATE 01:03:1980 in English #AIC 171
ABSTRACT
Describes portable apparatus used to measure the air leakage of houses. A fan is used to exhaust air from the house and the air flow rate is measured. The air flow rate and corresponding pressure difference across the building can then be used to evaluate the relative air tightness to the

house. The fan pressurization test equipment is portable, inexpensive and simple to operate. Describes test procedure and gives a few examples of house characteristic curves.
KEYWORDS
pressurization, fan, house, air leakage.

(58) Dickson D.J.
#NO 763 Methods of measuring ventilation rates and leakage of houses. Electricity Council Research Centre report ECRC/M1419 April 1981 13p. 12 figs. #DATE 01:04:1981 in English #AIC 406
See Reference (18)

(59) Shaw C.Y.
#NO 727 Air tightness: Supermarkets and shopping malls. ASHRAE jnl. March 1981 p.44-46 6 figs. 5 refs. #DATE 01:03:1981 in English #AIC 364
ABSTRACT
Reports measurements of air leakage in several supermarkets and an enclosed shopping mall, all constructed between 1954 and 1979. All tests were conducted by using a large fan to depressurize the building. Gives graphs of leakage rates. Finds supermarkets are two to four times leakier than schools or high-rise office buildings.
KEYWORDS
air leakage, supermarkets, pressurization, commercial building,

(60) Shaw C.Y.
#NO 1006 Improvement of airtightness in four schools. Building Practice Note no.34 National Research Council of Canada June 1982 6pp. 6 figs. 1 ref. #DATE 01:06:1982 in English #AIC 607
ABSTRACT
Air leakage tests (using the fan pressurisation method) were conducted on four schools, before and after they were retrofitted, in order to determine the effectiveness of various measures for reducing leakage. Caulking wall joints will generally reduce air leakage and is worthwhile if the joints are accessible. Replacing leaky windows will also improve airtightness but may not be cost effective. Routine inspection of outside dampers of the air handling system can help ensure continued airtightness of schools.
KEYWORDS
air leakage, pressurization, school, retrofit, caulking,

(61) Shaw C.Y. Sander D.M. Tamura G.T.
#NO 44 Air leakage measurements of the exterior walls of tall buildings. ASHRAE trans. vol.79 part.2 p.40-48 10 figs. 6 refs. = D.B.R. research paper no.601. in English #DATE 01:06:1973 #AIC 34
ABSTRACT
Describes experimental method of determining air leakage characteristics of exterior walls of a building. Method involves pressurising the building with the supply air system and measuring flow rates of outside supply air and resultant pressure differentials across building enclosure. Uses results to obtain flow coefficient and exponent for exterior walls. Checks method by results of computer simulation of a building, finding good agreement.
KEYWORDS
walls, air leakage, computer, pressurization, high rise building,

(62) Railio J.
#NO 935 Measurement of the tightness of a building with its own ventilation system. Tiiviyden mittaus rakennusken omalla ilmanvachtojarjestelmalla LVI

vol.33 no.3 March 1982 p.33-35 1 fig. 1 tab. 3 refs. #DATE 01:03:1982 in Finnish #AIC 555

ABSTRACT
Shows that the leakage test in most buildings with mechanical ventilation may be performed with the ventilation system itself with only a slight reduction in the accuracy of the measurements. Using fans in the ventilation system, the pressure difference inside/outside may often reach a measurable value of 5-10 pa. If such a pressure difference is not obtained, the leakage exceeds allowable values and the building should be tightened. Before measuring, all of the supply air openings in outer core of the building should be closed and taped. All doors inside the apartment should be open. The exhaust air flow and the pressure difference inside/outside is measured in every apartment and the results are extrapolated to a reference pressure. Measurements should be carried out in calm weather conditions.

KEYWORDS
air leakage, mechanical ventilation, air change rate,

(63) Nylund P-O.
#NO 508 Tightness and its testing in single and terraced houses Tathetsprovning av smahus och radhus. Tyrens technical memorandum 1979:5 ▪ Byggmasteren no.5 1979 #DATE 01:05:1979 in Swedish, English AIC=A.I.C. Translation no.4

ABSTRACT
The Swedish building regulations give recommended tightness values for buildings of 3 air changes per hour for single houses, 2 air changes per hour for other housing with not more than two stories and 1 air change per hour for taller buildings. These values are measured at a pressure differential between outside and inside of 50 pa. Air leaks from terraced houses to the outside and through party walls to adjoining houses. Suggests method for assessing air leakage through party walls. One house is pressurized and the two adjoining houses are sealed and the pressure differentials in them measured at the same time as in the house being tested. If the houses are very similar air leakage can be assessed after testing one of them. If dissimilar all three must be measured as test houses. Gives results from pressure testing of terraced houses in Sollentuna. Discusses standards for leakage of detached and terraced houses and concludes that leakage of terraced houses without correction for leakage to adjacent dwellings should be set higher than for single houses.

KEYWORDS
air leakage, terraced house, party walls, pressurization

(64) Nylund P-O.
#NO 610 The appplication of reciprocity in tightness testing. A.I.C. Conference "Instrumentation and Measuring Techniques." Windsor 6-8 October 1980 #DATE 07:10:1980 in english, swedish AIC=A.I.C. Translation No.9

ABSTRACT
Describes a method for determining the leakage of an entire building. Each room is pressurized in turn and the leakages of individual rooms are summed to find the total leakage of the building. Derives the equations for calculating total leakage and gives an example of the method applied to a row of three offices.

