AIVC

AUSTRALIA

An apparatus for AIR-TIGHTNESS MEASUREMENTS on houses

D. MICHELL - K.L. BIGGS

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
DIVISION OF BUILDING RESEARCH

AN APPARATUS FOR AIR-TIGHTNESS MEASUREMENTS ON HOUSES

by

D. Michell and K.L. Biggs

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION OF BUILDING RESEARCH

CSIRO
Division of Building Research
P.O. Box 56
Highett, Victoria, 3190
AUSTRALIA

ISBN 0 643 03018 2

Printed by BUILDRESEARCH Melbourne

AN APPARATUS FOR AIR-TIGHTNESS MEASUREMENTS ON HOUSES

by

D. Michell and K.L. Biggs

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION OF BUILDING RESEARCH

AN APPARATUS FOR AIR-TIGHTNESS MEASUREMENTS ON HOUSES

SUMMARY

An apparatus for measuring the air-tightness of houses is described. It consists of a quick-release door panel, a steel duct containing an electric axial fan and a system of Pitot tubes for measuring the mean air-flow, a variable auto-transformer for adjusting the speed of the fan, two differential micromanometers, a digital thermometer and a two-pen chart recorder.

The test procedures and processing of data are explained.

INTRODUCTION

Air infiltration through cracks, crevices and ventilators in the building envelope plays a significant role in the heating requirements of Australian homes.

Many workers (Blomsterberg and Harrje 1979; Kronvall 1978; Beach 1979; Orr and Figley 1980; Shaw and Tamura 1980; DOE/ASHRAE 1979) have characterized the 'air-tightness' of a building by measuring the air-flows required to establish known pressure differences across the building envelope in the range 0 to ± 60 Pa.

It is customary to determine from the measurements the air-flow at a specified pressure difference (usually 10 or 50 Pa) and to divide this by either the surface area or the volume of the envelope and to use the values thus obtained as parameters which specify the air-tightness of the building.

The apparatus described in this report was constructed at the CSIRO Division of Building Research to enable the measurement of air-flows in both the suction and the pressure modes and the determination of the air-tightness parameters for Australian houses. The apparatus is similar to that used overseas but with a fan selected to give the rather larger output required for Australian houses.

DESCRIPTION OF APPARATUS

The schematic arrangement of the apparatus is shown in Figure 1, and the actual equipment being used to make measurements on a typical house is shown in Figure 2. It consists of a quick-release door panel, a steel duct approximately 4500 mm long and 308 mm in diameter within which is mounted an electric axial fan, and a system of static and Pitot tubes. An auto-transformer for adjusting the speed of the fan, two differential micromanometers, two temperature sensors and a two-pen chart recorder complete the equipment.

The adjustable door panel, details of which are shown in Figure 3, is inserted and clamped within the doorway by means of spring-loaded top and side pieces. A lever-operated cam system enables the quick release of the spring pressure to facilitate installation and removal of the panel without deleterious effects to the door frame. A 10 x 30 mm rubber seal inserted in a groove around the edges of the door panel provides some air sealing and this is supplemented by further sealing of the panel to the door frame with masking tape.

The steel duct of Figure 1 consists of two galvanized steel tubes, each 1800 mm long, and two shorter sections, each approximately 300 mm long. One of these shorter sections contains the axial fan and motor and the other a system of four static-pressure tubes and four Pitot tubes arranged to form a 3/4 radius meter (Ower and Pankhurst 1966). The sections have end flanges and are held together with eight bolts around the periphery of the flanges. The complete assembly is reversible and may be bolted to the door panel so that air is either blown into, or drawn out of, the house. The assembly may be unbolted to form two equally long sections for ease of handling and to facilitate carrying on a car roof rack.

