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Measurement Techniques Special

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This edition of Air Infiltration Review features a selection of articles dealing with air infiltration and ventilation measurement methods, coinciding with the publication of the AIVC's latest applications guide, 'The Measurement Techniques Guide'.

The advancement of air exchange rate and airtightness measurement techniques has been central to the interests of the Air Infiltration and Ventilation Centre since the first AIVC conference eight years ago. At that inaugural conference three automated single tracer gas measurement systems were described and several papers dealing with the fan pressurization technique were presented. Since that time tracer gas technology has advanced to the stage where air flow rates between the internal spaces of a compartmentalized building can be evaluated. Similarly airtightness measurement techniques have progressed to include the use of multi-fan pressurization methods to obtain detailed information about the leakage characteristics of a variety of building types. During the last eight years several new techniques have been put into practice. Notable amongst these are the perfluorocarbon tracer (PFT) methods and the AC pressurization technique. PFT technology allows the ventilation characteristics of a large number of buildings to be evaluated in a cost effective manner. AC pressurization utilizes a piston, rather than fan, to evaluate the air leakage characteristics of the building envelope. Technical papers examining a multiple tracer gas method, the multiple fan pressurization technique, a pressure compensating flow meter and AC pressurization are presented in this issue of Air Infiltration Review.

Recently the technical work programme of the Air Infiltration and Ventilation Centre has focused on the subject of air exchange rate and airtightness measurement techniques. As part of this effort the AIVC held an international measurement techniques workshop in Køge, Denmark. The workshop was attended by representatives from 12 countries and offered an ideal opportunity for research workers to share ideas and experiences of air infiltration and ventilation measurement techniques. Eight technical papers were presented and these concentrated mainly on the PFT technique, advanced pressurization methods and international measurement standards. Workshop proceedings have now been published as AIVC Technical Note 24 and details of the content and availability of this document are contained in this issue.

The culmination of the measurement techniques work programme is the publication of the AIVC's guide to air exchange rate and airtightness measurement techniques. This document draws on the knowledge and experience of a wide range of people who are actively involved in making air infiltration and ventilation measurements. The guide provides the fundamental theory and practice of air exchange rate and airtightness measurement methods and presents detailed descriptions of several measurement techniques. An account of the contents and availability of this guide is presented in this issue.

Measurement techniques continue to play an important role in air infiltration and ventilation studies. They enable primary data to be obtained from existing structures, allow building retrofit measures to be evaluated and provide the means of validating mathematical models. Techniques vary in cost, sophistication and application, therefore expert guidance is required for anyone contemplating work in this complex field. The measurement techniques guide fulfils this role and, together with this issue of AIR and the workshop proceedings, provides a comprehensive review of the current status of air infiltration and ventilation measurement technology.

Inside this issue:

Measurement of low air flow rates using a simple pressure compensating meter

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Introduction

The accurate evaluation of air flow rates at HVAC supply or extract grilles is difficult. Most air flow meters utilize a cone or hood, and an anemometer (Figure 1).

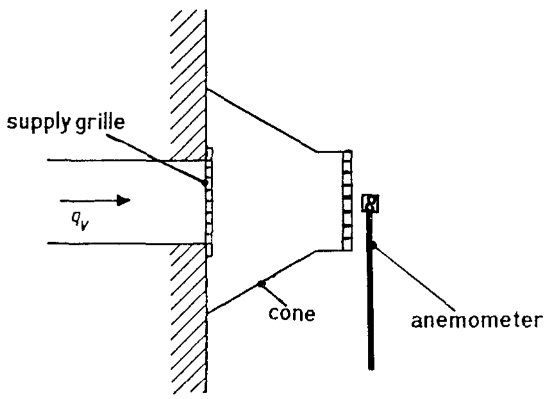

Figure 1: Ordinary flow rate meter with a cone and anemometer

When measuring at supply grilles the velocity profile through the cone is generally not fully developed. This can lead to very large errors and, in some cases, may even indicate a flow rate in the wrong direction.

Another problem is the air resistance of the cone. This introduces a pressure drop which is proportional to the square of the measured flow rate. At low flow rates and air velocities below 4 m/s, this pressure drop is a few Pascals. As duct pressures are often higher than this, no significant error will result. At higher flow rates and velocities the pressure drop over the cone will not be negligible with respect to the duct pressure. In this case the indicated flow rate may be lower than the actual flow rate.

These problems can be overcome by compensating for the pressure drop over the flow meter in such a way that the pressure on the duct side of the grille remains the same before and after the positioning of the flow meter. This is a very well known technique. However in the field of air conditioning, devices using this principle are rare. The compensation of the pressure drop is performed by a fan and regulator which blows just enough air through the flow meter to meet the pressure compensation before the grille. At first we used a large controllable fan, a set of DIN measuring tubes with orifice plates, and a box with a pressure meter to be placed over the grille. All connections were made with flexible tubing. The whole set up was accurate but very large and not easy to move from position to position (Figure 2).

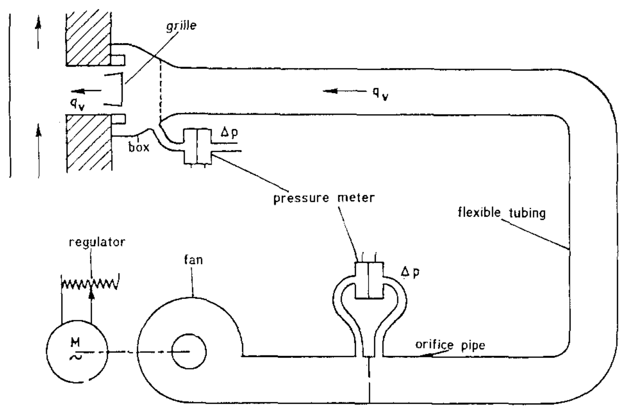

Figure 2: Original large scale flow rate measurement equipment with pressure compensation

Air Infiltration Review

Editor: : Janet Blacknell
Technical Editor : Peter Charlesworth

Air Infiltration Review has a quarterly circulation of 3,500 copies and is currently distributed to organisations in 34 countries. Short articles or correspondence of a general technical nature related to the subject of air infiltration and ventilation are welcome for possible inclusion in AIR. Articles intended for publication must be written in English and should not exceed 1,000 words in length. If you wish to contribute to AIR, please contact Janet Blacknell at the Air Infiltration and Ventilation Centre.

An extra advantage of the use of pressure compensation is that grids can be placed in the meter to prevent eddies from the supply grille entering and disturbing the flow meter. On the other side, grids prevent eddies from the blow side of the meter disturbing the flow through extract grilles (Figure 3).

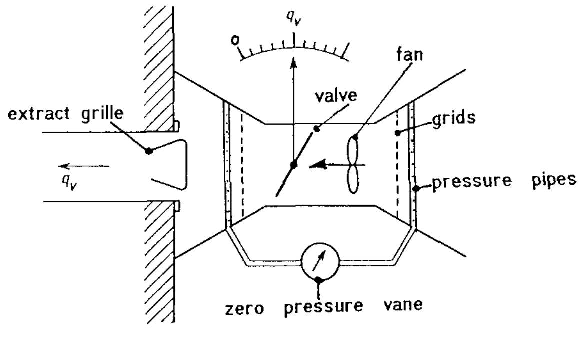

Figure 3: Schematic cross-section of flow meter showing measurement principle

Inexpensive air heating systems with low duct pressures are becoming more popular. Hence the need for an accurate low pressure drop flow meter has grown. In air heating systems the heat distribution over the rooms is proportional to the distribution of the flow rate over the rooms, i.e., half the flow rate and the heat input is also halved. This sensitivity to flow rate is much higher than for hot water central heating systems. This is one of the reasons why there have been many complaints resulting from badly commissioned air heating systems.

Development of the flow meter

Any meter must be able to measure the total flow rate required for the ventilation of one dwelling. In Holland this is 0.063 m^3/s (225 m^3 per hour or 130 ft^3 per minute).

As the pressure drop over the flow meter, including the grids, is less than 100 Pa, a very small battery operated axial fan can be used. Experiments showed that regulating the speed of the fan did not enable a stable indication of the flow rate or a wide flow rate range to be obtained, especially at low air speeds. A simple manually controlled throttle valve gave very good reproducibility and a wide range of flow rates, from zero to the maximum (Figure 3). The relation between valve position and flow rate is not linear. The shape of the valve results in larger scale divisions at low flow rates. The shape of the scale is determined by calibration at a number of flow rates against a reference wind tunnel with an orifice plate. It appeared to be unnecessary to control the fan to a constant speed. A constant voltage gave excellent reproducibility with the fan used. As the fan does not change speed dramatically, repositioning the valve instantaneously changes the flow rate. This allows fast manual operation, without the need to wait until the meter is settled. Automatic zeroing for continuous flow rate read-out was not the aim.

To obtain pressure compensation it is necessary to have an indicator for the pressure difference over the flow meter just outside the inlet and outlet grids. A vane indicator gives the required resolution of less than 1 Pa. In the prototype the mechanism of a milliampere meter, with holes drilled in the housing to the left and right of the needle, was used. This is very sensitive and mechanically well balanced.

It is slightly better to zero the pressure over the meter than to zero the (static?) pressure difference before the grille and outside the cone. At high flow rates the static pressure before the extract grille will be down a few Pascals. If one equals this static pressure with the static pressure outside the cone of the flow meter the indicated air flow rate will be too large. In fact one should balance the total pressure, but this total pressure is difficult to obtain at supply grilles.

On explaining the very simple mechanism of such a meter, people often ask where the flow rate is measured in this flow meter. One would expect an anemometer or pressure transducer somewhere. It must be realised that this flow meter contains no real meters to measure the flow rate. The indicated flow rate is the result of the constant running fan and the positioning of the throttle valve. As long as the fan and the grids are kept free of fouling or dust layers, and the electric motor is free from aging effects, the calibration curve will be maintained.

After the prototype became operational an instrument manufacturer produced several commercial units (1) (Figures 4 and 5). The shape of the hood has, within wide ranges, no influence on the calibration. The hood fits on both sides of the flow meter, allowing supply and extract measurements to be made with the same calibation curve and to the same accuracy. The accuracy claimed, is 5% of the reading with a minimum of $\pm$ 0.0005 m^3/s (2m^3 per hour or 1 ft^3 per minute), while in general the difference between measurements of supply and extract flow is less than 2%. Reproducibility is within 1%. Calibrations have been made at different temperatures. The maximum temperature of the supply air is about 80°C. In the present flow meter the pressure vane has a magnetic suspension, which is sensitive to the strong magnetic fields that can occur in some factories. The flow meter can run for more than one hour continuously on the Ni-Cd Battery pack. Normally the battery will not run down during eight hours intensive measurements in the field. The weight of the meter is 3.7 kg. It is easy to handle with a large hand grip and large flow control knob.