KEYWORDS
air leakage, pressurization,

(65) Lundin L.
#NO 980 Air tightness in terraced houses. 2nd AIC Conference ,Building design for minimum air infiltration' Sweden 21-23 1981 p.185-196 5 figs. #DATE 21:09:1981 in English AIC
ABSTRACT
Outlines a method for measuring the air leakage through the surface exteriors of an apartment, by adjusting the pressure of the adjoining apartments to that of the test apartment, so that no air leakage occurs through adjoining walls. Fans are placed in the adjacent apartments to adjust the pressure, and a fan with a measuring duct for measuring air flows is used in the test apartment. A micromanometer is used to determine the dynamic pressure in the measuring duct, the registered pressure corresponding to a specific air flow. A micromanometer is also used to register the difference in pressure between the exterior and the interior. Presents results from measurements in two terraced houses. In test house A, a pressurisation test without supporting fans gives a higher air change rate (3.1 ach at 50 pa) then one with supporting fans (2.5 ach). This difference is because the supporting pressures prevent any air flow through adjoining walls. The two corresponding results in test house B show little difference, because the air-vapour barrier does not cover the part of the apartment separating wall which is part of the exterior wall. This design principle for wood frame houses can cause serious air leakage problems.
KEYWORDS
terraced house, air leakage, fan, pressurization, vapour barrier

Alternating (infra-sonic) method

(66) Graham R.W.
#NO 501 Infrasonic impedance measurement of buildings for air leakage determination. Dept. of Electrical and Computer Engineering, Syracuse University. Technical report TR-77-15 54p 9 refs. #DATE 01:06:1977 in English AIC
ABSTRACT
Reports preliminary research directed towards developing a new method for measuring the air leakage property of an enclosure. The low-frequency acoustic impedance of the enclosure is measured by an infrasonic method. Describes and analyses a diaphram-type motor-driven source and a pressure sensor with electronic filters used to measure infrasonic impedance. Reports tests run in enclosures of different volumes and degrees of leakiness. Compares results with blower tests and finds disagreement of less than 10% for small enclosures, but for larger enclosures results differed by more than a factor of three.
KEYWORDS
air leakage, alternating pressure.

(67) Card W.H. Sallman A. Graham R.W. Drucker E.E.
#NO 463 Air leakage measurement of buildings by an infrasonic method Dept of Electrical and Computer Engineering, Syracuse University technical report TR-78-1 110p. 28 refs. #DATE 31:01:1978 in English AIC
ABSTRACT
Describes an infrasonic method as an alternative to blower method for measuring the composite effective size of all the air-leakage passages of a

building. Sinusoidally varying volumetric flows between 0.05 and 5Hz are generated by a motor-driven bellows-like source located inside the building under test. Resulting pressure variations are measured using a microphone-like sensor having an electronic signal processor. Reports system design and test results obtained to date. One house, five apartment and three interior rooms have been tested. Finds results of infrasonic tests usually agree with results of blower tests within a factor of three.
KEYWORDS
alternating pressure, pressurization, air leakage.

(68) Card W.H. Sallman A. Graham R.W. Drucker E.E.
#NO 500 Infrasonic measurement of building air leakage-a progress report. Proceedings ASTM, ASHRAE, NBS, DOE Symposium on Air infiltration measurements Washington D.C. March 13, 1978 = Department of Electrical and Computer Engineering, Syracuse University, Technical Report TR-78-5. 13 figs 4 refs. #DATE 01:03:1978 in English AIC
ABSTRACT
Describes infrasonic method of measuring the air leakage of a house or apartment. Describes apparatus, consisting of a motor driven source of known output a sensitive pressure pickup and an electronic signal processor. A low frequency (about one cycle per second) alternating air flow of known magnitude is applied to the interior of the building, and the alternating component of inside pressure that results is measured. The pressure response is a function of the type and size of leakage paths. Describes measurements made on three interior rooms and gives sample results. Concludes that the accuracy of the present system is rather low and that interpretation is difficult but that the system is easier to set up than a blower.
KEYWORDS
air leakage, alternating pressure,

(69) Sherman M.H. Grimsrud D.T. Sonderegger R.C.
#NO 459 Low pressure leakage function of a building. Proceedings ASHRAE/DOE. Conference "Thermal performance of the exterior envelopes of buildings" Dec. 3-5 1979 Florida. 6 figs, 5 refs. #DATE 03:12:1979 in English. #AIC 20
ABSTRACT
Outlines the problems of modelling air infiltration. Reports measurements of the leakage function measured at low pressures using an alternating pressure source with variable frequency and displacement. Synchronous detection of the indoor pressure signal created by the source eliminates the noise due to fluctuations caused by the wind. Presents comparisons between these results and extrapolations of direct fan leakage measurements.
KEYWORDS
pressurization, alternating pressure, air infiltration,

