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BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

A FIELD STUDY OF NATURAL VENTILATION IN BETTER INSULATED HOUSES

FINAL REPORT

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CONTENTS

ABSTRACT

A significant fraction of energy used for heating domestic houses is lost through uncontrolled air filtration and ventilation. This infiltration depends on many factors including wind speed and the construction and design of the house. Another important aspect of determining actual ventilation ratesin houses is the occupant's behaviour in opening windows. The opening of windows by just a small amount can increase the air change rate several times. Unfortunately, this factor has been ignored in existing heat loss calculations for most cases.

Air leakage and tracer gas (SF_6) measurements were made in twenty-two better insulated houses. It was found that the leakage in the 'test' houses was on average 10% higher than that in the 'control' houses. About 40% of the total (average 21.3 ach) leakage rate at induced pressure difference of 50 Pascals flowed into houses through the floor boards and the air-bricks under the crawl spaces. The results of tracer gas measurement indicated that average leakage with closed windows lie in the range of 0.52 to 1.65 air changes per hour, with a mean value of 0.9. Opening a window by just a small gap can increase the number of air changes by a factor of 2 to 5.

The study also includes the possibility of correlating window-opening habits with its impact on ventilation rate. Window-opening observations established that there is a definite relationship between the outdoor air temperature and the number of open windows and 'test' house occupants open twice the number of windows compared to the 'control' house occupants in the heating season. As a result, theoretically, 'test' houses can consume 40% more energy than 'control' houses at $0^{o}C$. The three family factors which influence window opening behaviour are : whether the house is continuously occupied; the size of the family and the number of smokers in each family.

Nomenclature and Units

A	Area of opening (m^2)
Ach	Ventilation rate, in air change per hour
Cd	Discharge coefficient
P	Pressure (Pa)
ΔP	Pressure difference (Pa)
Q	Volume flow rate (m^3/s)
Q*	Predicted volume flow rate (m^3/s)
Q_{50}	Volume flow rate caused by induced pressure difference of 50 Pa (m^3/s)
R	Ventilation rate (air change/hour)
T_i	Indoor air temperature (^oC)
T_o	Outdoor air temperature (^oC)
U	Wind speed (m/s)
α	Flow coefficient
β	Flow exponent
ρ	Density of air (kg/m^3)

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PART A : AIR FILTRATION MEASUREMENT

A.1 Introduction

The energy required to maintain the interior of a house at a different temperature to that outdoor is largely determined by the amount of heat conduction together with the rate of natural ventilation through the exterior envelope.

While the former has received considerable attention, the latter has often accepted philosophically as a residual term, difficult to quantify. However, it can account for a third or more of the total heat loss in a highly insulated house.

In order to provide basic data on the air infiltration characteristics of better insulated houses in practice, a programme of air leakage and ventilation rate measurements were conducted in twenty-two houses, eight of which were found to be better insulated than others.

As the exterior wall elements of the standard and better insulated houses differ primarily in the insulation thickness, a comparison of the simultaneously obtained infiltration data should show whether or not there is a correlation between insulation and air tightness.

Tests were carried out over a period of two months (18 December 1981 to 19 February 1982) over a range of wind speed and direction, and air temperature. All the measurements were taken in occupied houses. Whenever possible, both air leakage and tracer gas measurements were conducted on the same day.

Attempts were made to obtain an unoccupied house for a longer period to enable a more detailed investigation over the influence of meteorological parameters on the magnitude of ventilation rates. This intention was abandoned because no unoccupied house was available.

A.2 Descriptions of test site and houses

The houses in this study are located at Kinneil Estate in Bo'ness, some twenty miles north west of Edinburgh, on the south shore of the Firth of Forth. The houses on the site are all orientated towards the N-E on a steep, north facing hillside. The site lies between 50 and 75 metres above sea level with a difference in height of some 25 metres between houses at the topand bottom of the site. The hill slope provides some shelter from the wind on the south side; otherwise the situation is exposed except for a few rows of terraced houses on the west side and trees on the east side of the slope. (See Fig. A1).

The site comprisesforty-two units of two-storey houses, with gross areas of approximately 100 m^2 but of three different house types built in 1977-78 as shown in Table A1 and Fig. A2. All houses are constructed of 250 mm thick no-fines concrete external walls cast in-situ, harled externally and dry lined internally. Roofs are covered with concrete interlocking tiles on timber trussed rafters. Ground floors are of timber joists supported on honeycomb brick sleeper walls with approximately 300 mm crawl space ventilated by air-bricks at one metre centres. First floors are of timber suspended floors supported on internal stud partitions. Both front and rear doors are timber framed with single glazing. Each house has ten timber framed windows - nine horizontally pivoted at the mid-points of the vertical sides and one louvered as listed in Table A2. Both external doors have a gap of approximately 8 mm between the door leaf and the floor.

All the houses were built to Scottish Special Housing Association (SSHA) standard detailings, and complying with the 1975 Building Standards (Scottish) Regulations. Nineteen of the total forty-two houses were better insulated than others in the roofs, walls and floors (for details, see [1]).

In this study, the better insulated houses are referred to as 'test' houses, and other as 'control' houses. In all other respects there are no visible differences between 'test' and 'control' houses.

A.3 Meteorological measurements

Outdoor air temperature, relative humidity, wind speed and direction and rainfall are monitored continuously with the weather station mounted at a height of approximately 4 metres above ground level on the roof of the garage. The weather station is a combined system which provides continuous output of the sensors onto inbuilt chart recorder; and a day's weather data can be visually obtained immediately from the chart. Total solar irradiance on the horizontal surface is measured by two pyrometers mounted near the weather station. Their outputs are recorded by an automatic potentiometer and registered directly on a paper chart.

A.4 Air leakage measurements

Ventilation takes place through intentional and fortuitous gaps in the house envelope. The actual ventilation rate at any time depends both on the leakiness of the house and on the weather.