The fan is a 'GEC WOODS' small variable-pitch aerofoil fan, type J, 305 mm in diameter, with a rated output of up to 4500 m^3/h at 125 Pa. The fan assembly weighs approximately 9.5 kg and the complete duct assembly 36 kg. The fan motor is an induction motor rated at 900 W, 240V and 50 Hz. Satisfactory variation of the output of the fan is obtained by varying the applied voltage to the motor by means of a variable auto-transformer (Variac).

The quantity of air flowing through the duct is obtained by multiplying the mean velocity of the air through the duct by the cross-sectional area of the duct. This velocity is determined from the difference in pressure between the static-pressure tubes and the total-head Pitot tubes as measured by a Furness model MDC differential micromanometer.

The difference in pressure between the inside and the outside of the building envelope is determined with a second Furness Model MDC differential micromanometer connected to two pressure tubes, one passing through the door panel to a region within the house remote from the exit of the duct, and the other tube to a region outside the house sheltered from the duct and prevailing winds.

Internal and external temperatures are measured with an Analog Devices temperature sensor, type AD 590, coupled to recommended circuitry (Analog Devices 1979) to give a direct reading in degrees Celsius.

Atmospheric pressure values are determined from Meteorological Bureau data for the particular time and day.

A portable motor-generator unit (1500 W, 240V, 50 Hz) is used when measurements are made in new houses not connected to an electricity supply.

TEST PROCEDURE

The house is prepared for testing by installing the door panel in a suitable external door opening and assembling the duct work and measuring equipment as in Figure 1. Within the house, chimneys and vents on heating appliances are sealed off as are the ceiling ventilators in laundries, bathrooms and kitchens. Wall ventilators are not sealed. All internal doors are open during the tests with the exception of toilet doors, which are closed. All windows are closed and all plumbing water traps either filled with water or taped over. This is the standard procedure adopted by many workers in this field and facilitates comparison of results.

It is usual to establish a positive pressure difference between the inside and the outside of the building envelope for the first series of measurements. Measurements are made of air-flow for five pressure differences in the attainable pressure range. The maximum pressure difference may be as much as 100 Pa but as low as 25 Pa, depending on the type of construction. The whole of the duct assembly is then reversed and a second series of measurements made for negative pressure differences. This procedure is adopted since some apertures in the building envelope may be sensitive to the sign of the pressure difference. The mean values of air-flow for positive and negative pressure differences will compensate to a large extent for this behaviour.

Measurements are made only on days of negligible wind, since wind effects can produce significant variation in the pressure difference across the building envelope. Although an allowance may be made for the effect of light winds by sealing off the duct work and measuring the pressure difference across the building envelope before and after the induced pressure difference measurements are made and correcting the measured pressure differences by the mean of this wind pressure, the wind is seldom constant in velocity and even small gusting can make determinations very difficult. The outputs of the micromanometers are fed to a two-pen recorder and mean values of the pressure differences obtained from the traces.

For a single house, the total time required to assemble and disassemble the equipment, and to make the necessary measurements, is approximately two hours. Where a number of adjoining houses is being investigated, this time may be somewhat less.

CALCULATIONS OF LEAKAGE PARAMETERS

It is usual to specify the permeability of a dwelling either as the 'air change rate' defined as the air leakage rate, at a stated pressure difference, divided by the volume enclosed by the building envelope ($m^3/m^3.h$), which corresponds to air changes per hour (a.c./h), or as the 'specific air leakage' defined as the air leakage rate, at a stated pressure difference, divided by the surface area of the building envelope ($m^3/m^2.h$).

Both these parameters require the determination of the flow rate at a specified pressure difference and the determination of the size of the building envelope from either measurements or the builder's plans.

The volume flow rate, Q (m^3/h), for each of the five induced pressure differences may be determined from the characteristics of a 3/4 radius meter and the measured velocity heads.