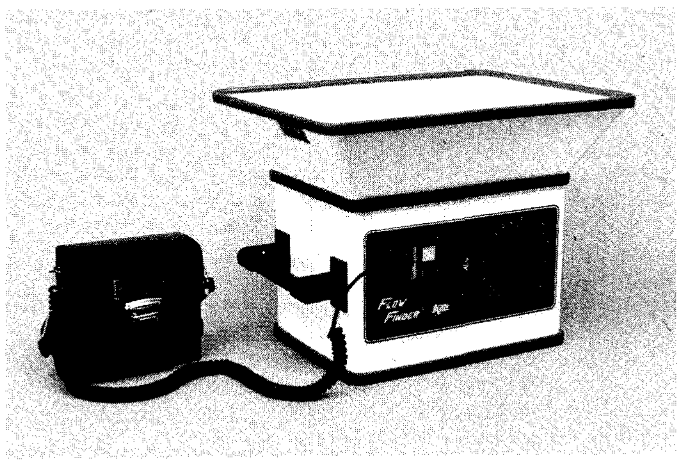

Figure 4: Flow Finder and battery pack. Different hoods fit on both sides

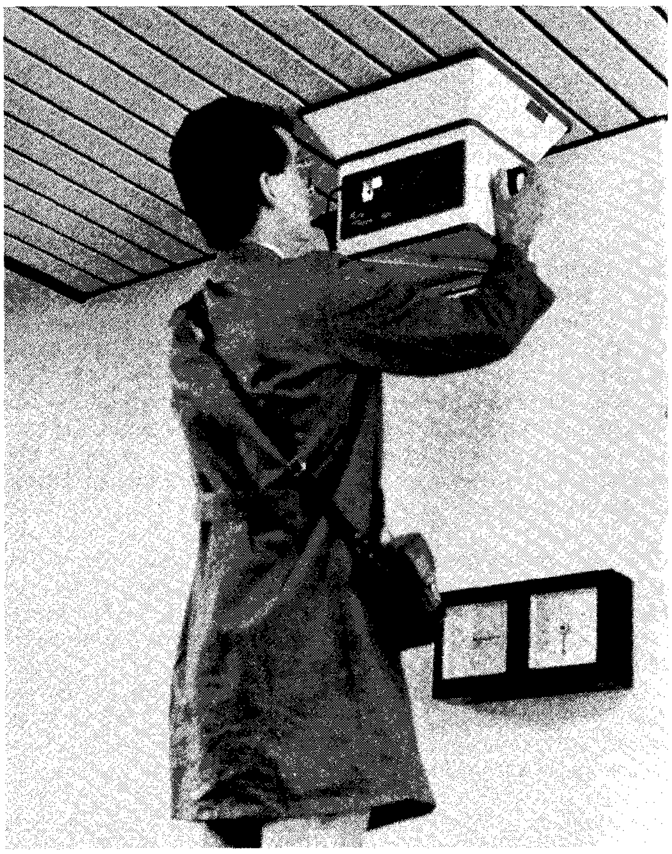

Figure 5: Measurement at a ceiling grille

Measuring flow rates with the meter

The meter is switched on, and placed against the wall over the grille. The flow control knob is turned until the pressure vane reads zero. Then flow rate can be read on the large scale round the flow control knob which is connected to the valve.

For accurate measurements the gap between the hood and the wall must not be too large. If a large gap exists the pressure vane becomes insensitive and will move only for a large change in the position of the flow control knob, introducing a wide inaccuracy band. This also happens at duct pressures of less than 5 Pa. In research situations this can be improved by using a very sensitive 1 Pa electronic pressure transducer on the pressure pipes.

If the flow is too large then pressure compensation cannot occur. Inability to reach pressure compensation may indicate air flow in the opposite direction, in which case the hood must be placed on the other side of the meter. Sometimes it is possible to make a measurement on part of a large grille in order to obtain an estimate of the total flow through the grille. This is the normal technique used for line diffusors.

In many cases it is possible to measure the flow through grilles on ducts of natural or passive ventilation systems. Even if this flow fluctuates, the meter is fast enough to follow the changes. It may require a skilled operator to perform this type of measurement.

In a lot of situations the hood will not fit the grille to be measured, because the wall is not flat or there is some obstacle. An advantage is that the shape of the hood normally does not change the calibration.

Flow distribution during a blower door test

In airtight houses we have succeeded in measuring the leakage flow rate through the facades of the individual rooms during a blower door test. At constant pressure in the house a cardboard shield is placed on the opening of the internal door of the room. The flow meter is pressed on an opening in the board and indicates the flow through the facade. This is done for all rooms with a leakage of less than 0.063 m^3/s. If the leakage of a room to the adjacent internal rooms is much greater than the leakage through the facade the measurement becomes insensitive. The pressure vane stays around zero at all positions of the flow control knob.

This method is the same as using two blower doors. One for the whole house and the second in the opening of the internal door (Figure 6). A blower door could be produced in the same way as the flow meter described here. In 1983 a prototype was produced which worked well. The flow rate calibration curve is only valid for one blower door pressure. The prototype had a set of scales at 0 Pa, 20 Pa and 50 Pa, allowing interpolation.

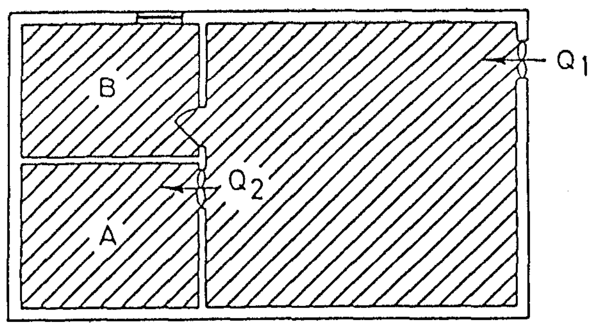

Figure 6: Measurement of facade leakage in one room with two blower doors (2)

If the flow is too large for this flow meter, Wouters' method (2) can be performed.

Direct crack flow measurements during blower door tests have been performed by placing a sealed box on the investigated part of the facade. The flow meter is placed on an opening in this box. The flow meter indicates the leakage flow without influencing the blower door pressure over the cracks.

Concluding remarks

The meter is most useful for short term measurements in which the meter is hand held over the grille. This is because there is no facility for automatic pressure compensation.

For research work the pressure vane could be made more sensitive or pressure transducers could be used.

A flexible hood would increase the number of locations at which the meter could be used.

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2. Wouters, P, et al, Advanced single fan pressurisation, CSTC/WTCB, Brussels, March 1988.

Four cell ventilation and air movement measurements using a new multiple tracer gas technique

Rodger Edwards and Chris Irwin

University of Manchester, Institute of Science and Technology, United Kingdom.

Chris Irwin is now employed by Willan Building Services Ltd, Sale, Cheshire.

Introduction

This article briefly describes a new piece of apparatus, recently developed at UMIST, which can be used for the determination of ventilation rates in, and air movement rates between, four interconnected cells.

Description of Technique

Ventilation and air movement research has been in progress at UMIST for over eight years. In this time, the tracer gas detection equipment used has developed from a simple, single separation column gas chromatograph (1) to a twin column gas chromatograph (2) which is able to analyse an air/tracer gas sample within 45 seconds for the case of three tracer gases. However, this system cannot fully cope with the four cell, four tracer gas situation, since, in order to achieve the maximum one minute sampling interval required for successful mathematical analysis of the data (3), tracer gas peak resolution is reduced to an unacceptable level at low tracer gas concentrations. It has therefore been necessary to develop a new piece of equipment in order to facilitate the satisfactory use of four or more tracer gases.

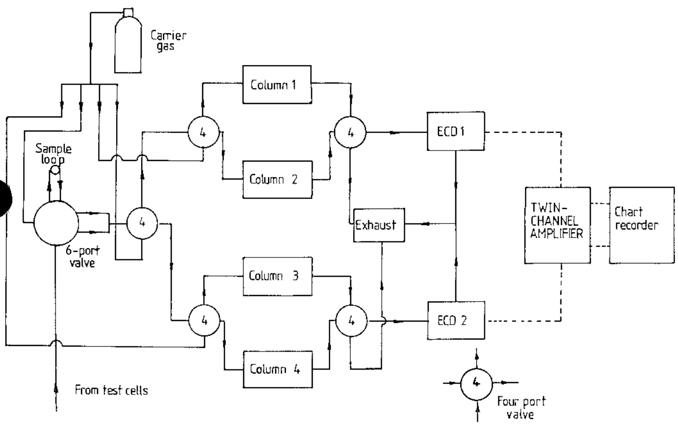

Figure 1: Measurement Equipment

The equipment is shown in Figure 1. It consists of an Analytical Instruments model 505 portable gas chromatograph, as per the previous two pieces of equipment. However, in this case, the modifications made are on a significantly greater scale. The gas chromatograph now has two electron capture detectors fitted in parallel, which are capable of being operated both simultaneously and independently. The signal amplifier/invertor board originally fitted has been replaced by a custom made twin channel board. Each electron capture detector is connected to a pair of separation columns in the same manner as the parallel column equipment. Five four-port valves are used to direct sample flow through the system. Later work with the parallel column equipment showed that problems of pressure equalisation in the system were obviated if the system was pressurised by means of a pump at its front end, instead of using a pump to suck gas through: the same idea is used in this apparatus.

The gas chromatographic separation columns used are of 6 mm internal diameter, and 3 metres length. The packing is 10% squalane on a ceolite (non-acid washed) base. In order to ensure the best possible response match between the columns, the column preparation and operating procedure described by Irwin and Edwards (2), is again used. When in operation, the columns are immersed in a thermostatically controlled water bath and stirrer unit at a temperature of 40°C: apart from minimising baseline drift problems, this practice also helps to improve column response match. During laboratory calibration checks, the maximum response difference observed between the two electron capture detectors at the same tracer gas concentration was not greater than 0.5%.

A range of tracer gases have been assessed for use in four cell measurements, (4). The gases chosen are Freons 13B1, 12, 114 and perfluorocarbon PP1. Using these four gases, one air/tracer gas sample can be analysed in one minute: this means that the apparatus can receive one air/tracer gas sample every 30 seconds, since the use of parallel detectors doubles the available time for which detector output can be monitored for a given sample. This extra time reduces the urgency for rapid tracer gas peak throughout, and hence improves peak resolution at lower tracer gas concentrations.