Tracer procedures provide a measure of air leakage rates under more or less natural conditions. Where building tightness is of primary concern, apart from weather conditions, the most popular approach is to use a large fan to pressurise or depressurise thebuilding and then measure the volumetric flow of air caused by the fan. This approach can be applied to the entire house or on specific components.

A.4.1 Principle of pressurisation method

Houses of normal workmanship have numerous openings which permit outside air to penetrate the structure under the influence of wind stack effect. This leakage can be evaluated by deliberately applying a pressure difference between the house exterior and interior and noting the air flow.

The house is pressurised by a fan fitted to a substitute exterior door. The air flow Q through the fan is measured. At equilibrium, the air flow into the house through the fan equals the total air leakage out of the house. Using the formula for air flow through a sharp-edged orifice, the equivalent leakage area A, can be evaluated as below :

$$Q = C_d . A \left(\frac{2\Delta P}{\rho}\right)^{\frac{1}{2}} \quad \text{.... (A.1)}$$

By assuming coefficient of discharge as 0.60 and density of air as 1.25 kg/m^3.

$$Q = 0.76\ A \times \Delta P^{\frac{1}{2}} \quad \text{.... (A.2)}$$

Equation A.2 can only be applied when the sum of the area of the individual openings behave as sharp-edged orifices.

In practice, all ventilation openings (including windows and exterior doors) should be closed, and all interior doors should be kept opened to allow free air flow within the test space during the pressurisation tests. Under this condition, the most commonly used expression is of the form

$$Q = \alpha . A . \Delta P^{\beta} \quad \text{.... (A.3)}$$

A graph can be plotted of air flow against pressure difference to characterise the leakage of the building as it is at the time of test. The curve is generally of smooth 'S'-like form as shown in Fig. A.3.

Alternatively, air leakage characteristics of the test space can be determined by taking logarithm on both sides of equation A.4.

$$\log_e Q = \log_e (\alpha . A . \Delta P^{\beta})$$
$$= \log_e (\alpha . A) + \beta \log_e \Delta P$$

By rearranging

$$\log_e Q = \beta \log_e \Delta P + \log_e (\alpha . A) \quad .... \quad (A.5)$$

This can be compared to the straight line equation Y = mX + C. By plotting Q against ΔP on a log-log scale, the measurements should fall on a straight line whereby the slope is represented by the flow exponent β and its initial value is represented by (α.A) as shown in Fig. A.4.

A.4.2 Test equipment

The principal assembly consists of a flow measurement duct and a variable speed axial flow fan connected in series. A plywood dummy door is placed in an exterior doorway of the house to be tested. The fan unit and flow measurement duct are then mounted on either side of this dummy door. The original door of the house was left on its hinges. (See Figure A.5 and Plate 2). Gauze screens were placed across the inlet of the duct and outlet of the fan to achieve a sufficiently uniform air distribution so that a reliable flow can be obtained from a single measurement of air speed.

The air flow rate driven via the duct and fan was measured by means of a pitot-static tube which was fixed in alignment with the axis of the duct and connected to an inclined manometer. A pressure tap was installed in the dummy door to measure the pressure difference between the inside and outside of the house during testing.

A.4.3 Test procedure

In brief, whole house air leakage measurements were made by applying an uniformly positive or negative induced pressure difference across the envelope by using a large fan sealed into an external door frame. The total volume flow rate was then measured. The fan could be arranged both to pressurise and depressurise the house with respect to external air static pressure. All windows and external doors were kept closed and internal connecting doors kept opened throughout the test. The overall characteristics of the house envelope could therefore be determined by simultaneously measuring applied pressure and air flow rate.

In order to determine the flow coefficient α of a house, three additional tests were conducted. As above, the first test was conducted with windows closed and then one of the windows (kitchen) was opened by varying degrees in respective runs. Test conditions were as follows (see Plate 3) :

Condition 1 :	All windows tightly closed
Condition 2 :	One window opened at approximately 1° 30' (10 mm gap)
Condition 3 :	One window opened at approximately 6° (45 mm gap)
Condition 4 :	One window opened at approximately 17° (135 mm gap)

Entire house leakage measurements were made over a range of pressure difference up to 60 Pa. However, for the purpose of comparison with other published results, it is convenient to take the mean of the volume flow rates, that is 50 Pa, to represent the 'leakiness' of the envelope.

A.4.4 Test results

Measurements of whole house air leakage were taken with either positively or negatively induced pressurisation in twenty-two houses listed in Table A.3.

Houses 1, 6 and 11 were selected as 'reference houses' and were tested both by pressurisation and depressurisation methods. Results for pressurisation were plotted in the upper right-hand quadrant whilst depressurisation were plotted in the opposite quadrant as shown in Fig. A6 and Table A4. To compare these two techniques, average readings for pressurisation and depressurisation were presented in the same quadrant; an average curve was drawn as shown in Fig. A7. In Fig. A7, the pressurisation curve intersected the depressurisation curve at the pressure difference of 20 Pa. At this point of intersection, both techniques give the same rate of air leakage for the house. At pressure difference of 5o Pa, pressurisation reading show an over-estimate of 2.3%, whereas depressurisation show an under-estimate of 2.3% from the mean flow rate. All other readings at 50 Pa pressure difference were adjusted accordingly to obtain fair house to house comparisons.

For each set of results, the air leakage rate was plotted against pressure difference to characterise the air tightness of the house under the test conditions as shown in Fig. A8.

In order to find out those factors which may influence the magnitude of whole house leakage rate, a list of house to house comparisons has been drawn up in Table A5. Houses of similar parameters or test conditions were grouped together and average air leakage rates calculated. The calculated results of the different groups of houses were then compared.

Spot checks were carried out on two occasions (House 1 and House 41) to determine the air leakage rate through some of the components. A vane anenometer was hand-held to face the direction of air flow through the components and readings taken were shown in Table A6. A constant pressure difference of 50 Pa was kept in the test house during these spot checks.