(70) Grimsrud D.T. Sherman M.H.. Sonderegger R.C.
#NO 479 Air leakage in a building at low pressures using an alternating pressure source. Proceedings XXI International Congress for Building Services Engineering 17-18 April 1980 #DATE 17:04:1980 in English #AIC 193
ABSTRACT
Reports low-pressure measurements of the leakage function of a building using an alternating (AC) pressure source with variable frequency and displacement. Synchronous detection of the indoor pressure signal created by the source eliminates the noise due to fluctuations caused by the wind. Finds good agreement between AC and DC leakage results in pressure regions

where the results can be compared. The low-pressure values made with the AC source suggest that the air flow is dominated by orifice flow effects down to pressures less than one Pascal.
KEYWORDS
pressurization, alternating pressure, air infiltration

3.3.2 In-Situ Testing of Leakage Openings

(71) ANSI/ASTM
Standard test method for rate of air leakage through exterior windows, curtain walls and doors. USA Standard ANSI/ASTM E-282-73

(72) Tamura G.T. Shaw C.Y.
#NO 299 Air leakage data for the design of elevator and stair shaft pressurization system. ASHRAE trans vol 82 part 2 p179-190 8 figs, 3 tabs, 8 refs. = D.B.R. Paper No. 717 #DATE 01:06:1976 in English #AIC 35
ABSTRACT
Describes research project to find air leakage values of walls of elevator and stair shafts in order to use these values in the design of pressurization systems. Describes method of test and gives results. Concludes that leakage rates for walls of elevator shafts constructed of masonary units are higher than those of cast-in-place concrete. Variations in the leakage of stair shafts could not be related to the type of wall construction but probably depended on the workmanship in sealing crack openings. Finds that internal flow resistance of a stair shaft is substantial and must be taken into account in designing a stair shaft pressurization system.
KEYWORDS
air leakage, elevator shaft,walls, pressurization,

(73) Olsson A.
#NO 342 Ventilation and the draught-proofing of windows in old blocks of flats. Lund Institute of Technology, dept. of building science, report. 1977. 11p. 11 figs. #DATE 01:01:1977 in English #AIC 130
ABSTRACT
Presents results of measurements of ventilation rate and window air leakage made in blocks of flats in Sweden. Describes measurement of ventilation rate using nitrous oxide as a tracer gas and pressurization tests on windows. Gives graphical results of tests. Finds that the majority of windows do not satisfy 1975 swedish building code. Reports measurements of air leakage of windows before and after renewal of draught excluders. Concludes that old windows can be made relatively draught-free and that this is not expensive or time- consuming. Discusses briefly types of weather-strips and the procedure for retrofitting windows. Illustrates method of caulking the joint between window frame and wall.
KEYWORDS
windows, air leakage, weatherstripping, flat, tracer gas, joints, nitrous oxide,

(74) Shaw C.Y.
#NO 311 Methods for conducting small-scale pressurization tests,and air leakage data of multi-storey apartment buildings ASHRAE trans. vol86 part 1. 11 figs, 1 tab, 4 refs. #DATE 01:01:1980 in English #AIC 103
ABSTRACT
The overall air leakage of high-rise buildings cannot be measured using a

full pressure method because of the large volume involved. Describes a method of conducting small-scale pressurization tests on the exterior walls of apartments in multi-storey buildings. Gives results of measurements in a test building. compares direct method with values obtained by summing the air leakage of individual components. Finds good agreement.Concludes that floor/wall joints, windows and window sills are the three major air leakage sources in exterior walls. Results from one building indicated no measurable leakage through ceiling joints.
KEYWORDS
air leakage, walls, joints, pressurization, high rise building, residential buildings, flat, component leakage,

(75) Siilonen V.
#NO 1105 Measurement of local airtightness in buildings. Technical Research Centre of Finland Research Note 125 July 1982 12 pp. 4 figs. 1 tab. #DATE 01:07:1983 in English #AIC 676
ABSTRACT
Decribes the "collector chamber" method, where a room or whole building is pressurised and the air leaking through the target areas is collected with a pressure compensated chamber to a measurement device.
KEYWORDS
component leakage, instrumentation, measurement technique,

(76) Nantka M.
Tightness of prefabricated outer walls and its influence on heat demand in apartment dwellings. AIR vol.4 no.2 February 1983
ABSTRACT
Describes work done in Poland on air infiltration through external walls constructed of prefabricated blocks, especially in apartment buildings. Measurements of air leakage have been carried out using pressurization test equipment. Uses a computer model to carry out a theoretical analysis of the performance of different kinds of ventilation system for a specific building through one year. The program calculates air infiltration by determining an internal pressure distribution such that air inflow is balanced by outflow. Gives results of calculations.

3.3.3 Laboratory Testing of Components

(77) BSI
Methods for testing for resistance to air and water penetration - Windows and gasket glazing . British Standard BS 4315 part 1 1968

(78) BSI
Methods of testing windows Part 1. Air permeability test. British Standard BS 5368 Part 1 1976 = European Standard EN42

(79) DIN
Windows:air permeability of joints and driving rain (water tightness) protection. German Standard DIN 18055 T2 August 1973

(80) SIS
Windows. Air tightness test. Swedish Standard SIS 818126 April 1977

(81) ISO
Joints in building - method of test for the resistance of joints to air penetration. Draft International Standard ISO/DIS 6589 February 1979

(82) ISO
Windows and door-height windows - air permeability test. International Standard ISO 6613-1980(E)

(83) NSF
Methods of testing windows. Air tightness. Norwegian Standard NS 3206 1974

(84) NNI
Windows. Air permeability, water tightness, rigidity and strength: methods of test. Norwegian Standard NEN 3660 1975