Discussion

The test cell arrangement used during the commissioning program is shown in Figure 2. The kitchen, living room/lobby and dining room have been taken as separate cells, whilst the whole upstairs has been taken as one cell. The tracer gases are injected as follows: Freon 12 in the dining room (gas A); Freon 13B1 in the kitchen (gas B); PP1 in the living room/lobby (gas C); Freon 114 upstairs (gas D). A set of tracer gas growth/decay curves measured in the dining room during a typical test is shown in Figure 3, whilst the complete set of calculated ventilation rates and interzonal air flows for that same test are given in Table 1.

	1	2 X	3	4
N_x (ach)	4.33	6.83	3.40	1.63
Nett airflow to/from outside (m^3/hr)	+40	+45	−5	−80
F_{1x} (m^3/hr)	x	80	20	30
F_{2x} (m^3/hr)	65	x	100	40
F_{3x} (m^3/hr	15	70	x	150
F_{4x} (m^3/hr	10	10	120	x

Table 1: Ventilation and airflow rates

At the present time, the authors do not have access to a four cell controlled environment system, and therefore validation of the measurement of the technique is not possible. However, on the basis of validation exercises conducted for the cases of two and three interconnected cells, it is expected that the likely error in calculated air flows will be of the order of +/–15%.

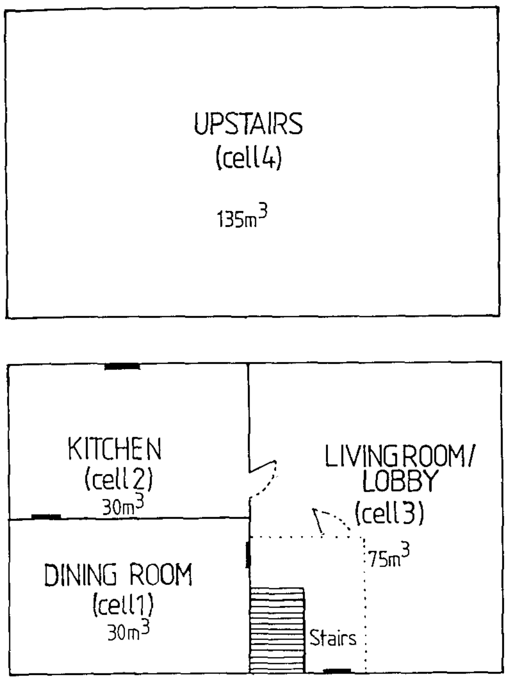

Figure 2: Test Cell Details

Conclusions

The prototype parallel column apparatus is currently undergoing modifications in order to improve its performance. There are a substantial number of tracer gases available which are suitable for use with this apparatus, (4) the current controversy concerning the ozone layer notwithstanding. With careful optimisation of column operating conditions, this apparatus could be used with five or more tracer gases. This is obviously well in excess of the capability required for air movement studies in domestic premises, but offers great potential in the field of air movement measurement in large spaces.

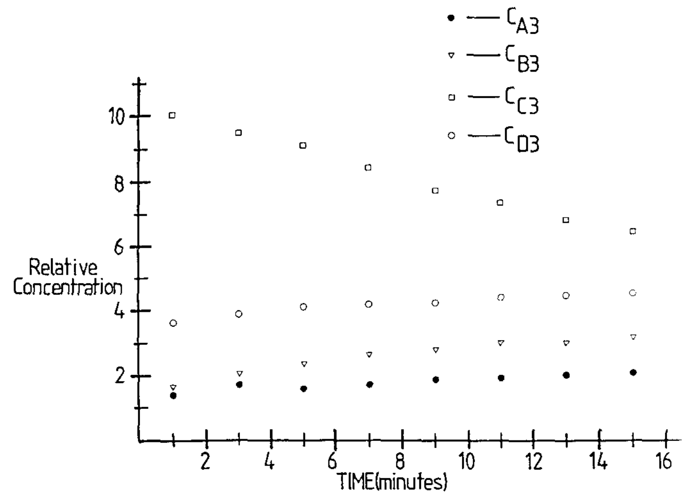

Figure 3: Tracer concentrations in dining room (cell 3)

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AIVC at Warwick University Science Park

Relocation Update

The Centre is due to move to Warwick University Science Park on 1st September 1988. Full details for contacting the AIVC are as follows:

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Balanced fan depressurization method for measuring component and overall air leakage in single- and multifamily dwellings

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Abstract

The procedure for applying the balanced fan depressurization technique to measure the air leakage characteristics of row houses in individual house storeys is described. The technique was tested on a detached two-storey house and a row house. The results are presented and discussed.

Introduction

The fan depressurization method developed for measuring the overall air leakage rate of a building cannot be applied directly to semi-detached houses, row houses, or apartments because these units are not independent of their adjacent units for air leakage from outside. For example, if a single unit is depressurized, outside air will be drawn into that unit as well as adjacent units. In this example outside air enters the depressurized unit directly through its exterior envelope and indirectly through the interior partitions that the unit shares with adjoining units. To minimize the indirect air leakage, the balanced fan depressurization technique was developed (Shaw 1980; Reardon, Kim and Shaw 1987). This paper gives a brief description of the method.

The Balanced Fan Depressurization Technique

The balanced fan depressurization technique uses at least two fans, a main fan to depressurize the test component and another fan to balance the pressures between the test component and its adjacent surroundings (Reardon, Kim and Shaw 1987). A schematic diagram of the simplest setup for a balanced fan depressurization test is shown in Figure 1.

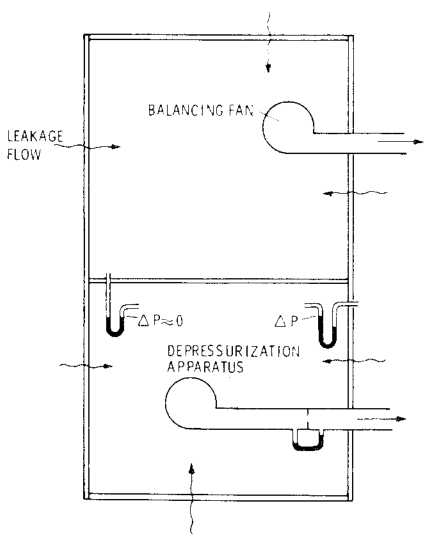


Figure 1: Schematic of the setup for a balanced fan depressurization test

The primary depressurization apparatus consists of a fan, a means for controlling the flow rate through the fan, and a means for measuring that flow rate (CGSB 1986; ASTM 1986). It is set up to depressurize the building component to be tested. The tested component must be isolated as much as possible from its neighbouring building components using existing and temporary partitions (if necessary) to establish the boundaries of the test chamber. Temporary partitions should be as rigid as possible to permit reasonably quick pressure adjustments. The balancing fans, which also require flow rate controls but not flow rate measurement capabilities, are set up to depressurize building components adjacent to the tested component. This will allow the pressure differences between the test chamber and its surrounding areas to be reduced to zero, and hence, prevent any air leakage (other than that through the tested component directly from outside) into the test chamber. Manometers are connected to measure pressure differences across the tested component(s) and between the test chamber and the adjacent areas. The procedures for balancing the pressures are as follows:

1. The flow rate through the primary depressurization fan is adjusted until the desired pressure difference across the tested component is obtained.

2. The flow rate through each balancing fan is adjusted until the pressure differences between the test chamber and the adjacent areas are reduced to zero.

If the balancing fans are equipped with the capability to measure flow rates, the air leakage characteristics of more than one component can be measured simultaneously.

It may not be possible to directly apply the balanced fan depressurization technique to measure the leakage characteristics of a specific buliding component of interest, such as an individual storey of a house. In such cases the leakage characteristics of interest must be calculated from several measurements of combined leakage characteristics. For example, the leakage rates for each of three storeys in a house (the basement, Q_b, the first floor, Q_1, and second floor, Q_2) can be measured using only one depressurization apparatus and one balancing fan. The depressurization apparatus is installed in the middle storey and first used to measure the leakage rate for the entire house, Q_T. After installing the balancing fan in the lowest storey and isolating it from the two upper storeys, a set of measurements is made to obtain the leakage through the two upper storeys combined, Q_{1+2}. Finally, the balancing fan is moved to the top storey which is then isolated from the two lower storeys and a set of measurements is made to obtain the leakage through the two lower storeys combined, Q_{b+1}. These three sets of measurements can then be used to calculate the leakage rates for the individual storeys using the following equations (see Figure 2):

$$Q_b = Q_T - Q_{1+2} \quad (1)$$

$$Q_2 = Q_T - Q_{b+1} \quad (2)$$

$$Q_1 = Q_T - (Q_b + Q_2) \quad (3)$$

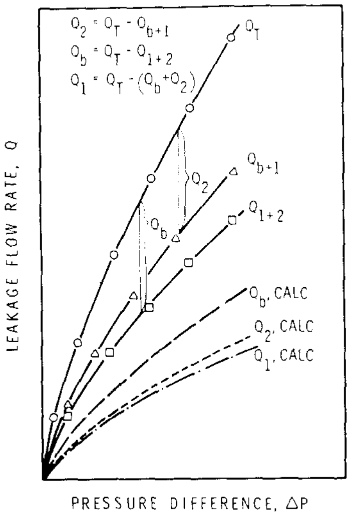


Figure 2: Illustration of calculation method and typical measurement results for indirect application of the balanced fan depressurization technique

The technique is also appropriate for measuring the leakage through the party wall separating two row houses. The air leakage rate of the unit, Q_U, is first measured when pressures inside the unit are balanced with those in adjacent units. The measurements are repeated with the pressures balanced in all but the adjacent unit that shares the party wall of interest to obtain Q_{U+PW}. The leakage rate through the party wall, Q_{PW}, can then be determined from:

$$Q_{PW} = Q_{U+PW} - Q_U \tag{4}$$

Field applications of the technique

Field applications of the balanced fan depressurization technique have been undertaken to measure component air leakage characteristics in several residential buildings. Two such applications are given below.

Case 1: Two-Storey House

Two fan depressurization apparatuses were installed in a two-storey house: one on the first floor and one on the second floor. The individual air leakage characteristics of the second storey and of the first storey and basement combined were measured directly using the balanced fan depressurization technique. After this, a routine fan depressurization test was carried out on the whole house. Figure 3 shows the results of these tests; the sum of the individual air leakage rates compares very favourably (within 5%) with the air leakage rate of the whole house, which was measured directly.