The power law function ($Q = \alpha . A . P^{\beta}$) was fitted to each set of results and the mean values of effective leakage areas (α.A) and flow exponent β calculated (with programmable calculator) for each test house and the results are shown in Table A7. The flow coefficient α was found by using calibrated leaks, i.e. tests conducted with various known area of window gaps in every respective run. (Complete set of α and β analysis is given in Appendix A). Fig A9 and Table A8 show the flow versus pressure difference curves for house 6 for the four conditions :

a) Background leakage areas only. (A m^2)
b) Background + 2 x 1.00 mm x 0.01 m gap (A + 0.02 m^2)
c) Background + 2 x 1.00 mm x 0.045 m gap (A + 0.09 m^2)
d) Background + 2 x 1.00 mm x 0.135 m gap (A + 0.27 m^2)

These curves satisfy respectively :

a) $Q = 203.96 \times \Delta P^{0.779}$ $\therefore (\alpha . A) = 203.957$ ··· (1a)
b) $Q = 247.47 \times \Delta P^{0.773}$ $\therefore (\alpha . A + 0.02) = 247.468$ ··· (2a)
c) $Q = 436.09 \times \Delta P^{0.735}$ $\therefore (\alpha . A + 0.09) = 436.089$ ··· (3a)
d) $Q = 847.30 \times \Delta P^{0.682}$ $\therefore (\alpha . A + 0.27) = 847.295$ ··· (4a)

Solving by simultaneous equations :

Equations 1a & 2a : $\alpha = 2175.55$
2a & 3a $\alpha = 2694.59$
3a & 4a $\alpha = 2284.48$
4a & 1a $\alpha = 2382.73$

Given a mean value of $\alpha_{av.} = 2384.34$

The equivalent leakage area (A) is determined by :

$$A = \frac{\alpha . A}{\alpha_{av}} = \frac{203.957}{2384.34} = 0.0855 \ m^2$$

We now obtained the power law equation for the House 6 :

$$Q = 2384.34\ A \times \Delta P^{0.779} \qquad (m^3/hour)$$

or

$$Q = 0.662\ A \times \Delta P^{0.779} \qquad (m^3/sec.)$$

A.4.5 Analysis of results

The general shape of the air leakage characteristics of the house was found to be of a smooth S-like curve when overall pressure measurements were made over a range of pressure differences from about -60 to +60 Pa. However, for the purposes of comparison with other results, it was convenient to takethe mean of the volume flow rates at +50 Pa and -50 Pa to represent the 'leakiness' of the envelope. Houses where only one of the two tests, namely, pressurisation and depressurisation, were conducted, a mean of generalising the results was necessary. Little difference was found for results obtained from both techniques for the pressure regime below 20 Pa pressure difference. As the pressure difference increased, the differences became more significant. An average value 4.6% higher was found for tests conducted using pressurisation rather than depressurisation methods at a pressure difference at 50 Pa. It was, therefore, on this basis that a reduction of 2.3% was made to all Q_{50} using pressurisation measurements and an addition of 2.3% to all Q_{50} using depressurisation measurements.

Houses of the three different plan layouts show little difference in wholehouse leakage rates under the test conditions (see Table A.5a). The exposed surface area of external walls was found to have an effect on the air tightness of the house as shown in Table A.5b. Detached houses which have four exposed surfaces revealed higher air leakage as compared to end-terraced houses (three exposed surfaces) and mid-terraced houses (two exposed surfaces). At first glance, 'control' houses i.e. the less well insulated houses, appear to be 'tighter' than 'test' houses. As six out of eight 'test' houses compared to seven out of fourteen 'control' houses which were included in this survey were detached houses, no significance in their air-tightness can be established.

Table A5d shows that houses with weather-stripping applied to their doors and windows were not more than 10% 'tighter' than houses without weather-stripping. This magnitude clearly illustrates that infiltration/exfiltration through these components can only account for a minor proportion of the whole house leakage rate.

Beside other possible sources of leakage, spot examination showed that a great proportion of air flowed into houses through the floor boards and the ventilation under the crawl space. This leakage source was found to account for between 25% of total air leakage for mid-terraced houses to 40% for detached houses as shown in Tables A5e and A6.

The effect of wind speed on air leakage rate is shown in Table A5f. Although there was a positive proportional relationship between wind speed and air leakage rate, the effect of wind direction relative to the orientation of the house and its openings could account for some of these differences. Unfortunately, an adequate study of any of these variables could not be conducted on the test houses because of their occupants.

The relationship between the flow rate through an opening and an applied pressure difference depends upon two parameters, namely Reynolds Number and the geometry of the opening. The situation becomes more complicated as the number and type of flow paths of different areas are acting together as in thecase of the leaky house subjected to an induced pressure difference. It is generally convenient to express the air leakage characteristic of a house by power law function of the form $Q = \alpha.A.\Delta P^{\beta}$. By using power regression analysis, the effective leakage area (α.A) and flow exponent β were empirically determined for each set of results as list in Table A7. The average flow coefficient $\alpha_{av.}$, was then calculated by simultaneous equations as shown in a previous section.

A new parameter is now introduced to characterise the leakage of a structure - the equivalent leakage area (A). The role of this parameter in predicting energy loss due to infiltration is analogous to the role of thermal resistance in determining conduction heat loss. The leakage rate of a house is proportional to the equivalent leakage area as shown in Fig. A10 also shows that when the wind speed is higher than 2.0 m/s, the values begin to scatter and increasingly moves away from the predicted line as the wind speed increases.

The average value of α_{av}, β_{av} and A for all results obtained from pressurisation and depressurisation tests respectively are presented in Table A9. All results were then aggregated into an equation which neutralised both pressurisation and depressurisation. The generalised equation takes the form of,

$$Q^* = 2600\ A \times \Delta P^{0.73} \qquad \text{... (A.6)}$$

In all cases, the flow exponent β should lie between 0.5 for flows which were independent of viscosity and 1.0 for flows which were dominated by viscosity. For any given range of applied pressure, the smaller the cross-stream dimension of the opening, the closer β will approach to 1.0. This effect is shown in Fig. A.11.