Thus, $Q = 3600\,vA$

where A is the cross-sectional area of the tube (m^2),
and v is the average air velocity in the tube (m/s)

$$\text{given by } v = \left[\frac{P_v}{0.5\rho} \times \frac{1013.25}{P} \times \frac{T}{273.2}\right]^{1/2} \text{ at NTP,}$$

where P_v is the difference in pressure measured between the static and total head tappings on the 3/4 radius meter (Pa),

ρ is the density of air (kg/m^3),
T is the temperature (K), and
P is the atmospheric pressure (mb).

For the apparatus described here

$$Q = 642 \left[\frac{P_v T}{P}\right]^{1/2}$$

An expression of the form $Q = C\,\Delta P^n$ describes well the relationship between the volume flow rate and the difference in pressure (ΔP) existing across the building envelope. The constants C and n may be determined by plotting the values of Q and ΔP on a log-log basis as shown in Figure 4, n being determined from the slope of the line of best fit and C from the intercept where $\Delta P = 1$, i.e. $\log \Delta P = 0$. Alternatively, C and n may be determined from a least squares fit of the data using a programmable calculator.

Knowing the values of C and n, Q may be calculated for any desired value of ΔP. In practice values of flow rate are calculated at pressure differences across the envelope of 10 and 50 Pa. The value of C is equal to the air-flow for a pressure difference of 1 Pa.

A program has been developed for a HP41C calculator which enables the rapid calculation of air-flow rates for the measured pressure differences, the values of n and C together with the correlation coefficient R^2, and the flow rates for pressure differences of 1, 10 and 50 Pa.

The volume of the house is taken as the volume between floor, ceiling, and boundary walls with deduction for those volumes such as water closets which are isolated, but with no deduction for internal walls and built-in fittings such as kitchen cupboards.

The surface area of the building envelope is taken to be the sum of the gross floor area, the gross ceiling area and the area of the outer walls between floor and ceiling. However, for houses in which the floor is a continuous concrete slab, the floor area is not included.

The format of a print-out of the results for a typical house is shown in Figure 5. This house had a volume of 280 m^3 and an envelope surface area of 354 m^2.

Thus at 10 Pa,
the 'air change rate' is 2558/280 = 9.1 m^3/m^3.h (or a.c./h)
and
the 'specific air leakage' is 2558/354 = 7.3 m^3/m^2.h.

At 50 Pa,
the 'air change rate' is 6671/280 = 23.8 m^3/m^3.h.
and
the 'specific air leakage' is 6671/354 = 18.8 m^3/m^2.h.

For convenience the values of air-flow given in Figure 5 are calculated to two decimal places, but it is believed that the overall accuracy of these flow rates is within ± 2 per cent.

Although it is difficult to directly relate this type of measurement with the rates of air infiltration measured by tracer gas methods, it is reasonable to assume that houses of similar design and similar air-tightness will exhibit similar rates of air infiltration.

The equipment described in this report has been used successfully in an investigation of the air-tightness characteristics of houses in the Melbourne and Sydney metropolitan areas. In some cases the capacity of the fan unit was insufficient to enable a difference in pressure of 50 Pa to be established across the building envelope. To obtain values of air-flow at 50 Pa pressure difference, it was necessary in these cases to extrapolate the plot of log Q versus log ΔP to 50 Pa or to calculate them from the derived values of C and n.

REFERENCES

Analog Devices (1979). Data Acquisition Products Catalog Supplement, p.89S.

Beach, R.K. (1979). Relative tightness of new housing in the Ottawa area. NRC Canada. Building Research Note No.149.

Blomsterberg, A., and Harrje, D.T.H. (1979). Evaluating air infiltration energy losses. ASHRAE Trans. 85 Part 1.

DOE/ASHRAE (1979). Conference on Thermal Performance of the Exterior Envelopes of Buildings, Orlando, Florida, December.

Kronvall, J. (1978). Testing of houses for air leakage using a pressure method. ASHRAE Trans. 84 Part 1.

Orr, H.W., and Figley, D.A. (1980). An exhaust fan apparatus for assessing the air leakage characteristics of houses. NRC Canada. Building Research Note No.156.