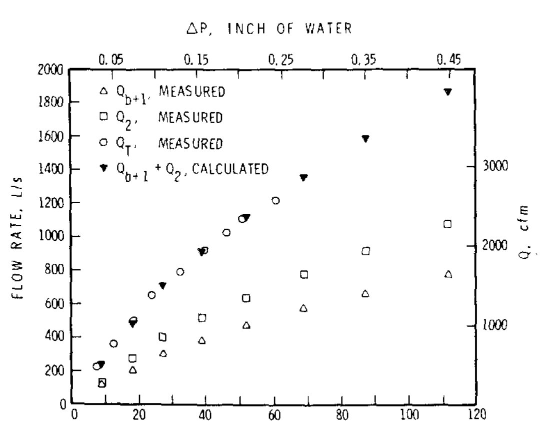
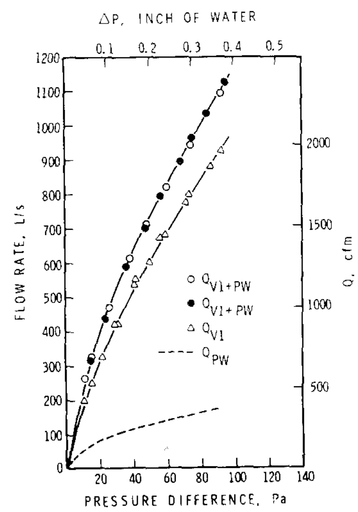


Figure 3: Air leakage measurements in a two-storey house

Case 2: Two-Storey Row House

The end unit of a two-storey row house was tested with a depressurization apparatus installed in it and a balancing fan installed in the adjacent unit with which it shares a common interior wall. All the doors and windows of both the end unit and the adjacent unit were closed tightly, and a depressurization test of the end unit was carried out; Test 1. In Test 2 the door of the adjacent unit was opened and a second depressurization test was made on the end unit with no pressure balancing. Finally, in Test 3 the balancing fan was removed, its opening sealed, and the door of the adjacent unit closed tightly and a final depressurization test of the end unit was performed with no pressure balancing. The results of these three series of measurements are shown in Figure 4. They indicate that air leakage across the party wall, calculated using the scheme described previously in Equation 4, accounted for approximately 17% of the total air leakage rate (through the exterior walls and the party wall combined) as measured in tests 2 and 3. No measurable difference was observed between the results of tests 2 and 3, indicating that opening or closing of the adjacent unit's door had no effect on the measurement of the total air leakage rate in the end unit.



o ADJACENT UNIT MAIN DOOR OPEN
o ADJACENT UNIT MAIN DOOR CLOSED

Figure 4: Air leakage measurements in a two-storey row-house and unit

Summary

This paper gives a brief description of the balanced fan depressurization method. This technique has been applied successfully for measuring leakage rates through various sections of both detached houses and row houses.

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1988 ASHRAE Annual Meeting

Ottawa, Canada, 25 – 29 June
Report by Martin Liddament, Head of AIVC

The 1988 ASHRAE Annual Meeting included a short symposium on wind infiltration as well as several technical papers related to airflow and ventilation in buildings. The wind pressure symposium, entitled 'Wind Pressure Effects on Ventilation', was chaired by Fred Bauman from the University of California and began with a presentation by Martin Liddament on the calculation of wind induced infiltration. This presentation also included a discussion on the relative significance of wind as a driving force in relation to stack effect and mechanical ventilation. Richard Aynsley from the Georgia Institute of Technology considered the calculation of wind induced flow through buildings with large openings. He especially concentrated on the effects of friction losses within the building due to long corridors and other internal flow routes. Resistance based flow theory as currently used for estimating mine ventilation was used to calculate these losses.

The symposium was completed with a presentation by Fred Bauman on the effects of surrounding buildings on wind pressures and natural ventilation in large buildings. In his presentation, he described the results of wind tunnel studies to show how the shelter effect of surrounding built-up environment can make it more difficult to obtain large enough pressure differences across a building to produce adequate natural ventilation airflow rates. The use of 'jack roof' configurations (Figure 1) as an effective means of natural ventilation in urban areas was demonstrated.

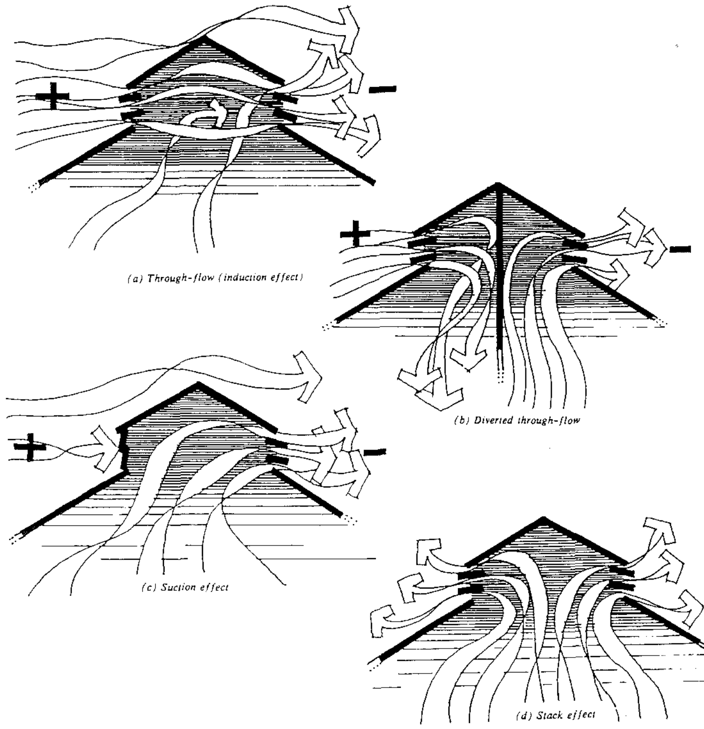

Figure 1: Jack roof flow configurations

Airflow and ventilation related papers presented in the Technical Sessions included a contribution by Chen Qingyan and Jan van der Kooi from the Delft Technical Institute in the Netherlands on a computer program entitled 'ACCURACY' – a program for combined problems of energy analysis, indoor airflow and air quality. This is a coupling program which combines a cooling load algorithm with an airflow algorithm. It solves transient equations for the conservation of energy and contamination concentrations, using airflow patterns which are precalculated using conventional airflow codes.

Shinsuke Kato from the Institute of Industrial Science, University of Tokyo, Japan, presented a paper on new ventilation efficiency scales based on spatial distribution of contaminant concentration aided by numerical simulation. Three scales for measuring ventilation efficiency in a room were defined in order to evaluate the distribution of 'ventilation effectiveness' at each point. The three proposed scales for ventilation efficiency (SVE) were:-

SVE1 – the spatial average of contaminant concentration in a room where contaminants are generated at a single point source.

SVE2 – the mean radius of contaminant diffusion in a room.

SVE3 – the concentration at a given point in a room, where the contaminant is uniformly generated throughout the room.

The results of numerical airflow and diffusion simulations were used to evaluate the usefulness of these proposed scales.

A paper by Shuzo Murakami, also from the Institute of Industrial Science in Japan, described a numerical and experimental study on turbulent diffusion fields in conventional flow type clean rooms. Good agreement between measured and simulated conditions were obtained and it was concluded that numerical techniques provide a useful method of comprehending flow and diffusion patterns.

J.H. Eto discussed the HVAC costs of increased fresh air ventilation rates in office buildings. It concentrated on the changes in annual energy operating costs and in equipment sizing that would result from increasing minimum ventilation rates from 2.5 L/s to 5.0 L/s and 10.0 L/s. By using DOE-2 building energy analysis program to calculate hourly heating and cooling loads, it was concluded that a fourfold increase in minimum ventilation rates would result in a maximum increase in annual energy costs of only 5%. The primary reason for this, it was argued, was because HVAC end uses represent only a fraction of the total energy costs for modern buildings.

J.W. Linton from the National Research Council, Canada presented a paper on the economics, testing and evaluation of an exhaust air heat pump. Its performance was compared with that of an air to air heat recovery system and a balanced ventilation system without heat recovery. An exhaust air heat pump with nonfrosting evaporator was found to provide excellent performance over a wide range of outdoor temperatures. The coefficient of performance (including the use of a 1 kW resistance heater at low temperatures – 10° and 2.4 at –25°C.

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A Major New Public

Air Exchange Rate and Airtigh – an Applic

Peter S. Ch
Senior Sci

The provision of an adequate supply of outdoor air suitable for the needs of the occupants is an important aspect of building design and construction. Ventilation (the transport of air into, through and out of a building) can be promoted by natural or artificial forces. It is necessary to understand this process since it affects both the energy consumption and internal environment of a building. Excessive ventilation will place an undue burden on the building's heating system and may lead to energy wastage, or an unacceptable thermal climate within the building. Insufficient ventilation can cause problems relating to the quality of the air within the building. The internal environment can become uncomfortable or, in extreme cases, harmful to the building occupants.

Bulk movement of air into and out of a building, whether it is promoted by natural or artificial forces, causes air to flow between the various internal spaces of the building. This exchange of air between internal spaces is of particular importance in relation to the movement of airborne contaminants and moisture from one part of the building to another. An illustration of this would be the effect of air flow between occupied spaces in a dwelling and the cold, unheated roof space above. Here warm moist air could be carried from the living areas and cause condensation problems on the cold internal surfaces of the roof space. Air flow patterns within the structure cannot be ignored when considering the ventilation behaviour of buildings.

Ventilation of buildings is an important and complex process, which is influenced by a variety of constructional, behavioural and environmental parameters. It is because of these complexities that ventilation is often regarded as one of the least understood aspects of building physics. In recent years the development of several specialised measurement techniques, has enabled the ventilation behaviour of a wide variety of buildings to be quantified. Now techniques are available which enable the flow rate of air into a building, under normal environmental conditions, to be evaluated. Measurement methods also exist which allow the air exchange rate between the internal spaces of a building to be quantified. Evaluation of the overall airtightness of the building envelope has become routine and, in some countries, mandatory. The location and distribution of air leakage sites can be determined, and the air leakage characteristics of specific building components or leakage paths can be evaluated.

Measurement techniques are the fundamental means of acquiring a greater understanding of air infiltration and ventilation, in that they enable primary data to be obtained from existing buildings. In recognition of the importance of these practical methods, the AIVC has produced a document which examines many of the measurement techniques used in air infiltration and ventilation studies. The broad aims of the guide are to identify the parameters which require evaluating, indicate the variety of measurement techniques which are available, provide detailed information about several techniques, and offer advice regarding the selection of a technique for a particular application.