(85) Shoda T. Terasawa T. Katayama T.
#NO 282 Experimental study on air and water tightness of metal window sashes. Proceedings 5th International Congress for Heating, Ventilating and Air- Conditioning, Copenhagen, 17-19 May 1971, Heating problems in relation to windows p27-35 7 figs, 3 tabs, 3 refs. #DATE 17:05:1971 in English. BSRIA bk.
ABSTRACT
Describes apparatus and test method used for measuring air leakage through metal windows in the laboratory. Gives results for different types of windows and summarises air tightness standards in Japan and other countries.
KEYWORDS
windows, air leakage,

(86) Fleury G. Thomas M.
#NO 183 Variation in the airtightness of windows as a function of the outside temperature: measurement apparatus and examples of application. Variation de la permeabilite a l'air des fenetres en fonction de la temperature exterieure : dispositif de mesure et exemples d'application Cahiers CSTB September 1972 vol.132 1129 #DATE 01:09:1972 in French BSRIA j.
ABSTRACT
Describes study and operating principles of device allowing a window (or more usually a light-weight cladding unit) to be placed in variable temperature conditions simulating actual summer and winter conditions, in order to determine the airtightness of the window under these conditions. Describes testing of three plastic window frames in the device and supplies the measured values of the airtightness before, during and after the tests, and the corresponding curves.
KEYWORDS
air leakage, windows, temperature difference,instrumentation

(87) Sabine H. Lacher M.B. Flynn D.R. Quindry T.L.
#NO 568 Acoustical and thermal performance of exterior residential walls, doors and windows. National Bureau of Standards, Building science series 77 158p 76 figs, 130 refs. #DATE 01:11:1975 in English #AICR US3
ABSTRACT
Reports laboratory tests of sound transmission loss, thermal transmittance and rate of air leakage conducted on full-scale specimens of typical residential exterior wall constructions, either unbroken or penetrated by a door or window. A total of 109 acoustical tests and 48 thermal tests are

reported. The resultant data are compared with literature data on similar constructions. Some correlation was found between sound transmission loss and air leakage.
KEYWORDS
air leakage, windows, sound, walls,

(88) Carruthers J.F.S. Newman C.J.
#NO 230 The repeatability and reproduceability of test results on windows and wall span elements and the expected results. Building Research Establishment current paper 49/77 = Proc. Paul Rousseau Symposium on the Testing of Wall Elements and Windows. Vilvorde near Brussels, Belgium 3 October 1977. #DATE 03:10:1977 in English #AIC 82
ABSTRACT
Discusses variations in the test results which occur with the laboratory procedures for assessing the air and water penetration attributes of windows. Presents data for windows examined under British Standard BS 4315 : part 1 "Methods of test for resistance to air and water penetration - windows and gasket glazing systems". Considers the implications of these tests for the development of performance levels for use in standards and procurement documents, and proposes a two-stage statistical procedure, based in the first instance on tests on five windows. The use of such a procedure will permit the acceptance with confidence of a window type under the assessment procedure. Emphasises the need to correlate laboratory assessment of windows with the actual performance of windows installed and in use in buildings.
KEYWORDS
air leakage, windows, standard,

(89) Meert E. Van Ackere G.
#NO 741 Tightness of facades and roofs. Etancheite des facades et des toitures. Centre Scientifique et Technique de la Construction, Brussels. final report IC-IB June 1977 202p. figs. tabs. #DATE 01:06:1977 in French, Flemish #AICR BE1
ABSTRACT
Reports study of wind and rain over fifteen years and gives table of results. Reports measurements of wind pressure and driving rain on buildings. Discusses laboratory measurements of the tightness of facade elements under pressures of up to 50 Pa. and with temperature differences of -40 to +30 deg.C. across the facade. Describes pressurization of buildings and gives results of measurements in test dwellings. Discusses movement of joints in buildings and describes measurement of this movement. Discusses permeability of both flat and sloping roofs. Reports tests of resistance of roofs to suction from wind pressure and to driving rain. Section 3 on roofs is in French: the rest of this report is in Flemish.
KEYWORDS
pressurization, air leakage, rain, wind pressure, roof, wall, joint,

(90) D'Have R. Spehl P.
#NO 670 Comparison between some existing performance requirements for air permeability and water-tightness in buildings. in 'Performance test methods and the interpretation of results.' C.I.B. Working Commission W60. December 1979 p.7-12 3 figs. #DATE 01:12:1979 in English #AIC 328
ABSTRACT
Compares some existing performance requirements for air permeability and water-tightness of windows. Gives tables showing main European standards. Finds that a large variety of methods of test and grading systems is used and concludes that steps should be taken to unify the systems.