Fig. A.12 shows the measured whole house leakage rates at 50 Pa pressure difference, Q_{50}, compared with the predicted values, Q_{P50}. These results were considered rather encouraging, as some of the differences were mainly due to the effect of wind speed.

Fig. A13 shows the distribution of the mean volume flow rate for houses in this study, expressed in air changes per hour. Published results obtained in U.K. and other countries [4] indicated that varying levels of efforts were put in to obtain higher standards of air-tightness in dwellings. (See Table A10 for details).

A.5 Tracer gas measurements

Measurements were made of whole house ventilation rates using the exponential decay rate technique. Each measurement was conducted immediately after the pressurisation test in the individual occupied house. Every effort was made to avoid any inconvenience to occupants. One measurement was allowed for each window opening condition as shown in Plate 3 during this short duration.

A.5.1 Tracer equipment

Test apparatus consists of a cylinder of SF_6 gas, a portable SF_6 detector chromagraph, an X-Y recorder and an electrical fan as shown in Plate 4. The detailed description of the test apparatus and its calibration were given in an earlier report [2].

A.5.2 Test procedure

The tests were conducted with an electron capture detector using sulphure hexafluoride (SF_6) as a tracer gas. The concentration of such tracer gas can be detected in the range of 5 to 65 ppb. The tracer gas detector was situated in the downstairs hall. All windows were kept closed and all internal connecting doors kept opened. Tracer gas was introduced into the room, and distributed evenly throughout the house by means of an electric fan. Concentration of the tracer gas was continuously monitored over similar time intervals. The decay rate of the tracer gas was then used to determine the instantaneous air filtration rate under natural conditions. The tests were conducted first with windows closed and then one of the windows opened by varying degrees in every respective run.

A.5.3 Test results

The rate of tracer concentration decay method gives a single result which is an estimate of the rate of change of air in the enclosure assuming perfect mixing. The air change rate is the ratio of the volume of air which enters (or leaves) the enclosure to the volume of the enclosure. A typical result for the decay of tracer concentration is shown in Fig. A14.

The results of the ventilation rate measurements for twenty houses, together with meteorological data during the tests are tabulated in Table A.11. As these houses were constructed by similar techniques and of similar materials, built by the same contractor and at the same time period, it is therefore reasonable to assume that their ventilation characteristics are quite similar.

In general, wind speed was found to be the dominant variable and the ventilation rate for each house was fitted to wind speed as shown in Fig. A15. Table A12 shows the enormous increase in ventilation rates resulting from the two parameters of opening of a window and wind speed influence.

A.5.4 Analysis of results

One should remember that these measurements are not intended to be representative but merely serve to indicate the general magnitude and range of whole house ventilation rates found in better insulated houses in practice. The mean ventilation rate was found to be 1.0 ach for fourteen houses, the remaining being rejected because their tests were carried out under wind speeds exceeding 4.0 m/s. It is of interest to compare these results with test results carried out by BRE [3] on 26 houses which yielded a mean ventilation rate of 0.7 ach.

Although there was a fairly good correlation between the ventilation rate and wind speed, as shown in Fig. A15, a large number of factors could have influenced the resultant ventilation rate. These factors include wind direction and turbulence, orientation of the houses, interior air chamber effects and indoor-outdoor temperature differences. So far, available data from this study are too few to yield a definitive correlation of ventilation rate in terms of the above variables.

With the exception of two points, the data are reasonably well correlated for each house type in terms of wind speed alone. It can be fairly well expressed in terms of the following equations :

For 'control' houses,

$$R = 0.401 + 0.351\,U \qquad \ldots \qquad (A.7)$$

For 'test' houses,

$$R = 0.558 + 0.318\ U \qquad \ldots \quad (A.8)$$

where R = Air change per hour
U = Wind speed (m/s)

The difference in leakiness for 'control' and 'test' houses of virtually identical design could arise for a number of different reasons. Two possible contributing explanations are :

a) 'test' housesin this study comprised a higher proportion of detached houses which have a greater exposed surface area compared to 'control' houses.

b) most of the 'test' houses in this study were not weather-stripped around the doors and windows.

The results of ventilation rate measurement showed that opening a window by just a small amount can increase the number of air changes per hour by a factor of 2 to 5, as shown in Table A12 & Fig. A16.

A.6 Comparison of pressurisation and tracer gas measurements

Tracer gas methods of measuring are generally complex and time-consuming but it can provide a direct estimate of natural ventilation rate under the test conditions. The instrumentation is expensive and requires skill to operate it. Unfortunately, although pressurisation techniques are simpler, they do not give the true air change rate of the building under natural (small irregularly distributed and fluctuating pressure differences) conditions.

The whole house leakage is a global characteristic and as such would not be a good basis for ventilation prediction because no indication of the locations of communications of the measured leakage is given. For example, two houses with the same measured leakage, one of which has all the open area on external walls and the other dividing the area between floor and ceiling, would conceivably have quite different ventilation characteristics even if sited side by side.

The usefulness of the pressurisation test would be considerably enhanced if it can be demonstrated that the natural ventilation rate of a house can be related to leakage characteristics. The measurements, using both types of equipment, conducted in twenty houses were reduced to equivalent leakage areas and ventilation rates and then compared as shown in Fig. A17. The correlation is not good enough to draw any conclusions mainly because of the influence of strong winds during the tests.

Fig. A18 shows a scatter plot of the whole house ventilation rate against air leakage rate at 50 Pa pressure difference. It indicated that wind speed plays a more predominant role one tracer gas ventilation rate greater than on air leakage rate. However, there appears to be no useable relationship between leakage rate and ventilation rate. Long-term experiments (to eliminate the effect of weather) could perhaps determine any useful relationship between these two characteristics.

A further complexity in relating leakage and ventilation is the apparent variation with time of the whole leakage. As well as a possible seasonal variation, there appears to be considerable changes in a building as it settles and ages from its 'new' state [4].