Ower & Pankhurst (1966). 'The Measurement of Air Flow'. p. 241. (Pergamon Press: Oxford.)

Shaw, C.Y., and Tamura, G.T. (1980). Air tightness and air infiltration measurements. NRC Canada. Building Research Note No.162.

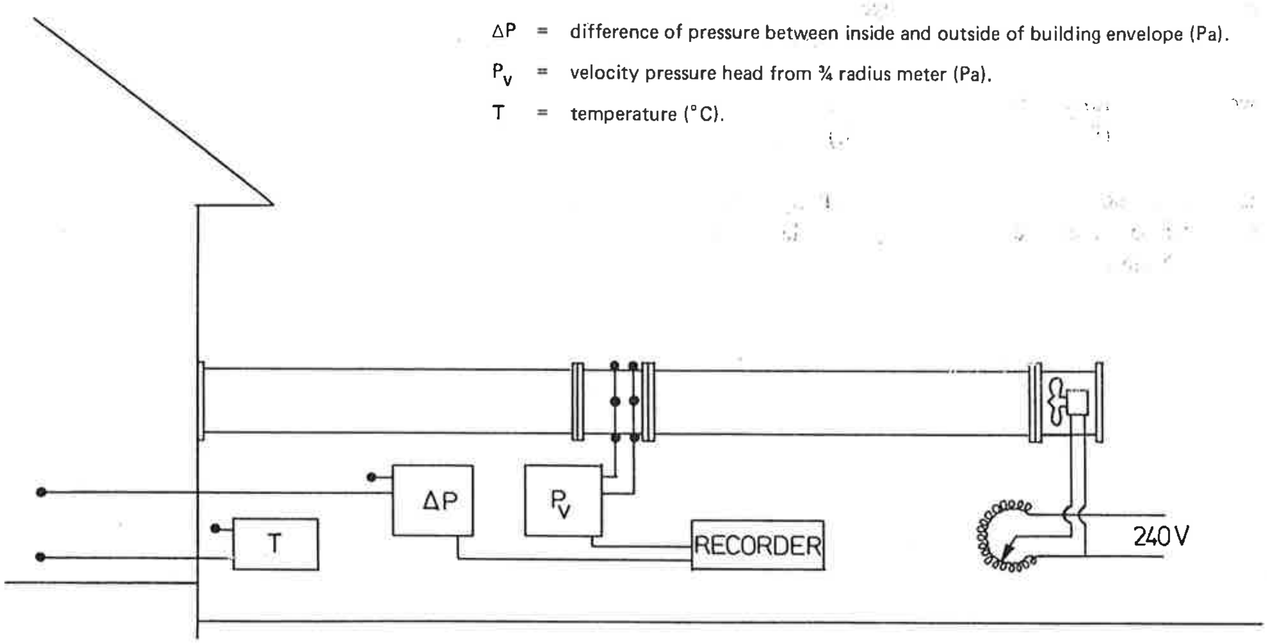

Figure 1. Schematic arrangement of apparatus used for air-tightness measurements on Australian houses.