KEYWORDS
air leakage, window, standard,

(91) Carruthers J.F.S. Newman C.J.
#NO 671 The variability of test results when assessing the resistance of windows to water and air penetration using BS4315. in 'Performance test methods and the interpretation of results' C.I.B. Working Commission W60. December 1979 p.18-24 #DATE 01:12:1979 in English #AIC 328
ABSTRACT
Reports a programme of tests of the resistance of windows to air and water penetration. These were intended to assess the variation in the results due to different designs of window, differences between individual windows of the same type, different pressure test boxes, and different test operators. Gives tables of results and finds considerable variation but no single source of the variation. Suggests new test procedure and a statistical criterion for acceptance.
KEYWORDS
air leakage, window, standard,

3.4 Miscellaneous Techniques

3.4.1 Smoke Tests

(92) Dickson D.J.
#NO 763 Methods of measuring ventilation rates and leakage of houses. Electricity Council Research Centre report ECRC/M1419 April 1981 13p. 12 figs. #DATE 01:04:1981 in English #AIC 406
See Reference (18)

3.4.2 Thermography (infra-red)scanning

(93) Kronvall J.
#NO 185 Testing of houses for air-leakage using a pressure method. ASHRAE trans. vol 84 no 1 p 72-79 5 figs, 13 refs. #DATE 01:01:1978 in English #AIC 26
See Reference (54)

(94) Pettersson B.
#NO 270 Field tests of thermal insulation and airtightness of buildings Faltprovning av byggnaders varmeisolering och lufttathet National Swedish Authority for Testing Inspection and Metrology 1978. SP-RAPP 1978: 11. 105pp. #DATE 01:01:1978 in Swedish BSRIA sp.
ABSTRACT
Treats methods of determining energy losses in a building given in 1975 swedish building regulations. Presents findings of a number of measurements using pressure method and thermography carried out during 1977 and winter of 1978. The apparatus and methods have been developed for field work. Presents results which depict different grades of airtightness in different types of building. Discusses use of thermography, which has been extensively used in recent years in Sweden in particular for new buildings. States method has been developed to become subject of a swedish standard. Regulations have also been drawn up to cover personnel carrying

out thermographic tests on buildings.
KEYWORDS
energy losses, thermography,

(95) Petterson B. Axen B.
#NO 375 Thermography. Testing of the thermal insulation and airtightness of buildings. Swedish Council for Building Research D5. 227p. 20tabs 128 figs 21 refs. #DATE 01:01:1980 in English #AICR SE10
ABSTRACT
Discusses in general terms energy consumption and energy requirements and the testing and checking of buildings. Gives principles of thermography and discusses the influence of various parameters on the thermography of buildings. Gives rules for interpretation of thermograms and use of comparative thermograms. Gives examples of comparative thermograms for common defects in insulation and airtightness, and actual cases where certain constructions and components were examined. Shows effectiveness of improvements made to remedy certain types of defects in insulation and air tightness. Reports results of a general survey to find systematic defects in insulation and airtightness. Recommends preparations to be made before measurement and indicates a suitable procedure for the thermography of buildings. Gives a brief history of the application of thermography to buildings.
KEYWORDS
thermography, air leakage, insulation,

(96) Harrje D.T. Grot R.A.
#NO 264 Instrumenting energy audits. Princeton University, Center for Environmental Studies Report PU/CEES 91 #DATE 01:07:1979 in English #AIC 44
ABSTRACT
Discusses ways of increasing accuracy and thoroughness of energy audits of buildings by use of specialized instruments and improved audit techniques. States air infiltration measurements are key item in audit procedure. Describes 'house doctor' kit which with records of past energy usage, knowledge of prevailing weather and a questionnaire are used to establish the energy signature of a house. The kit includes blower door, infrared camera, temperature probes and appliance consumption meter. Describes simple tracer gas method using sulphur hexafluoride collected in sample bottles. Discusses development and use of kit which can be used by homeowners with minimal training
KEYWORDS
instrumentation, pressurization, tracer gas, thermography, sulphur hexafluoride, blower, air infiltration,

(97) Tjernberg K. Odmansson E.
#NO 791 Thermography. The effects of external factors upon thermal images. Termografering. Matningsbetingelsers inverkan pa varmebilder. Swedish Council for Building Research report R86:1980 75p. 82 figs. 4 refs. #DATE 01:01:1980 in Swedish #AICR SE17
ABSTRACT
Reports an investigation of the effects of temperature differences, pressures, sun and wind conditions on a thermal image produced by thermography. This investigation is concerned mainly with measurement points associated with air leakage. Reports measurements on a single-storey timber-framed house under a pressure difference of 5,-2,-10 and -20 Pa. Finds that the importance of a high internal underpressure decreases with the difference between indoor and outdoor temperature and that a relatively large underpressure is required for reliable

identification of leaks if the temperature difference is small. Finds that leaks are difficult to locate if there is an internal overpressure. Wind can give rise to convective air currents which are difficult to locate under calm conditios.
KEYWORDS
thermography, pressurization, wind, pressure difference, temperature difference, sun,

(98) Harrje D.T.
#NO 725 Building envelope performance testing. ASHRAE jnl. March 1981 p.39-41 2 figs. 1 tab. 16 refs. #DATE 01:03:1981 in English #AIC 362
ABSTRACT
Discusses use of an instrumented energy audit, as opposed to a walk-through audit. Describes use of the audit to pinpoint infiltration sites. Method used is to depressurize a building and use thermography to locate air leaks. Briefly describes equipment and gives example of an instrumented audit of a residential building. States advantage of instrumented audit is that it gives a quantitative energy analysis as opposed to a qualitative one.
KEYWORDS
energy audit, energy losses, thermography, pressurization,