A.7 Conclusions

a) Air leakage and tracer gas (SF_6) measurements were conducted in twenty-two houses. It was found that the leakage in the 'test' houses was about 10% higher than that in the 'control' houses. The probable reason for the higher air leakage in 'test' houses could be attributed in part at least to the higher proportion of detached houses that took part in this study.

b) Little difference was found in the results obtained from both pressurisation and depressurisation techniques for pressure regime below 20 Pa pressure difference. As the pressure difference increased, the difference becomes more significant.

c) The exposed surface area of external walls have an effect on the air tightness of the house. Detached houses revealed higher air leakage rates compared to that of end-terraced houses and mid-terraced houses.

d) Houses with weather-stripping applied to their doors and windows were found to be not more than 10% 'tighter' than houses without weather-stripping.

e) Air leakage rates through various building components were measured in selected houses. The results indicated that a high proportion of air flowed into houses through the floor boards and the air-bricks under the crawl spaces. This leakage source was found to account for up to 40% of the total leakage rate.

f) A new parameter, the equivalent leakage area, was introduced to characterise the leakage of a structure It has a linear relationship with air leakage rate.

g) Results of pressurisation and depressurisation tests were aggregated to form a generalised equation, $Q = 2600\ A \times \Delta P^{0.73}$. The predicted results were fairly close to the measured results.

h) Tracer gas measurements conducted in fourteen houses indicated that average ventilation rates, with windows and other controllable openings closed, lie in the range of 0.52 to 1.65 air change per hour. The remaining measurements were rejected because their tests were conducted in wind speed conditions exceeding 4.0 m/s. It also indicated an approximately linear variation with wind speed.

i) Houses in this study and British houses on the whole, are relatively less air-tight than houses in countries such as Sweden and Canada. This is probably why whole-house air infiltration rates are relatively high.

j) Pressurisation measurements at steady high pressure can be used as a basis for house-to-house air tightness comparison. Unfortunately, they give no indication as to the locations or communications of the measured leakage. Measurements show that nearly 40% of the total leakage of these houses flowed into the interior through the carpet, floor boards and ventilators under the crawl spaces; under natural conditions these flow paths may not have played such an important role to the air change rate.

k) A long term investigation into the relationship between whole house leakage characteristics and natural ventilation rates of a house, that is, comparing simultaneous measurements to eliminate the effect of weather, will be required before any useful relationship between two characteristics can be determined.

1) Practical difficulties experienced in the measurement of ventilation in occupied houses, and in organising sufficient access precluded any other definite conclusions.

A.8 References

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Table A.1 Details of house types

House Code	Detached		Mid-terrace		End-terrace		Total
	Test	Control	Test	Control	Test	Control	
03/065	2	2	1	2	1	1	9
03/066	6	6	-	1	2	2	17
05/062	2	3	2	3	3	3	16
Total	10	11	3	6	6	6	42

(See Plate 1 for pictorial views of detached and end-terrace house

Table A.2 Rooms and openable windows for an average house

Room	No. of window each room	Type of window	Size of window	Area of window
3 Bedrooms	1	h.p.	1000 x 910mm	0.910 m
1 Living*	3	h.p.	1 x 1000 x 910mm	0.910 m
			2 x 780 x 780mm	0.710 m
1 Kitchen	1	h.p.	1000 x 910mm	0.910 m
1 Dining	1	h.p.	1000 x 910mm	0.910 m
1 Bath	1	h.p.	1000 x 510mm	0.510 m
1 W.C.	1	louvred	190 x 560mm	0.106 m

* Only some of the houses have the extra side window

NOTE : h.p. = horizontally pivoted

Table A.3 Types of test houses

House code	Detached		Mid-terrace		End-terrace		Total
	Test	Control	Test	Control	Test	control	
03/065	2	1	-	1	1	1	6
03/066	2	4	-	-	-	2	8
05/062	2	2	-	3	1	-	8
Total	6	7	-	4	2	3	22

Table A.4 Whole house leakage measurements for three 'reference houses'

Reading No.	Pressurisation Test						Depressurisation Test						Average Values			
	House 1		House 6		House 11		House 1		House 6		House 11		Pressure.		Depressure.	
	ΔP	Q	ΔP	Q	ΔP	Q	ΔP	Q	ΔP	Q	ΔP	Q	ΔP	Q	ΔP	Q
1	2.5	335	3.5	550	2.2	335	6.5	750	4.5	670	4.0	600	5	658	5	703
2	4.0	552	6.2	840	5.5	669	9.7	1040	7.5	1000	8.2	990	10	1129	10	1167
3	12.5	1405	15.0	1610	9.5	1004	18.4	1840	16.2	1840	16.5	1800	15	1549	15	1569
4	21.5	2074	22.5	2340	26.0	2342	27.4	2340	21.4	2240	31.6	2760	20	1938	20	1937
5	35.0	3011	36.1	3350	39.9	3178	41.0	3180	34.9	3280	52.2	3644	25	2307	25	2280
6	51.3	3880	44.6	3950	48.6	3680	51.8	3680	44.8	3810	53.5	3720	30	2659	30	2605
7	55.0	4149	48.6	4230	56.1	4049	57.7	3910	49.8	4080	58.8	3930	40	3328	40	3215
8	59.2	4316	51.1	4350	-	-	61.4	4010	52.1	4250	-	-	50	3960	50	3784
9	63.3	4482	53.6	4500	-	-	64.2	4150	54.1	4350	-	-	60	4565	60	4324
α.A	179.77		203.96		178.98		195.87		221.44		233.03		187.60		216.78	
β	0.782		0.779		0.779		0.742		0.750		0.701		0.780		0.731	
r^2	0.997		0.999		0.999		0.996		0.999		0.996		0.999		0.999	
Q_{50}	3824.4		4287.3		3763.7		3565.1		4165.1		3619.2		3960		3784	
Q_{20}	1869.0		2100.8		1844.1		1806.9		2094.8		1903.5		1938		1937	