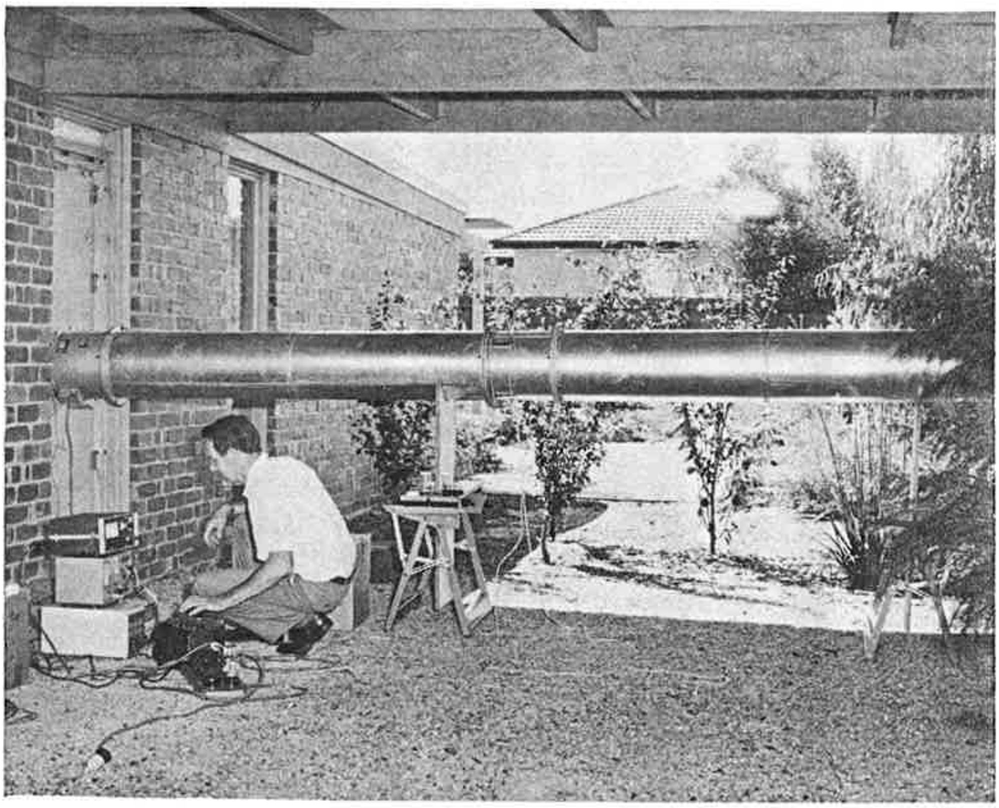

Figure 2. Equipment being used to make measurements on a typical house.