(99) Siviour J.B.
#NO 1090 Some practical aspects on the infra-red thermography of buildings. ECRC Rep.No.1483 October 1981 6pp. #DATE 01:10:1981 in English #AIC 664
ABSTRACT
Illustrates some practical aspects of the use of one IR camera and associated equipment discusses some of the problems in interpretation of some pictures representing temperatures of the inside and outside surfaces of buildings particularly problems due to residual effects of the sun on external surfaces, reflection of sunlight into the IR camera, storage of heat from the sun in walls, and cold spots inside a building caused by heat loss by thermal bridges or cold-air infiltration.
KEYWORDS
thermography, instrumentation,

3.4.3 Acoustic Methods

(100) Esdorn D.E.
#NO 659 Development of an acoustic method for the determination of the air leakage of building elements installed in a building. Entwicklung einer akustichen Messmethod zur ermittlung der Luftdurchlassigkeit von Bauelementen in eingebauten Zustand. Kurzber. Bauforsch. vol.19 no.7 1978 p.521-527 3 figs. 1 tab. #DATE 01:01:1978 in German #AIC 314=AIC Translation No.11
ABSTRACT
The conduction of sound through the gap between window and wall depends on the width of the gap. This width also determines the air leakage, suggesting that air leakage might be measured by an acoustic method. Notes method requires that cracks are relatively large and have fewer than three kinks. Reports measurements in a wind tunnel of air flow through crack models made from aluminium and compares results with theory. Finds empirical expression relating pressure difference to air flow and gives graphs of results.
KEYWORDS
window, joint, air leakage, sound,

(101) Keast, D.N.;
#NO 2038 ACOUSTIC LOCATION OF INFILTRATION OPENINGS IN BUILDINGS; LOCATION = North America; RESEARCH.LOC = Cambridge, MA; RESEARCH.LOC = Brockton; TYPE = REPORT; #DATE 01:10:1978; VOLUME.TITLE = Brookhaven National Laboratory Report 50952; PAGES = 1-144; REPORT.no = BNL 50952; PUBLISHER.NAME = National Technical Information Service U.S. Department of Commerce; PUBLISHER.CITY = Springfield, VA 22161; in English #AIC 301
ABSTRACT
Unnecessary air infiltration ,draftiness, in buildings can be a major cause for excessive energy consumption. A method for using sound to locate, for subsequent sealing, the openings of air infiltration leakage paths in buildings has been investigated. The results of pertinent analytical studies, laboratory experiments, and field applications of this acoustic-location method are reported, and a plan is provided to encourage national implementation of the method. Low-cost, readily available equipment and procedures are described whereby the average building contractor or homeowner can use acoustic leak location to pinpoint many of the air infiltration openings in a building.;
KEYWORDS
= AIR INFILTRATION; SONIC TECHNIQUES, sound, AIR LEAKAGE; INSTRUMENTATION;

(102) Keast K.N. Pei H-S.
#NO 208 The use of sound to locate infiltration openings in buildings Proceedings ASHRAE/DOE Conference "Thermal performance of the exterior envelopes of buildings" Florida, December 3-5, 1979 #DATE 03:05:1979 in English #AIC 71
ABSTRACT
Suggests the use of sound waves to locate openings in buildings that allow air infiltration. Reports results of an experimental program, including laboratory tests of a specially constructed partition and field tests on eight buildings. Finds that on average openings that can be located acoustically transmit sound that is about twice as loud as that through adjacent, sealed locations. Laboratory studies indicate that the sound level increase through a leakage opening is roughly correlated with the logarithm of the local air flow rate when a steady differential pressure is established across the partition. Concludes that acoustic leak location is most useful in buildings that are draughty but works less well in tight well insulated buildings. It is a simple and inexpensive method for finding hidden openings, needing no pressure or temperature differentials across the building envelope.
KEYWORDS
air leakage, air infiltration, instrumentation, sound,

(103) Bolon P.
#NO 683 Listening for air leaks - How to spot infiltration with your ears. Popular Science February 1981 p38,40 #DATE 01:02:1981 in English #AIC 332
ABSTRACT
Describes use of an acoustic method developed by Keast to detect air leaks. A loud source of sound is placed inside the building and a microphone, stethoscope, rubber hose or sound meter is used to detect places where an increase in sound indicates air leakage. Finds method is effective in detecting simple leaks but will not spot complex paths through walls.
KEYWORDS
sound, air leakage, house,

(104) Benedetto G. Brosio E.
#NO 690 A relation between transmission loss and air infiltration characteristics in windows. Istituto Elettrotecnico Nazionale Galileo Ferraris, Turin, 4p, 4 figs., 3 refs. #DATE 01:01:1981 in English #AIC 344

ABSTRACT
Reports tests on 4 different windows of air leakage and sound transmission loss. Expresses each of these two quantities by a single parameter and finds reasonable correlation between the parameters. Concludes, within the limitations of the method, that the air leakage class of a window can be deduced from field measurements of sound transmission loss, when the acoustical performance in perfect sealing conditions is known.

KEYWORDS
air leakage, windows, sound

APPENDICES

APPENDIX 1 – Tracer Gas Analysers

A variety of gas analysers is used in the detection and measurement of tracer gases. This appendix contains a description of the most commonly used types of analysers and a list of manufacturers. In most instances the main company address only is given, although the instrumentation listed is generally available world-wide. The addresses of national representatives and suppliers may be obtained directly from the relevant manufacturer.