Techniques for measuring the following parameters are examined in this applications guide:

Air Change Rate

The amount of air which enters and leaves a building is of fundamental importance in air infiltration and ventilation studies. One means of quantifying this movement is to state the air change rate of a building. This is a measure of the bulk movement of air into and out of a space and is defined as the volumetric rate at which air enters (or leaves) a space divided by the volume of the space. Often the air change rate is expressed in air changes per hour. One air change per hour means that the total volume of air passing through an enclosed space in one hour is equal to the volume of that space.

Internal Air Exchange Rate

The bulk movement of air into and out of a building causes air to flow between the various internal spaces of that building. This variable internal air movement plays a vital role in the distribution of internally generated pollutants throughout the ventilated space.

Air Leakage Characteristics

Air change rate and interzonal air flows are parameters which are themselves dependent upon a variety of variable influencing factors. A second basic approach in air infiltration and ventilation studies is to try to negate the influence of these variable factors and evaluate the air leakage characteristics of the building fabric only. In order to characterize the leakage performance of the building completely it is necessary to determine quantitatively the relationship between the air flow through, and the pressure differential across, the leakage paths. The building envelope can be examined in its entirety or, if more detail is required, relationships for individual building components or leakage paths can be developed.

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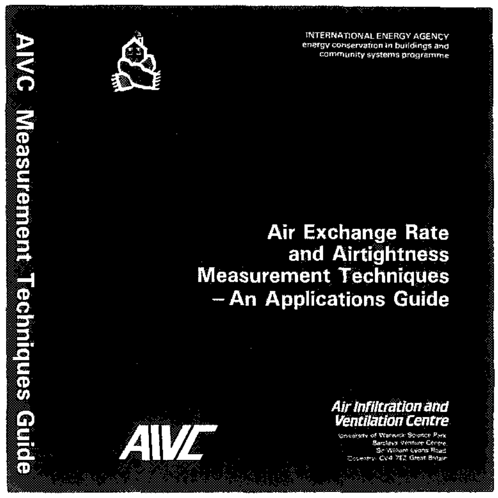

The intention of the AIVC Applications Guide is to increase general awareness of air exchange rate and airtightness measurement techniques and their application. By providing the fundamental theory and practice of making measurements and detailed information about several techniques it is hoped to meet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

Research and Academic

For people who already have experience of measurement technology the guide will act as a directory of current techniques, promote discussion about measurement techniques, and stimulate the development of improved measurement methods.

Specialist Consultants

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

Non-specialist Consultants

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

The guide has been designed so that the material suited to any user's particular area of interest or current level of expertise, is readily accessible. By examining the flow chart given in Figure 1 (this figure appears at the beginning of the guide) readers can determine which parts of the document will be appropriate to their requirements. The guide is produced in a loose leaf format thus enabling fresh developments in measurement technology to be readily accommodated.

The introduction to the guide provides a general overview of infiltration and ventilation in buildings. Ventilation studies are discussed and the aims of the guide outlined.

The Guide is then presented in seven chapters.

Chapter One defines the parameters which are important (these parameters have already been discussed in this article) and presents the reasons why they should be measured. The main applications of measurement techniques are discussed. A series of flow charts is presented, which provide the reader with a step by step guide to choosing a measurement technique for a particular application.

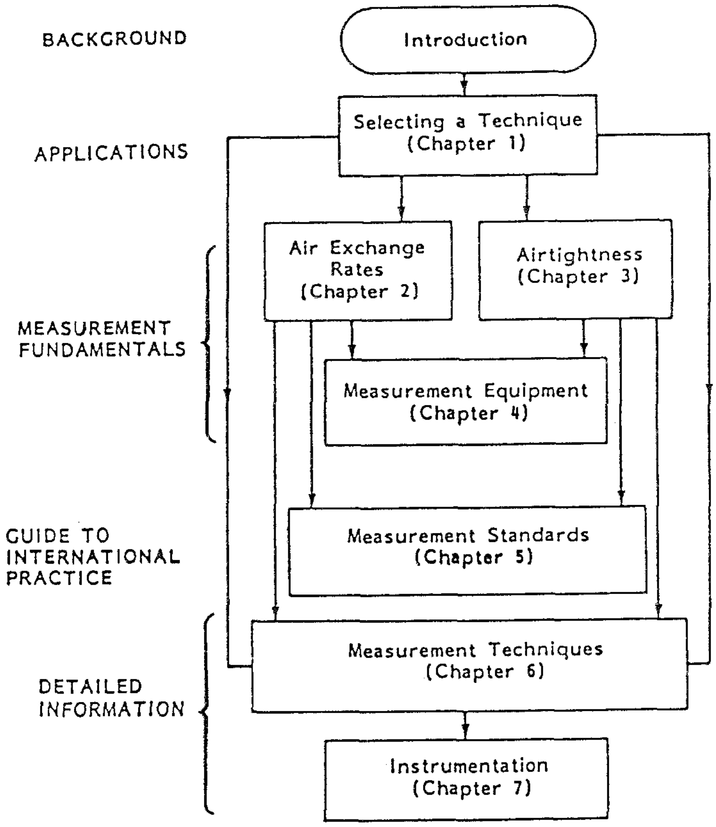

Figure 1 Structure of Guide

Chapter Two deals with the measurement of air exchange rates. Air exchange between a building and the external environment is examined, as is the air exchange between the various internal spaces of a building. These air exchange rates are most often evaluated using tracer gas methods, and the fundamental theory and practice of several tracer gas methods are presented.

Chapter Three is concerned with the measurement of building airtightness. The airtightness of the whole building envelope is considered, as is the airtightness of building components and individual leakage paths. Evaluation of the air leakage characteristics of a structure usually consists of superimposing a known artificial pressure difference across the envelope or component and measuring the flow rate through it. The fundamental theory and practice of several airtightness measurement techniques is presented.

Chapter Four discusses some of the specialist equipment and instrumentation required to make air infiltration and ventilation measurements. Specific topics include: tracer gases, tracer gas analysers, and commercial pressurization equipment (blower doors).

Chapter Five examines standards and regulatory documents which relate to air exchange rate and airtightness measurement techniques. Summaries of 11 standards are presented (four dealing with air change rate measurement and seven dealing with airtightness measurement) and standards dealing with similar techniques are compared.

Chapter Six currently contains detailed descriptions of nine measurement techniques. Because the guide is presented in a loose leaf format updates of current techniques or information about new techniques can be easily added. Information about each technique is presented in a standard format thus aiding comparison and selection. The information in the standard format is presented in the following main sections: type of technique, range of application, equipment and instrumentation, setting up and operating details, presentation of results, measurement accuracy, and availability of measurement systems.

The guide currently contains detailed descriptions of the following techniques:

Tracer Gas Decay Rate – Site Analysis

Tracer Gas Decay Rate – Grab Sampling (Bottles)

Tracer Gas Decay Rate – Grab Sampling (Detector Tubes)

Tracer Gas Constant Emission Rate – Passive Sampling

Tracer Gas Constant Concentration

Multiple Tracer Gas Decay Rate

DC Pressurization – External Fan

DC Pressurization – Internal Fan

AC Pressurization

Chapter Seven contains descriptions of instruments which have been used in making some types of air exchange rate or airtightness measurements. The descriptions are presented in a standard format and topics such as measurement method, precision, response time, input requirements and possible applications are addressed.

Appendix One provides a glossary of terms used in the guide relating to air exchange and airtightness measurement techniques.

Copies of this guide are currently available (to organisations in participating countries only) free-of-charge, through your national Steering Group Representative (see back cover of this newsletter).

AC Pressurisation Model Tests

Helen Sutcliffe and J.R. Waters
Coventry Polytechnic,
Coventry, United Kingdom

Introduction

Leakage area measurement by fan pressurisation becomes more difficult as the volume of a building is increased. The equipment becomes bulky, and measurements of air flow through the fan and the resulting pressure differential require more care. AC pressurisation offers an attractive alternative. However, in the case of large industrial buildings, the exterior envelope is often constructed of thin flexible sheet material, and also industrial leakage paths may have a much larger area than is found in, say, typical domestic construction. Thus the inertance effect described by Card et al (1) and the flexing constant described by Sherman (2) may be particularly important. In order to explore these problems, tests are being carried out on a laboratory model. This note reports the results of the first sets of measurements.

The Model

The model consists of a simple box, 1.6 x 1.0 x 0.6 m in size, constructed in 9 mm thick plywood of surface mass 0.58 kg/m^2. The edges of the plywood panels are reinforced with timber battens, and all joints are sealed. This alternating air flow is generated by a piston of 25 mm diameter and adjustable stroke introduced through a hole in the side of the box, and driven by a variable speed electric motor. This arrangement ensures that the volume displacement of the air in the box is accurately known. The resulting pressure signal is measured by means of 25 mm diameter condenser microphones, one placed inside the box, and one placed outside to monitor background noise. The usable frequency range is 4 Hz to 25 Hz, which is above the low frequency cut-off of the measuring system, but well below the lowest resonant frequencies of the box. The leakage is introduced by means of a rectangular opening cut in one of the plywood panels. The size of the opening can be varied from 20 x 14 mm up to 40 x 456 mm. Figure 1 is a photograph of the equipment.