Table A.5 List of house to house comparison with various parameters

	No. of sample	Mean air leakage rate at pressure difference of 50Pa	
		m /hour	Air change/hour
a) House plan			
Code 03/065	6	4862	21.1
Code 03/066	8	4878	21.1
Code 05/062	8	4975	21.5
b) House type			
Detached	13	5324	23.1
End-terrace	5	4877	21.1
Mid-terrace	4	4533	19.6
c) House group			
Control	14	4760	20.6
Test	8	5170	22.4
d) Weatherstripping doors/windows			
Houses with	12	4766	20.6
Houses without	10	5080	22.0
e) No. of crawl space ventilators			
11 numbers	1	4123	17.9
15 numbers	7	4727	20.5
21 numbers	10	5030	21.8
23 numbers	4	5122	22.2
f) Influence of wind speed			
Not exceeding 2 m/s	10	4585	19.9
2 to 4 m/s	6	5031	21.8
Exceeding 4 m/s	6	5327	23.1

NOTE : The mean air leakage rate for all twenty-two houses at pressure difference of 50 Pa = 21.3 ach.

Table A.6 Component leakage rates

Component	Air leakage rate per unit component at 50 Pa (m^3/hr)
Crawl space ventilator (15 nos.x 205 x 125mm)	95
Circular ventilator (2 nos.x 150mm)	190
Discharge pipe (1 no.x 38mm Ø)	8
Discharge pipe (2 nos.x 19mm Ø)	3

Table A.9 Generalisation of air leakage data

	a_{av}	S.D.	β	S.D.	A
Pressurisation test	2680	400	β_1 = 0.748	0.038	0.097
			β_2 = 0.739	0.047	0.117
			β_3 = 0.707	0.061	0.187
			β_4 = 0.666	0.049	0.367
Depressurisation test	2550	290	β_1 = 0.712	0.049	0.122
			β_2 = 0.702	0.044	0.142
			β_3 = 0.691	0.044	0.212
			β_4 = 0.639	0.042	0.392
Generalised equation	2600	310	β_{1av} = 0.727	0.048	0.110

Table A.7 Description of test houses, test conditions and air leakage characteristics

House No	Test date	House type	Test method	House Group	House volume	Envelope Area	Temp. diff.	Wind speed	Wind direction	Δ R.H.	Heating condition	weather stripping	No of ver[illegible]	$a_1 \cdot A$	β_1	R_1^2	a_{av}	Q_{50}	Q_{50adj}	Q_{50gen}	A_o	$\frac{Q_{50adj}}{V}$	$\frac{Q_{50adj}}{Ax}$	R (ach)
1	5.2.82	C	P	E.T	230.85	133.35	4	1.4	W	30	on	✓	15	179.77	0.782	0.9967	2683.36	3824	3736	3160	0.0670	16.18	28.02	0.55
			d											195.07	0.742	0.9959	2593.53	3565	3647	3388	0.0757	1580	23.32	–
3	17.12.82	C	d	E.T	230.85	133.35	15	0.7	Varies	-30	on	✓	15	312.33	0.714	0.9958	2805.32	5103	4986	4986	0.1114	21.34	37.39	0.74
6	5.2.82	T	P	D	230.85	163.22	3	1.4	W	30	on	X	21	203.96	0.779	0.9995	2384.34	4287	4188	3826	0.0855	18.14	25.66	0.90
			d											221.44	0.750	0.9991	2379.04	4165	4261	4458	0.0929	18.46	26.11	–
7	23.12.81	C	d	D	230.85	163.22	12	0.9	Varies	-15	on	✓	21	206.84	0.769	0.9950	2458.22	4193	4289	3763	0.0841	18.58	26.28	0.72
8	27.1.82	T	d	D	230.85	163.22	6	5.0	W	-2	on	X	21	411.12	0.685	0.9976	2672.65	6001	6139	6883	0.1538	26.59	37.61	2.57
11	18.2.82	C	P	M.T.	230.85	79.65	3	0.9	E	0	on	✓	15	178.98	0.779	0.9997	2544.36	3764	3677	3142	0.0702	15.93	46.16	0.84
			d											233.03	0.701	0.9962	2996.54	3619	3702	3473	0.0776	16.04	48.48	–
12	22.1.82	T	P	E.T.	230.85	133.35	9	3.0	SE	-35	on	✓	21	275.17	0.762	0.9978	2334.07	5431	5306	5281	0.1180	22.98	39.79	1.64
13	6.2.82	T	P	D	230.85	194.62	3	1.5	S	10	on	X	21	262.95	0.757	0.9990	2142.45	5089	5206	5487	0.1226	22.55	26.75	–
14	6.2.82	C	d	D	230.85	194.62	2	1.5	S	8	on	✓	21	198.47	0.802	0.9970	2049.65	4569	4674	4328	0.0967	20.25	24.02	1.08
15	30.1.82	C	d	D	230.85	194.62	4	4.9	W	12	off	X	23	417.89	0.655	0.9960	2415.13	5409	5534	7736	0.1728	23.97	28.43	1.85
16	4.2.82	T	d	D	230.85	194.62	6	1.7	E	12	on	✓	23	393.44	0.677	0.9990	2786.31	5557	5685	6319	0.1412	24.63	29.21	–
17	23.1.82	C	P	D	230.85	194.62	3	2.3	W	5	off	X	23	226.07	0.771	0.9989	2510.61	4610	4504	4037	0.0902	19.51	23.14	1.27
18	17.1.82	T	P	D	230.85	194.62	4	5.5	NW	-10	on	✓	23	234.84	0.775	0.9996	2820.92	4875	4763	3733	0.0834	20.63	24.47	1.88
19	21.12.81	T	d	E.T	230.85	133.35	5	2.5	SE	-15	on	X	15	438.31	0.645	0.9994	2684.32	5468	5594	7313	0.1634	24.23	41.95	1.21
22	18.2.82	C	P	M.T.	230.85	79.65	9	0.9	E	10	on	X	11	264.09	0.708	0.9977	3476.10	4220	4123	3406	0.0761	17.86	51.76	0.64
23	19.2.82	C	P	E.T.	230.85	133.35	3	2.5	E	10	on	X	15	327.97	0.692	0.9993	2778.31	4919	4806	5290	0.1182	20.82	36.04	0.52
25	21.1.82	C	d	D	230.85	194.62	4	1.0	NW	2	on	X	21	314.90	0.715	0.9973	2537.93	5165	5284	5550	0.1240	22.89	27.15	0.92
26	18.1.82	T	P	D	230.85	194.62	3	3.0	SE	-6	on	✓	21	331.21	0.669	0.9796	3345.00	4539	4435	4435	0.0991	19.21	22.79	1.62
33	10.2.82	C	d	D	230.85	194.62	4	4.8	E	8	off	✓	21	404.09	0.647	0.9986	2712.88	5087	5204	6664	0.1489	22.54	26.74	2.13
35	3.2.82	C	d	D	230.85	194.62	4	2.5	E	8	off	✓	21	285.29	0.752	0.9917	2006.88	5415	5540	6369	0.1423	24.00	28.47	1.20
40	29.1.82	C	P	M.T	230.85	79.65	4	4.6	NW	-5	on	X	15	279.13	0.763	0.9974	3343.19	5516	5389	5326	0.1190	23.34	66.87	2.70
41	29.1.82	C	P	M.T.	230.85	79.65	4	4.6	NW	-10	on	✓	15	294.83	0.735	0.9973	2781.65	5232	5112	4744	0.1060	22.14	64.18	1.92
	C – 'Control' house T – 'Test' house		P – Pressurisation D – Depressuri[illegible]			D – Detached. E-T – End-terrace. M[illegible]ace.				AVERAGE VALUE				283.68	0.728	–	2609.67	4785	4791	4912	0.1097	20.74	34.43	1.35