Description of analysers

Electron capture detector

This detector makes use of the electron capturing properties of various gases. In particular, it is used to detect very low concentrations (typically in the ppb range) of halogenated compounds such as sulphur hexafluoride and perfluoro tracers. A small, sealed, radioactive source is placed inside an ionisation chamber where it generates a cloud of electrons. When a pulsed voltage is applied across the chamber, a current flows. The air sample is introduced to the cell, whereupon electron capturing material reduces the number of electrons and hence the current flow. Molecular oxygen also has electron capturing properties and therefore a gas chromatograph should be used upstream of the detector to separate oxygen.

Flame ionisation detector

This type of detector is suitable for measuring methane and ethane tracer gas concentrations. The sample is fed into a hydrogen flame where it burns and produces ions proportional to the sample concentration. Electrodes placed around the flame measure the ionisation current inside the flame.

Katharometer

A katharometer measures the change in thermal conductivity of air due to the introduction of tracer gas. Typically, two pairs of thermistors are arranged in a wheatstone bridge network. The air/tracer is passed over one pair of thermistors, while 'clean' air is passed over the other. The resultant imbalance in temperature causes a current to flow in the bridge network. This detector is used to measure hydrogen and helium concentrations.

Infra-red absorption gas analysers

This type of analyser is normally used to measure nitrous oxide and carbon dioxide tracer gases; it may also be used to measure sulphur hexafluoride in the ppm range. The analyser makes use of the infra-red absorbing properties of certain gases. Two beams of infra-red radiation of equal intensity are passed through an analysis cell and a parallel reference cell respectively. The analysis cell contains a sample of air in which the tracer gas is present while the reference cell contains a non-absorbing reference gas. The difference in intensity between the two streams after passing through these cells provides a measure of tracer gas concentration.

List of Manufacturers

Address of company	Product
Analysis Automation Ltd Southfield House Eynsham Oxford OX8 1JD Great Britain Tel: 0865 881888 Telex: 837509	Infra-red absorption analysers

Address of company	Product
The Analytical Development Co Ltd Pindar Road Hoddesdon Herts EN11 0AQ Great Britain Tel: 09924 69638 Telex: 266952	Infra-red absorption analysers
Analytical Instrument Development Inc Rt 41 and Newark Road Avondale PA 19311 USA Tel: 215 268 3181 Telex: 835441	Atmospheric monitor with a choice of detectors, including – electron capture – flame ionization
Anarod PO Box 3160 Santa Barbara CA 93105 USA Tel: 805 963 8886	Infra-red absorption analysers
Anatek Instruments Ltd High Street Mayfair Sussex TN20 6AB Great Britain Tel: 0435 873477 Telex: 95632	
A1 Industrial London Road Pampisford Cambridge CB2 4EF Great Britain Tel: 0223 834420 Telex: 817536 *In USA:* Ion Track Instruments Inc 109 Terrace Hall Avenue Burlington MA 01803 USA Tel: 617 272 7233 Telex: 710 332 1808	Atmospheric monitors (gas chromatograph) with a choice of detectors, including – electron capture – flame ionisation – katharometer *(This product is widely used in tracer gas studies. N.B. The company provides a useful leaflet describing the theory behind each detection method – copies available from AIC)*
Beckman Instruments Inc Process Instruments & Controls Group 2500 Habor Boulevard Fullerton California USA Tel: 714 871 4848 Telex: 06 78413	Infra-red absorption analysers. Gas chromatographs. Air quality monitors

Address of company	Product
Cerberus AG CH 8708 Mannedorf Switzerland Tel: 01 922 6111 Telex: 875528 CSM CH	Computer controlled analysers specifically designed for tracer gas analysis
Columbia Scientific Industries Corp PO Box 9908 Austin Texas 78766 USA Tel: 800 531 5003 Telex: 910 874 1364	Gas analysers including a 'chermiluminescent' detector for oxides of nitrogen
Foxboro 28 Heathfield Stacey Bushes Milton Keynes Bucks Great Britain Tel: Telex: 825109 *In USA:* Wilks Infra-red Center PO Box 5449 South Norwalk CT 06856 USA Tel: 203 853 1616 Telex: 96 4331 *In Netherlands:* Foxboro Nederland NV Analytical Division Postbus 75 3760 AB Soest Netherlands Tel: 703166 Telex: 73007	*MIRAN* Infra-red absorption analysers
Hampden Test Equipment Ltd Bunting Road Industrial Estate Northampton N2 6EB Great Britain Tel: 0604 718177 Telex: 312160 HTEL G	'GAS-O-MAT' carbon dioxide indicator/controller
Horiba Instruments Ltd 5 Harrowden Road Brackmills Northampton NN4 0EB Great Britain Tel: 0604 65171 Telex: 311869	Infra-red absorption analysers specifically for monitoring indoor atmospheric carbon dioxide

(continued overleaf)