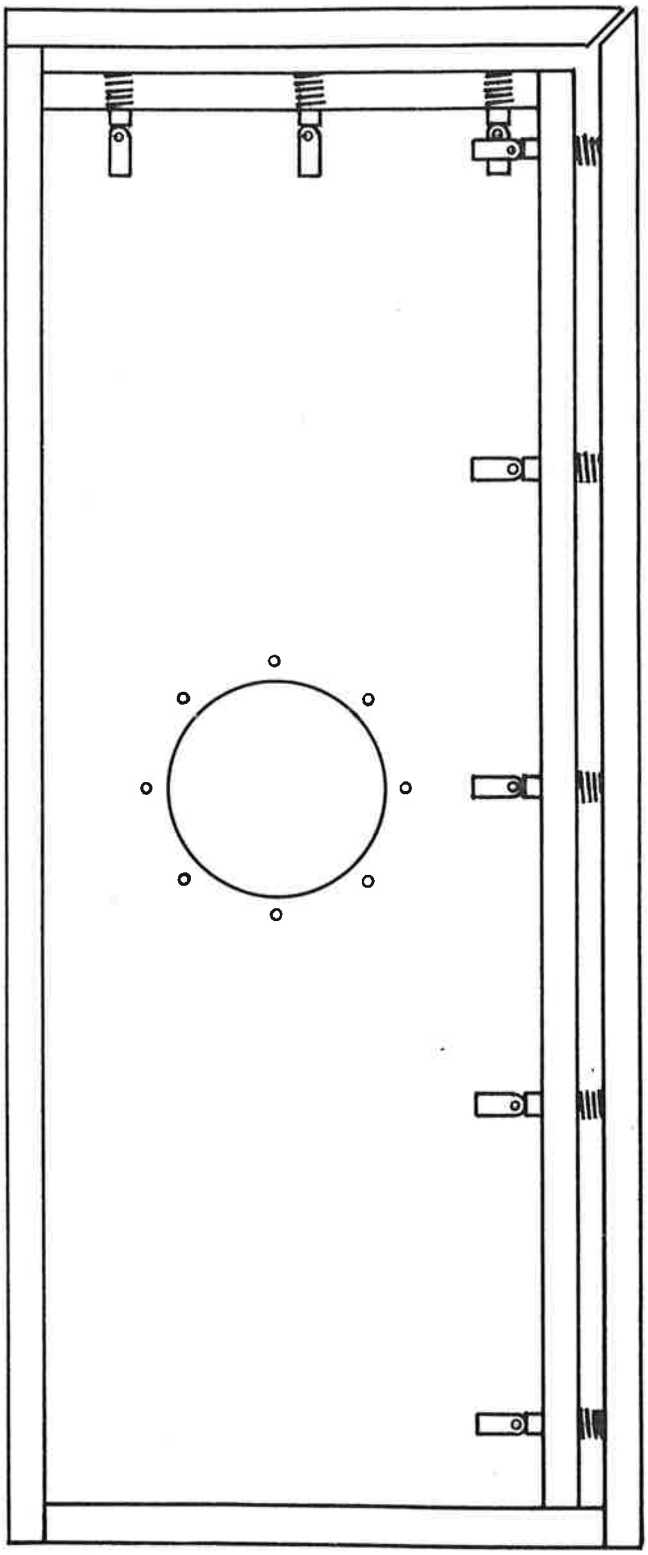

Figure 3. Adjustable door panel with spring-loaded top and side pieces.

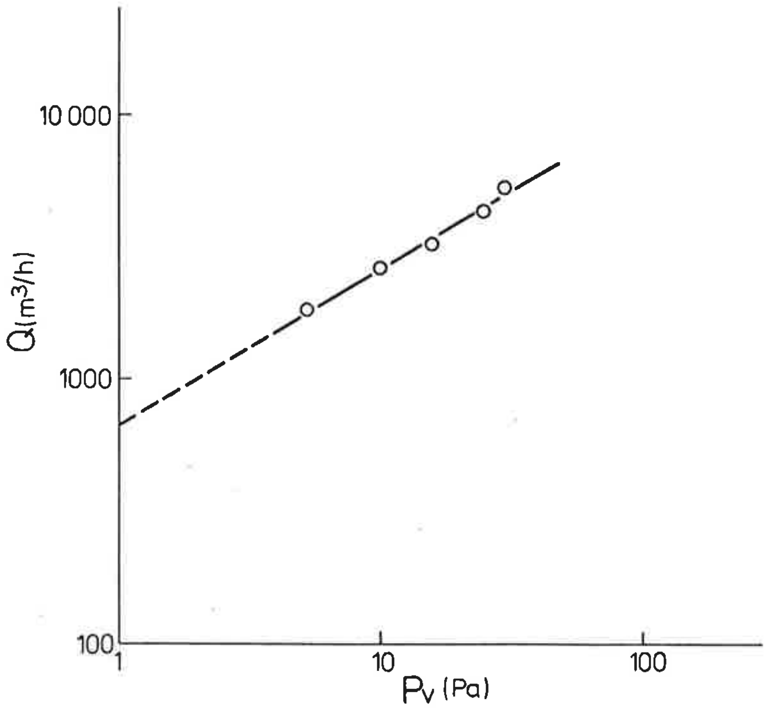

Figure 4. **Typical log-log plot of air-flow versus pressure difference across the building envelope.**

```
AIR TIGHTNESS NO. 8P

DATE 1.12.80

T <INT> DEG C = 28.50
T <EXT> DEG C = 31.00
AT PRES mb = 1,013.00

  ΔP                Q
31.00           5,168.14
25.20           4,427.24
16.20           3,330.86
10.20           2,507.38
 5.40           1,824.39

Q = C ΔP EXP N

C   = 649.03
N   =   0.60
R2  =   1.00
Q1  = 649.03    m³/h
Q10= 2,557.90 m³/h
Q50= 6,671.22 m³/h
```

Figure 5. **Format of print-out from HP41C programmable calculator.**