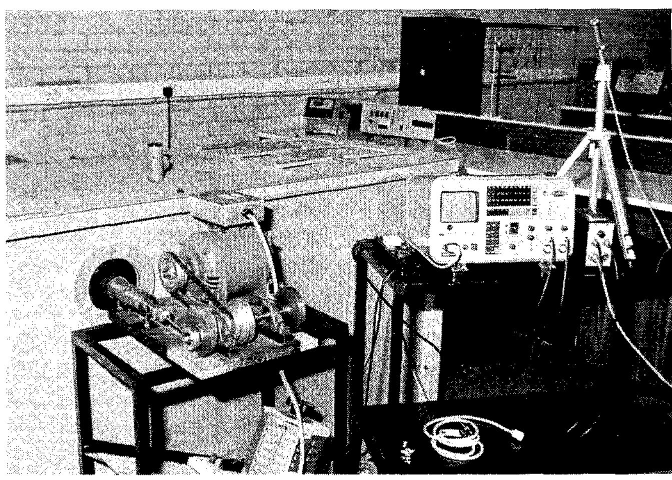

Figure 1: AC pressurisation model test equipment

Theory

In the steady state, the flow of air, Q, through a leakage path is usually written in the form

$$Q = Kp^n \qquad (1)$$

where K is the effective leakage area, p is the static pressure difference, and the index n is in the range $0.5 \leq n \leq 1$. For the alternating case when the flow is sinusoidally driven and p is the resulting pressure amplitude, the frequency response solution for $n = 1$ (the so-called linear case) may be written (ref. 1 and 2) as

$$p = \frac{V_s \omega}{[K_2 + (\omega C)^2]^{1/2}} \qquad (2)$$

where ω is the angular frequency, V_s is the amplitude of the applied volume displacement and C is the capacitance of the air volume in the enclosure. In the absence of flexing, C may be shown to be

$$C = \frac{V}{\gamma P} \qquad (3)$$

where γ is the ratio of the specific heats of air, P is atmospheric pressure, and V the geometric volume of the enclosure. If there is significant flexing of the walls, ref. 2 shows that a flexing constant, λ must be added to the capacitance.

$$C = \frac{V}{\gamma P} + \lambda \qquad (4)$$

The asymptotes of equation 2 are

$$p \rightarrow \frac{V_s \omega}{K} \text{ as } \omega \rightarrow 0 \qquad (5)$$

$$p \rightarrow \frac{V_s}{C} \text{ as } \omega \rightarrow \infty \qquad (6)$$

The asymptotes intersect at the break point frequency, ω_b, which is clearly given by

$$\omega_b = \frac{K}{C} \qquad (7)$$

If the response is linear, therefore, it should be possible to find the leakage area by observing the break point frequency. For the non-linear case when $n < 1$, an analytical solution for the frequency response is not available. Ref. 1 suggests that a good approximation is given by

$$p = \frac{V_s}{C} \frac{(\omega/\omega_2)^{1/n}}{[1 + (\omega/\omega_2)^{2/n}]^{1/2}} \qquad (8)$$

$$\text{where} \quad \omega_2 = \frac{K}{C^n V_s^{1-n}}$$

The high frequency asymptote is unchanged but the low frequency asymptote becomes

$$p \rightarrow \left(\frac{V_s = \omega}{K}\right)^{1/n} \text{ as } \omega \rightarrow 0 \qquad (9)$$

It follows that the breakpoint frequency is now equal to ω_2.

Finally, the acceleration of the air mass in the leakage opening gives rise to an inertance effect, L. For the linear case only, where there is a single leakage path, ref. 1 shows that the response function becomes

$$p = \omega V_s \left[\frac{R^2 + \omega^2 L^2}{(1 - \omega^2 LC)^2 + \omega^2 R^2 C^2}\right]^{1/2} \qquad (10)$$

where $R = 1/K$. Equation 10 has the same asymptotes as equation 2. In order to include inertance effects in the non-linear case, its is necessary to construct a frequency response which combines equations 8 and 10. A possible equation is

$$P = \frac{V_s}{C} \left[\frac{(\omega/\omega_2)^{2/n} + \omega^4 L^2 C^2}{(1 - \omega^2 LC)^2 + (\omega/\omega_2)^{2/n}}\right]^{1/2}$$

This has the same asymptotes as equation 8. It also reduces to equation 8 when $L = 0$, and to equation 10 when $n = 1$.

Figure 2 illustrates the effect of progressive improvements to the theory. Using the values of V_s and V for the model, and $K = 1000\ mm^2$, Figure 2 shows (a) linear response with $L = 0$, $\lambda = 0$, (b) non-linear response with $n = 0.5$, $L = 0$, $\lambda = 0$, (c) non-linear response plus inertance with $n = 0.5$, $L = 30$, $\lambda = 0$, and (d) non-linear response plus inertance and flexing, with $n = 0.5$, $L = 30$, and $\lambda = 1.5 \times 10^{-s}$.

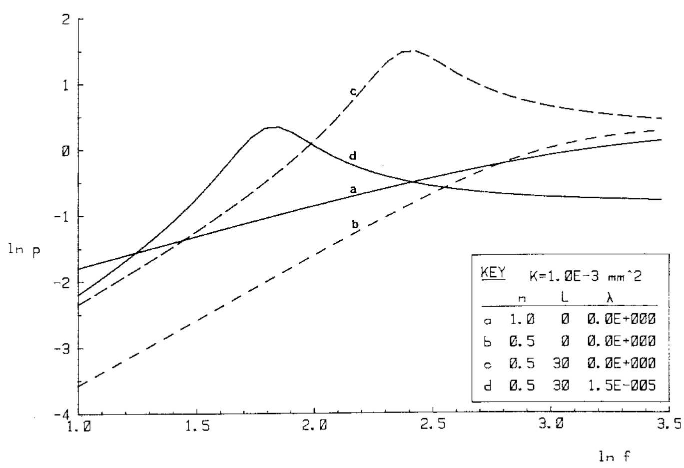

Figure 2: The effect of inertance and flexing on the frequency response curves

Measurements and Results

For all measurements reported here, the amplitude, V_s of the applied volume displacement due to the piston was 9.8 x $10^{-6}m^3$. For each leakage area, measurements were made at seven frequencies spaced at one-third octave intervals from 4 Hz to 16 Hz. From the measured sound pressure level, the amplitude of the alternating pressure was calculated. Results are shown in Figure 3, in which the natural logarithm of the pressure amplitude, p, is plotted against the natural logarithm of the frequency, f. Each point on the graph is the average of at least three independent measurements. Also shown is the expected high frequency asymptote in the absence of flexing effects (i.e with $\lambda = 0$).

Comparison of Figures 2 and 3 suggests that the experimental results are strongly influenced by both inertance and flexing effects. Furthermore the gradient at low frequencies indicates that the index n is considerably less than 1. It therefore appears necessary to use equation 11 to find a suitable fit to the experimental data.

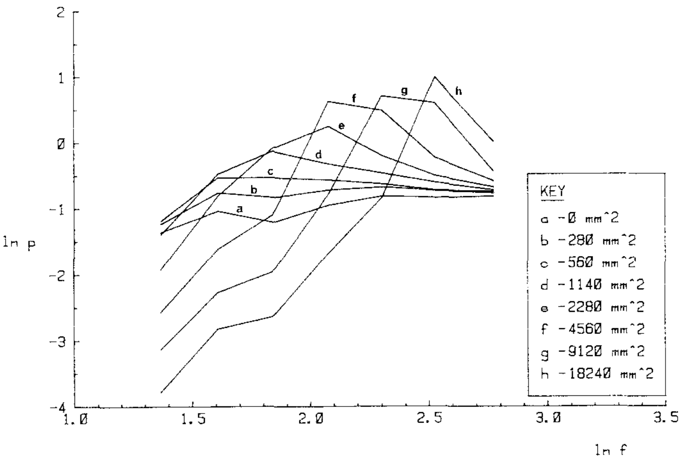

Figure 3: Measured frequency response curves for different leakage areas

The capacitance, C, was found from the high frequency asymptote. This gave a value of 2.19 x 10^{-5} m^5/N. Taking γ as 1.4, and atmospheric pressure as 10^5 N/m^2, the capacitance due to the volume of the enclosure only was 0.69 x 10^{-5} m^5/N. The difference gives the value of the flexing constant, i.e. λ = 1.50 x 10^{-5} m^5/N. Thus, in this particular enclosure the flexing constant was more than double the pure volumetric capacitance.

In the low frequency region, the experimental plots in Figure 3 have a gradient of about 5, implying that the index n is about 0.2. The steepness of the gradient is probably due to the experimental points being too close to the peak, so that the low frequency asymptote has not been reached. A value of n below 0.5 seems unlikely, and therefore it has been assumed that n = 0.5 is the most appropriate value here.

Using n = 0.5 and C = 2.19 x 10^{-5} throughout, and then adjusting the values of K and L, it was possible to obtain a reasonably good fit of equation 11 to the data for each leakage area. In doing so, it was noted that adjustments to L affected the position of the peak more than its height, whereas adjustments to K affected the height of the peak rather than its position. Table 1 lists the values of K and L which give the best fit, and Figure 4 plots four of these cases with their experimental points.

Table 1: Experimentally determined effective leakage area and inertance

	Geometrical leakage area A, mm²	Effective leakage area K	Effective inertance L	Discharge coefficient K/A
a	0	–	–	–
b	280	250	0	0.89
c	560	500	35	0.89
d	1140	750	30	0.66
e	2280	1250	22	0.55
f	4560	2000	15	0.44
g	9120	3000	9	0.33
h	18240	5000	6	0.27

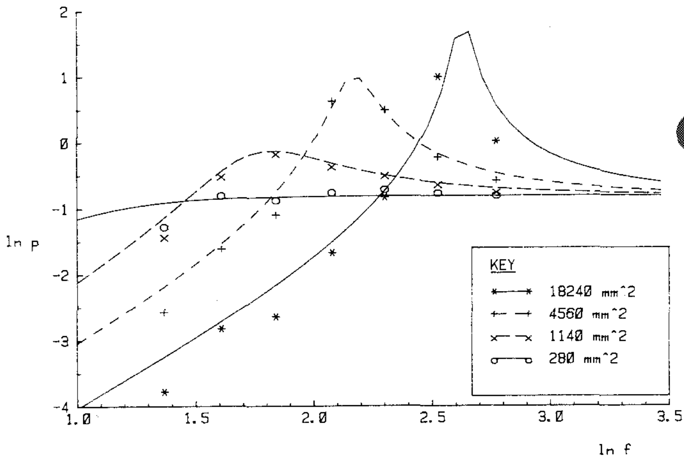

Figure 4: Comparison of measurements with lines of best fit

It is interesting to compare the values obtained for K in Table 1 with the geometrical leakage areas. Since n = 0.5, equation 1 is identical to the formula for flow through a circular orifice, providing K = C_dA where A is the geometrical area of the opening, and C_d is the discharge coefficient. Typically, for an orifice plate, C_d is 0.65. The final column in Table 1 shows values of K/A, and it may be observed that this ratio, which is similar to a discharge coefficient, ranges between 0.27 and 0.89, with the smaller values corresponding to the larger leakage areas.