Address of company	Product
(Other Horiba divisions) *In Japan:* Horiba Ltd Miyanohoigashi Kisshoin Minami-ku Kyoto Japan Tel: 075 313 8121 Telex: 5422130 *In Switzerland:* Horiba Instruments SA 1261 Chevannes-de-Bogis Switzerland Tel: 022 763522	
Leybold-Heraeus GmbH Wilhelm-Rohn Strasse 25 PO Box 1555 D-6450 Hanau 1 West Germany Tel: 06131 3641 Telex: 4 184741 LHH D	*BINOS* Infra-red analysers *(widely used in tracer gas studies*
H. Maihak AG Semper Strasse 38 Postfach 601709 2000 Hamburg 60 West Germany Tel: 040 27161 Telex: 21158	Infra-red absorption analysers
J & J Seiger Ltd 31 Nuffield Estate Poole Dorset BH17 7RZ Great Britain Tel: 0202 676161 Telex: 41138, 418475	Infra-red absorption analysers *(widely used in tracer gas studies)*
S-Cubed (formerly Systems, Science & Software) PO Box 1620 La Jolla California 92038 1620 USA Tel: 714 453 0060	Automated tracer gas monitor incorporating electron capture, gas chromatograph. *(Instrumentation specifically designed for air infiltration and related tracer gas studies – widely used)*
Valco Instruments Co PO Box 55603 Houston Texas 77055 USA Tel: 713 683 9345 Telex: 79 0033	Electron capture detectors. *(May be connected to existing gas chromatographs)*

(continued)

Address of company	Product
In Switzerland: Vici Ag Valco Switzerland Tannberg PO Box 13 CH 6214 Schenkon Switzerland Tel: 045 216868 Telex: 72609 VICI CH	

APPENDIX 2 – Pressurization Test Equipment (Blower Doors)

The majority of the blower doors listed in this appendix originate from Canada and the United States of America. Potential users in other countries should satisfy themselves that the voltage and phase of the local power supply is compatible with the operating requirements of this equipment.

List of Manufacturers

Address of company

Ener-Corp
2 Donald Street
Winnipeg Ossian Street
Manitoba
R3L OK5
Canada
Tel: 204 477 1283

Energy Conservation Systems
TWV Enterprises
4216 50th Suite F
Lubbock
Texas 79413
USA
Tel: 806 794 4459

Energy Efficient Laboratory
34177 Pacific Coast Highway
Suite 106
Dana Point
CA 92629
USA
Tel: 714 496 8920

Energy Works
44 Hunt Street
Watertown
MA 02172
USA
Tel: 617 926 8600

The Gadzo Blower Door
Princeton Energy Partners Inc
PO Box 1221
Princeton
NJ 08540
USA
Tel: 609 924 1177

Harmax Corporation
6224 Orange Street
Los Angeles
CA 90048
USA
Tel: 213 936 2673

Industrial Electronics and Automation Ltd
PO Box 741
Ahuriri
Napier
New Zealand
Tel: 55 123
Telex: 3241 NZ

Infilseal Corporation
4660 Beechnut
Suite 248
Houston
TX 77006
USA
Tel: 713 522 2656

Infiltec Air Leakage Measurement System
Infiltec
(A Division of Saum Enterprises Inc)
PO Box 1533
Falls Church
VA 22041
USA
Tel: 703 820 7696

Mekankonsult Lifa
Andvagen 26
S-353 42 Vaxjo
Sweden
Tel: 0470 22956

Retrotec Energy Innovations Ltd
176 Bronson Avenue
Ottawa
Ontario
K1R 6H4
Canada
Tel: 613 234 3368

Veab Elomicro AB
Box 22
S-360 50 Lessebo
Sweden
Tel: 0478 11376

APPENDIX 3 – Pressure Measuring Instruments (suitable for wind pressure measurements)

The manufacturers listed in this appendix produce pressure sensors suitable for the measurement of wind-induced surface pressures. While such instrumentation is not used in the direct measurement of air infiltration, it has applications in research investigations where it is necessary to relate the rate of infiltration to the corresponding driving forces.

List of Manufacturers

A1 Industrial
London Road
Pampisford
Cambridge
CB2 4EF
United Kingdom
Tel: 0223 834420
Telex: 817536

Bell & Howell Ltd
Lennox Road
Basingstoke
Hants
RG22 4AW
United Kingdom
Tel: 0256 20244
Telex: 858103

Furness Controlls Ltd
Beeching Road
Bexhill-on-Sea
East Sussex
TN39 3LJ
United Kingdom
Tel: 0424 210316
Telex: 957012

Gadsco Inc
209 Vetterlein Avenue
Trenton
NJ 08619
USA

MKS Instruments Inc
22 Third Avenue
Burlington
Massachusetts 01803
USA
Tel: 617 272 9255
Telex: 94 9375

Schaevipz EM Ltd
543 Ipswich Road
Slough
Berks
SL1 4EG
United Kingdom
Tel: 0753 37622
Telex: 847818 SCH EM G

E Schiltknecht Ing Sia
Inh J-P Schiltknecht dipl Ing ETH
Industriegebiet
CH 8625 Gossau ZH
Switzerland
Tel: 01 935 2121
Telex: 875759

Validyne Engineering Corporation
8626 Wilbur Avenue
Northridge
California 91324
USA

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Canada, Denmark, Italy, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States of America.

The Air Infiltration Centre provides technical support to those engaged in the study and prediction of air leakage and the consequential losses of energy in buildings. The aim is to promote the understanding of the complex air infiltration processes and to advance the effective application of energy saving measures in both the design of new buildings and the improvement of existing building stock.

Air Infiltration Centre

Old Bracknell Lane West,
Bracknell, Berkshire,
Great Britain,
RG12 4AH.

Tel : National 0344 53123
International + 44 344 53123
Telex: 848288 (BSRIAC G)
ISBN 0 946075 03 4

Operating Agent for International Energy Agency, The Oscar Faber Partnership, Upper Marlborough Road, St. Albans, Herts, Great Britain.