HOUSE NO. 6

DATA OF TEST : 5.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/062~~

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 162.22 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 11.5 °C, OUTDOOR : 9 °C, ΔT : 2.5 °C

WIND : SPEED : ____ Ft/min OR 1.39 m/s, DIRECTION : W

RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED

2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)

3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)

4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	3.5	5.0	3.0	2.0	550	840	1070	1270
2	6.2	7.0	5.2	2.5	840	1100	1610	1670
3	15.0	14.2	11.0	5.0	1610	2010	2610	2676
4	22.5	21.2	15.0	7.2	2340	2680	3180	3350
5	36.1	29.9	19.4	10.0	3350	3450	3950	4150
6	44.6	38.6	23.7	12.0	3950	4150	4480	4550
7	48.6	41.4	24.9	12.2	4230	4350	4680	4680
8	57.1	44.1	26.2	13.0	4350	4620	4750	4750
9	53.6	47.3	27.9	13.5	4500	4750	4950	4880
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A = 203.957$ $\beta_1 = 0.7785$ $r^2 = 0.9995$ $\alpha_1 = 2175.55$
2. $\alpha . (A + 0.02) = 247.468$ $\beta_2 = 0.7729$ $r^2 = 0.9988$ $\alpha_2 = 2694.59$
3. $\alpha . (A + 0.09) = 436.089$ $\beta_3 = 0.7345$ $r^2 = 0.9988$ $\alpha_3 = 2284.48$
4. $\alpha . (A + 0.27) = 847.295$ $\beta_4 = 0.6820$ $r^2 = 0.9924$ $\alpha_4 = 2382.73$

$\alpha_{av.} = 2384.34$

CONSIDER CONDITION 1 ONLY:

$Q_5 = 714.0$
$Q_{10} = 1224.7$
$Q_{20} = 2100.8$
$Q_{30} = 2880.6$
$Q_{40} = 3603.6$
$Q_{50} = 4287.3$

A = EQ. LEAKAGE AREA = 0.0855 m^2

GEN. EQ.: $Q = 0.0855 \alpha_{av.} \Delta P^{\beta_1}$

TABLE A.8 RESULTS OF AIR LEAKAGE MEASUREMENTS OF DIFFENT OPENING CONDITIONS FOR HOUSE 6 (PRESSURISATION)

Table A.10 A comparison of air leakage characteristics of dwellings in different countries

Author	Country	Simple size	Average house bolume (m^3)	Air leakage characteristics at 50 Pascals				
				Q_{50} (m^3/hr)	Q_{50}/V (ach)	Q_{50}/A_x ($m^3/m^2 hr$)	flow exponent β	applied pressure direction
Present results	U.K. (Scotland)	22	230	4900	21.3	34.7	0.73	Mean
Warren et al (1980)	U.K.	19	200	2740	13.9	22.1	0.60	Mean
Grimsrud et al (1979)	U.S. (California)	13	378	3330	9.4	-	-	Mean
Colet et al (1979)	Denmark	6	303	2730	8.6	-	0.70	Positive
Kronvall (1978)	Sweden	25	317	1360	4.5	5.0	0.77	Positive
Beach (1979)	Canada (Ottawa)	63	553	2420	4.4	8.4	0.66	Positive

(Abstracted from Warren and Webb, 1980)