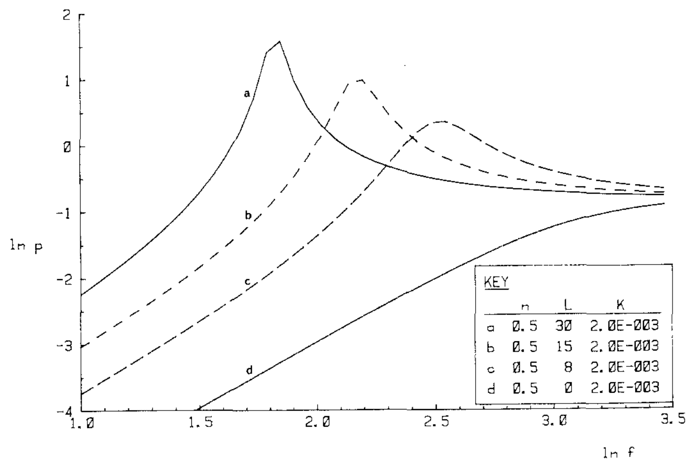

Figure 5: Effect of inertance

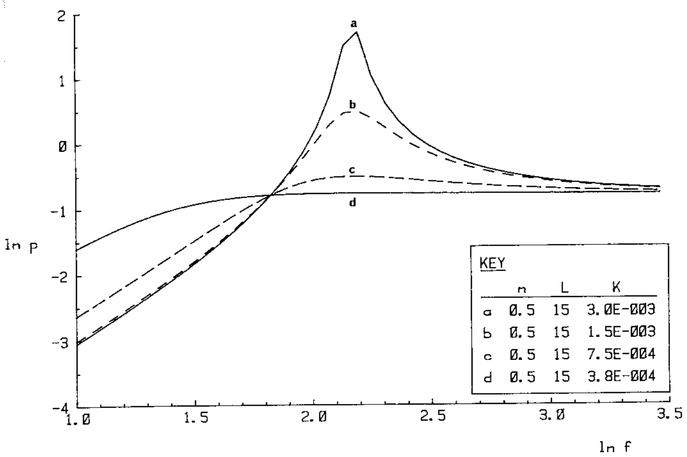

Figure 6: Effect on leakage area

Conclusions

The results show that flexing and inertance effects can have a substantial influence on the measured frequency curve.

Nevertheless, Table 1 shows that an estimate of the effective leakage area can still be obtained even though flexing and inertance are present. However, the agreement between the theoretical and experimental results is more sensitive to the choice of the value of inertance, L, than it is to the choice of leakage area, K. This is shown in Figures 5 and 6, which show the effect of varying L with K held constant, and then the effect of varying K with L held constant. Thus, it is likely that the effective leakage area determined in this way is subject to a large margin of uncertainty.

References

1. W.H. Card, A. Sallman, R.W. Graham and E.E. Drucker. 'Air leakage measurement of buildings by an infrasonic method'. Technical Report TR-78-1, Department of Electrical and Computer Engineering, Syracuse University, New York, January 1978.

2. M.H. Sherman, D.T. Grimsrud and R.C. Sonderegger. 'The low pressure leakage function of a building'. Proc ASHRAE/DOE Conference 'Thermal performance of the exterior envelopes of buildings'. Florida, 1979.

Book Reviews

Residential Building Design and Construction Workbook Second Edition.

By J.D. Ned Nisson. Cutter Information Corp, USA, 1988

The workbook grew out of a nationwide series of seminars sponsored by Energy Design Update Magazine. Conducted by the editor, J.D. Ned Nisson and Canadian builder Oliver Drerup, the seminar series and workbook were created to provide the practicing field professional with a working manual of construction techniques and background information that would be of immediate practical use.

The nine sections of the workbook cover:

1. Introduction: background and benefits of superinsulation.

2. Energy dynamics: heat loss and airtightness.

3. Moisture control: moisture diffusion, air/vapour barriers.

4. Walls: framing and insulation techniques.

5. Roofs and ceilings: trusses and insulation techniques.

6. Foundations: heat loss, materials, design types, insulation.

7. Windows: r-valves, window frames, glass types, shading devices, insulation.

8. Ventilation and indoor air quality: mechanical ventilation systems.

9. Heating and cooling: comfort, health, energy-efficiency.

In addition there are four appendices covering: insulation materials; glass and window manufacturers; air and vapour sealing products; and sources.

The book explains the theory and provides examples of how these theories are actually put to use to design and build high-quality, energy-efficient houses. It is written in non-technical language and includes hundreds of photographs, charts, graphs, and diagrams to make the information accessible and immediately useful to the readers, regardless of background or technical training.

Copies may be obtained from:

Cutter Information Corp.
1100 Massachusetts Avenue
Arlington, MA 02174
USA
Telephone: (617) 648-8700
Telex: 650 100 9891 MCI UW

Residential Ventilation: Achieving Indoor Air Quality

By Richard Kadulski.
A Solplan Review Handbook
Drawing Room Graphics Services, USA, 1988.

The publication discusses home ventilation systems which meet occupants' air quality needs with an emphasis on health and safety. The design of functional, practical ventilation systems which deliver fresh air are described. Principles of home ventilation and suggestions for compliance with new building codes are also presented. It is written in a matter of fact, accessible style which is suitable for ordinary householders as well as for builders, designers and others professionally interested in this important field.

Divided into eight informative chapters, the book leads us through an explanation of indoor air quality, and its problems, listing and describing a variety of common pollutants, then goes on to describe source control, the principles of ventilation systems design, the various types of ventilation system and code requirements, including a comparison of those of Canada with selected other countries. Finally there is a ventilation system design checklist for the householder, followed by equipment descriptions and a list of equipment manufacturers. A glossary of terms completes this informative introduction to the subject.

Copies may be obtained from:

The Drawing-Room Graphic Services Ltd
Box 866267,
North Vancouver, B.C.
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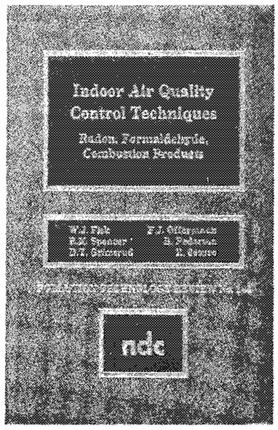
Indoor Air Quality Control Techniques: Radon, Formaldehyde, Combustion Products

By W.J. Fisk, R.K. Spencer, D.T. Grimsrud, F.J. Offerman, B. Pedersen, R. Sextro
Building Ventilation and Indoor Air Quality Group
Lawrence Berkeley Laboratory
University of California
Berkeley, California

Published by: Noyes Data Corporation, USA, 1987

This book reviews and evaluates existing indoor air quality control techniques. The indoor air pollutants of most concern are radon, formaldehyde, and certain combustion products – nitrogen dioxide, carbon monoxide, carbon dioxide, and various respirable particles. Many techniques exist to control the concentrations of these pollutants and other indoor pollutants that are only now being recognized as significant. The purpose of the book is to provide a current review and evaluation of these control techniques.



Environmental concern for air pollution has been largely focussed on questions of outdoor air contamination. Recently, attention has begun to shift to concerns about the quality of air within buildings. In the United States today, people spend only 10 to 15% of their time outdoors; the rest is spent at home, at work, or travelling in between. Yet existing air quality regulations are based on outdoor conditions, specifically on large scale, highly visible, outdoor air pollution sources, such as industrial effluents and vehicle exhaust. Buildings were assumed to shelter occupants from outdoor pollutants, and little thought was given to pollutants generated or trapped indoors. Recent studies have shown that concentrations of certain pollutants indoors exceed standards often correlated with exposure over time, it is clear that air quality indoors requires more attention than it has yet received. As an emerging health problem, contamination of indoor air has been linked with a wide variety of building materials and consumer products, as well as strategies that reduce the amount of infiltrating air as a means of promoting energy conservation.

Two main factors govern the concentration of any given pollutant indoors: the source strength of the pollutant and its removal rate. Buildings have various sources of indoor air pollution. People (and their pets) generate carbon dioxide, moisture, odours, and microbes simply through normal biological processes. Other more important potential sources of indoor air pollution are combustion appliances, building materials, tobacco, and the soil under and around the structure.

Effective and efficient control of indoor pollutant concentration depends upon an understanding of the chemical and physical properties of the sources of the individual pollutants being considered. Failure to understand these factors may lead to the use of a control technique that exacerbates rather than reduces an indoor air quality problem or that does not solve the problem in an efficient manner. Coupled with the need to improve our understanding of sources is the continuing need to understand the health effects of indoor pollutants. A control strategy that holds the concentration of a pollutant below 1 ppm may be adequate for one pollutant but totally inadequate for another. Thus the development and evaluation of indoor air quality control techniques must be performed in parallel with research on pollutant source characterization and health effects. The book provides an overview of current knowledge in this vital area, and should be extremely helpful to those involved in this problem.

Copies may be obtained from:

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AIVC-TN-24-88
AIVC Measurement Techniques Workshop
Proceedings and Bibliography

This document presents the proceedings of the AIVC's International Measurement Techniques Workshop held in Køge, Denmark on 21 – 23 March 1988. It contains the full text of the eight papers presented together with a record of the ensuing discussion. Topics include measurement techniques standards, air inlet performance, advanced fan pressurization techniques and newly developed tracer gas methods. The second section contains a bibliography of air exchange rate and airtightness measurement techniques. This consists of 61 abstracts selected from the AIVC's bibliographic database AIRBASE. This new bibliography is available as a separate literature list.

AIVC Literature List Update No. 13 Air Infiltration Measurement Techniques

A new literature list published to coincide with new AIVC publications: 'Measurement Techniques Guide' and 'Measurement Techniques Workshop Proceedings'

Forthcoming Conferences

1. Ventilation '88
20–23 September 1988
London
Great Britain

Further details from:

British Occupational Hygiene Society
1 St. Andrew's Place
Regent's Park
London NAW1 4LB
Great Britain
Tel: 01-486 4860

2. Combustion Processes and Indoor Environment
27–29 September 1988
Niagara Falls
New York, USA

Further details from:

APCA
PO Box 2861
Pittsburgh
PA 15230, USA
Tel: 412/232-3444

3. Housing for the 90's
29 November – 3 December 1988
Sheraton Tacoma Hotel
Tacoma, Washington

Further details from:

Patricia Anderson
Conference Coordinater
Energy Business Association
420 Maritime Building
911 Western Avenue
Seattle
WA 98104, USA
Tel: (206) 622 7171

4. Building Systems: Room Air and Air Contaminant Distribution
5–8 December 1988

Further details from:

Leslie L. Christianson
University of Illinois at Urbana-Champaign
Department of Agricultural Engineering
1304 West Pennsylvania Avenue
Urbana
Illinois 61801, USA
Tel: (217) 333 8220

5. Symposium on Air Change Rate and
Air Tightness in Buildings
17–18 April 1989
Atlanta, Georgia
USA

Further details from:

ASTM Publications Division
1916 Race Street
Philadelphia
PA 19103, USA

6. IAQ 89: The Human Equation:
Health and Comfort
17–20 April 1989
San Diego
California, USA

Further details from:

Jim Norman
Manager of Technical Services
ASHRAE, 1791 Tullie Circle
N E Atlanta
GA 30329, USA

7. CLIMA 2000, Second World Congress on Heating, Ventilation, Refrigeration and Air Conditioning
28 August – 1 September 1989
Sarajevo
Yugoslavia

Further details from:

Branislav Todorovic
CLIMA 2000/KGH
Knez Mihailova 7/II
11000 Belgrade
Yugoslavia

or:

Emil Kulic
CLIMA 2000, Masinski fakultet
Omladinsko setaliste bb
71000 Sarajevo
Yugoslavia

8. XXI International Symposium
Heat and Mass Transfer in Building Material
and Structure
4–8 September 1989
Hotel Libertas
Dubrovnik
Yugoslavia

Symposium sessions are as follows:

1. Advances in instrumentation and measurement techniques for thermal resistance, heat flow, and moisture transfer in materials and structure.
2. Basement, foundation and earth heat and mass transfer.
3. Insulation, vapour barriers, radiant barriers, and ventilation control of heat transfer and moisture damage in attics and roof structures.
4. Dynamic heat storage effects of thermal mass in building materials.
5. Thermal assessment techniques for window frames, insulation bridges, and other thermal anomalies.
6. Analysis and control of heat transfer and daylighting by windows, skylights, and sunspaces.
7. Moisture transfer in building structures.
8. Convective air motion and its effect on infiltration and heat flow in building material and structure.
9. Whole building energy calculation techniques.
10. Computer simulation of the thermal performance of buildings and envelope components.

Abstracts should be sent to:

Prof. Jack B. Chaddock
School of Engineering
Duke University
Durham
North Carolina 27705
USA
Tel: (919) 684 2098
Telex: 802829 Duktelcom Durm

One copy should be sent to:

Secretary General Prof. N. Afgan
International Centre for Heat and Mass Transfer
PO Box 552
11001 Belgrade
Yugoslavia

Deadlines:

Extended Abstracts: 20 January 1989
Announcement of Acceptance: 1 March 1989
Full Papers: 1 April 1989

9. Thermal Performance of the Exterior
Envelopes of Buildings IV
4–7 December 1989
Crowne Plaza Hotel
Orlando, Florida

Further details from:

George E. Courville
Building Thermal Envelope Systems and Materials
Oak Ridge National Laboratory
PO Box 2008
Oak Ridge
TN 37831-6022, USA

AIVC Publications List

PERIODICALS

Air Infiltration Review
Quarterly newsletter containing topical and informative articles on air infiltration research and application. Also gives details of forthcoming conferences, recent acquisitions to *AIRBASE* and new AIVC publications. *Unrestricted availability, free-of-charge.*

Recent Additions to *AIRBASE*
Quarterly bulletin of abstracts added to *AIRBASE*, AIVC's bibliographic database. Provides an effective means of keeping up-to-date with published material on air infiltration and associated subjects. Copies of papers abstracted in 'Recent Additions to *AIRBASE*' can be obtained from AIVC library. *Bulletin and copies of papers available free-of-charge to participating countries* only.*

GUIDES AND HANDBOOKS

AIC-AG-1-86 – Liddament, M.W.
'Air Infiltration Calculation Techniques – An Applications Guide'
A loose-leaf handbook divided into six chapters covering empirical and theoretical calculation techniques, algorithms, references and glossary of terms. *Available free-of-charge to participating countries* only, via your national Steering Group representative.*

AIC-AG-2-88 – Charlesworth, P.S.
'Air Exchange Rate and Airtightness Measurement Techniques – An Application Guide'
A loose-leaf handbook divided into seven chapters covering air change rate, interzonal air flow and building airtightness measurement techniques.

TECHNICAL NOTES

AIC-TN-5-81 – Allen, C.
'AIRGLOSS: Air Infiltration Glossary (English edition)'
Contains approximately 750 terms and their definitions related to air infiltration, its description, detection, measurement, modelling and prevention as well as to the environment and relevant physical processes. *Available free-of-charge to participating countries.* Price: £10 to non-participating countries.*

AIC-TN-5.1-83, AIC-TN-5.2-84, AIC-TN-5.3-84, AIC-TN-5.4-88 – Allen, C.
'AIRGLOSS': Air Infiltration Glossaries (German, French, Italian and Dutch) Supplements.

AIC-TN-6-81 – Allen, C.
'Reporting format for the measurement of air infiltration in buildings'
Produced to provide a common method for research workers to set out experimental data, so assisting abstraction for subsequent analysis or mathematical model development. May be used directly for entering results and as a useful checklist for those initiating projects. Example of use of format is included as an appendix. *Available free-of-charge to participating countries.* Price: £6 to non-participating countries.*

AIC-TN-10-83 – Liddament, M., Thompson, C.
'Techniques and instrumentation for the measurement of air infiltration in buildings – a brief review and annotated bibliography'
Four-section bibliography contains review papers, information on tracer gas techniques, pressurization methods and miscellaneous approaches. In addition the report contains a list of manufacturers of instrumentation currently being used in air infiltration investigations. *Available free-of-charge to participating countries.* Price: £15.00 to non-participating countries.*

AIC-TN-11-83 – Liddament, M., Allen, C.
'The validation and comparison of mathematical models of air infiltration'
Contains analysis of ten models developed in five participating countries. These range in complexity from 'single-cell' to 'multi-cell' approaches. Also contains numerical and climatic data for fourteen dwellings compiled to produce three key datasets which were used in model validation study. *Available free-of-charge to participating countries.* Price: £15.00 to non-participating countries.*

AIC-TN-13-84 – Allen, C.
'Wind Pressure Data Requirements for Air Infiltration Calculations'
An up-to-date review of the problems associated with satisfying the wind pressure data requirements of air infiltration models. *Available free-of-charge to participating countries.* Price: £20.00 (price includes copy of TN-13.1) to non-participating countries.*

AIC-TN-13.1-84
'1984 Wind Pressure Workshop Proceedings'
Report of written contributions and discussion at Workshop held in March 1984, Brussels. *Available free-of-charge to participating countries.* Also available to non-participating countries (see note at TN-13 above).*

AIC-TN-14-84 – Thompson, C.
'A Review of Building Airtightness and Ventilation Standards'
Lists and summarises airtightness and related standards to achieve energy efficient ventilation. *Available free-of-charge to participating countries* only.*

AIC-TN-16-85 – Allen, C.
'Leakage Distribution in Buildings'
Examines those factors which can influence leakage distribution, including building style, construction quality, materials, ageing, pressure and variations in humidity. *Available free-of-charge to participating countries.* Price: £20.00 to non-participating countries.*

AIC-TN-17-85 – Parfitt, Y.
'Ventilation Strategy – A Selected Bibliography'
Review of literature on choice of ventilation strategy for residential, industrial and other buildings. *Available free-of-charge to participating countries.* Price: £20.00 to non-participating countries.*

AIC-TN-19-86 – Charlesworth, P.
'1986 Survey of current research into air infiltration and related air quality problems in buildings'
Fourth worldwide survey by AIVC containing over 200 replies from 19 countries. Produced in two sections: an analysis in tabular form of survey results, followed by reproduction in full of research summaries and list of names and addresses of principal researchers. *Available free-of-charge to particpating countries* only.*

AIC-TN-20-87
'Airborne moisture transfer: New Zealand workshop proceedings and bibliographic review'
Proceedings of AIVC's Moisture Workshop, held at BRANZ New Zealand in March 1987, with bibliographic review. *Available free-of-charge to participating countries* only.*

AIC-TN-21-87 – Liddament, M.W.
'A review and bibliography of ventilation effectiveness – definitions, measurement, design and calculation'
Reviews definitions of ventilation efficiency and outlines physical concepts, measurement methods and calculation techniques. Includes bibliographic and list of author affiliations. *Available free-of-charge to participating countries* only.*

AIC-TN-22-87 – Blacknell, J.
'A subject analysis of the AIVC's bibliographic database – AIRBASE', 5th edition
Comprehensive register of published information on air infiltration and associated subjects. The articles are indexed, and full bibliographic details of the 2,600 documents are given. Also includes the AIRBASE Thesaurus, as well as a list of principal authors.
Available free of charge to participating countries only.*

AIC-TN-23-88 – Dubrul, C.
'Inhabitants' behaviour with regard to ventilation'
This report summarises the IEA annex VIII study into the behaviour of occupants with regard to ventilation. It assesses the extent to which the actions of occupants can be modified in order to minimise energy use yet maintain adequate indoor air quality. Chapters cover observational techniques, energy loss due to window opening, reasons for window opening and the resultant energy savings from modified use of windows. *Price: £15.00 to participating countries, £25.00 to non-participating countries.*

AIC-TN-24-88
'AIVC Measurement Techniques Workshop: Proceedings and Bibliography'
Workshop held at Køge, Denmark in March 1988. Available free-of-charge to participating countries* only.

LITERATURE LISTS – Listing of abstracts in *AIRBASE* on particular topics related to air infiltration.

- No. 1 Pressurization – Infiltration Correlation: 1. Models (17 references).
- No. 2 Pressurization – Infiltration Correlation: 2. Measurements (26 references).
- No. 3 Weatherstripping windows and doors (30 references) - updated.
- No. 4 Caulks and sealants (30 references) - updated.
- No. 5 Domestic air-to-air heat exchangers (25 references).
- No. 6 Air infiltration in industrial buildings (51 references) - updated.
- No. 7 Air flow through building entrances (22 references).
- No. 8 Air infiltration in commercial buildings (28 references).
- No. 9 Air infiltration in public buildings (10 references).
- No. 10 Humidity- Carbon Dioxide- and Demand Controlled-Ventilation (32 references).
- No. 11 Occupancy effects on air infiltration (15 references).
- No. 12 Windbreaks and shelter belts (30 references) - updated.
- No. 13 Air infiltration measurement techniques (27 references).
- No. 14 Roofs and attics (34 references).
- No. 15 Identification of air leakage paths (23 references).

Available free-of-charge to participating countries only.*

CONFERENCE PROCEEDINGS

- No. 1 'Instrumentation and measuring techniques'. £35.00 sterling.
- No. 2 'Building design for minimum air infiltration'. Price: £15.00 sterling.
- No. 3 'Energy efficient domestic ventilation systems for achieving acceptable indoor air quality'. Price: £23.50 sterling.
- No. 4 'Air infiltration reduction in existing buildings'. Price: £16.00 sterling.
- No. 5 'The implementation and effectiveness of air infiltration standards in buildings'. Price: £22.00 sterling.
- No. 6 'Ventilation strategies and measurement techniques'. Price: £16.00 sterling.
- No. 7 'Occupant interaction with ventilation systems'. Price: £25.00 sterling.
- No. 8 'Ventilation technology - research and application'. Price: £25.00 sterling.

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