Table A.11 Results of ventilation rate measurement for twenty houses

House No	Test date	House type	ΔT	Wind Speed	Wind Directn.	W-S	Window opening conditions 1	2	3	4
1	05.02.82	C	4	1.4	W	✓	0.55	0.66	0.98	1.38
3	17.12.81	C	15	0.7	varies	✓	0.74	0.85	1.28	2.45
6	05.02.82	T	3	1.4	W	X	0.90	1.08	1.10	1.44
7	23.12.81	C	12	0.9	varies	✓	0.72	0.87	1.44	2.23
8	27.01.82	T	6	5.0	W	X	2.57	3.80	3.80	8.87
11	18.02.82	C	3	0.9	E	✓	0.84	1.57	1.91	2.01
12	22.01.82	T	9	3.0	SE	✓	1.65	1.97	4.53	5.18
14	06.02.82	C	2	1.5	S	✓	1.08	3.29	3.26	5.00
15	30.01.82	C	4	4.9	W	X	1.85	3.76	6.78	10.26
17	24.01.82	C	3	2.3	W	X	1.27	1.40	1.84	3.87
18	17.01.82	T	4	5.5	NW	✓	1.88	2.27	5.08	-
19	21.12.81	T	5	2.5	SE	X	1.21	1.71	2.11	4.06
22	18.02.82	C	9	0.9	E	X	0.64	1.09	1.12	1.27
23	19.02.82	C	3	2.5	E	X	0.52	0.65	0.76	0.87
25	21.01.82	C	4	1.0	NW	X	0.92	1.53	1.82	3.39
26	18.01.82	T	3	3.0	SE	✓	1.62	4.04	4.34	5.40
33	10.02.82	C	4	4.8	E	✓	2.13	5.24	9.92	11.51
35	03.02.82	C	4	2.5	E	✓	1.20	1.41	1.82	5.91
40	29.01.82	C	4	4.6	NE	X	2.70	4.85	9.43	25.30
41	29.01.82	C	4	4.6	NE	✓	1.92	2.61	3.37	13.03

Table A.12 Increase of air change rate with position of window and wind speed

Position no.	Description of window position	Wind speed n.e.2 m/s (sample-8)	2 - 4 m/s (sample-6)	exc.4 m/s (sample-6)
1	All windows tightly closed	0.80	1.21	2.18
2	One window opened at approx. 1°30'	1.37	1.86	3.76
3	One window opened at approx. 6°	1.61	2.57	6.86
4	One window opened at approx. 17°	2.40	4.22	13.80
5	Two windows opened at approx. 1°30'	2.84	4.96	-
6	Two windows opened at approx. 6°	4.14	6.90	-

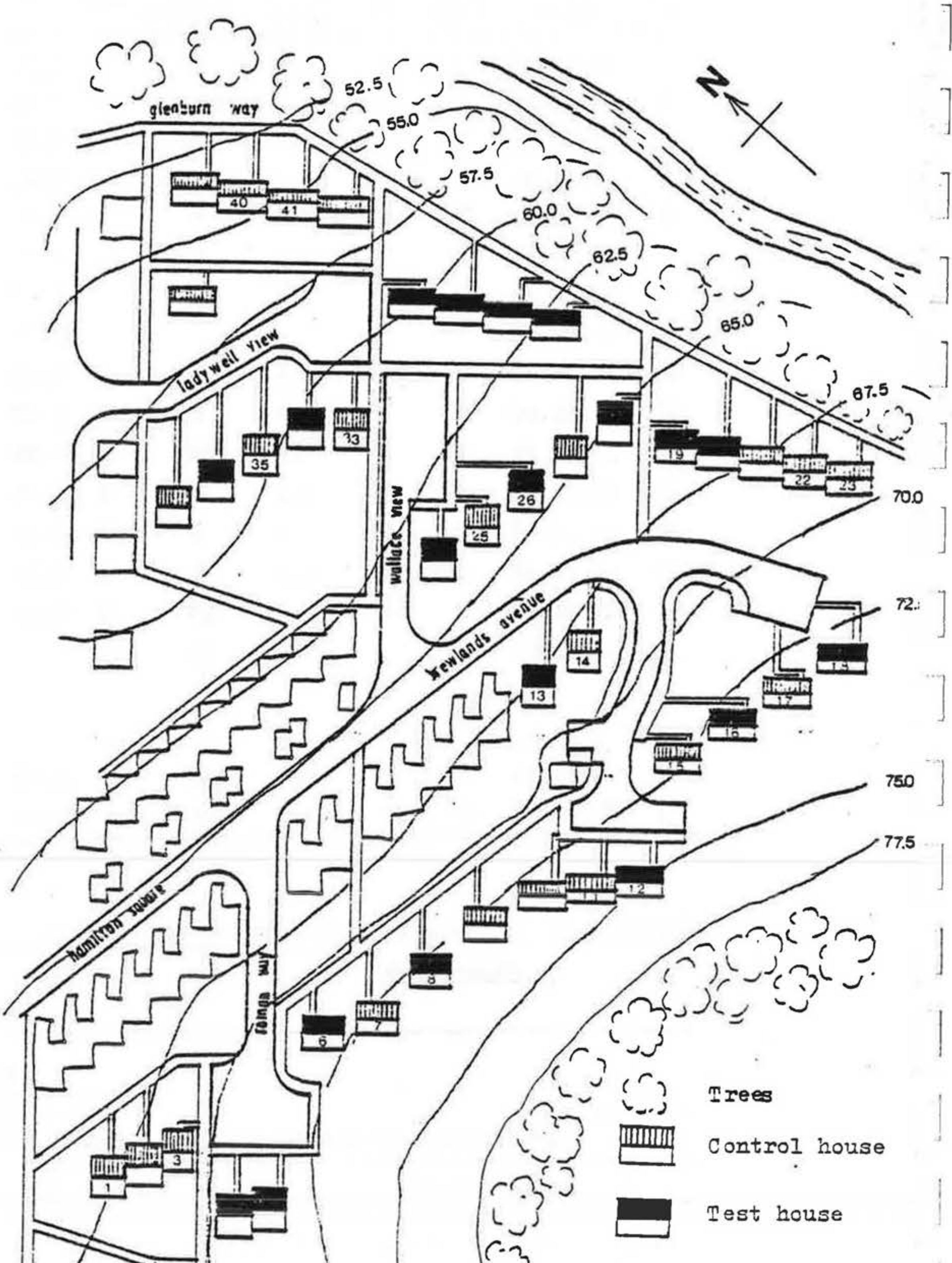


Fig. A.1 General site layout and house types

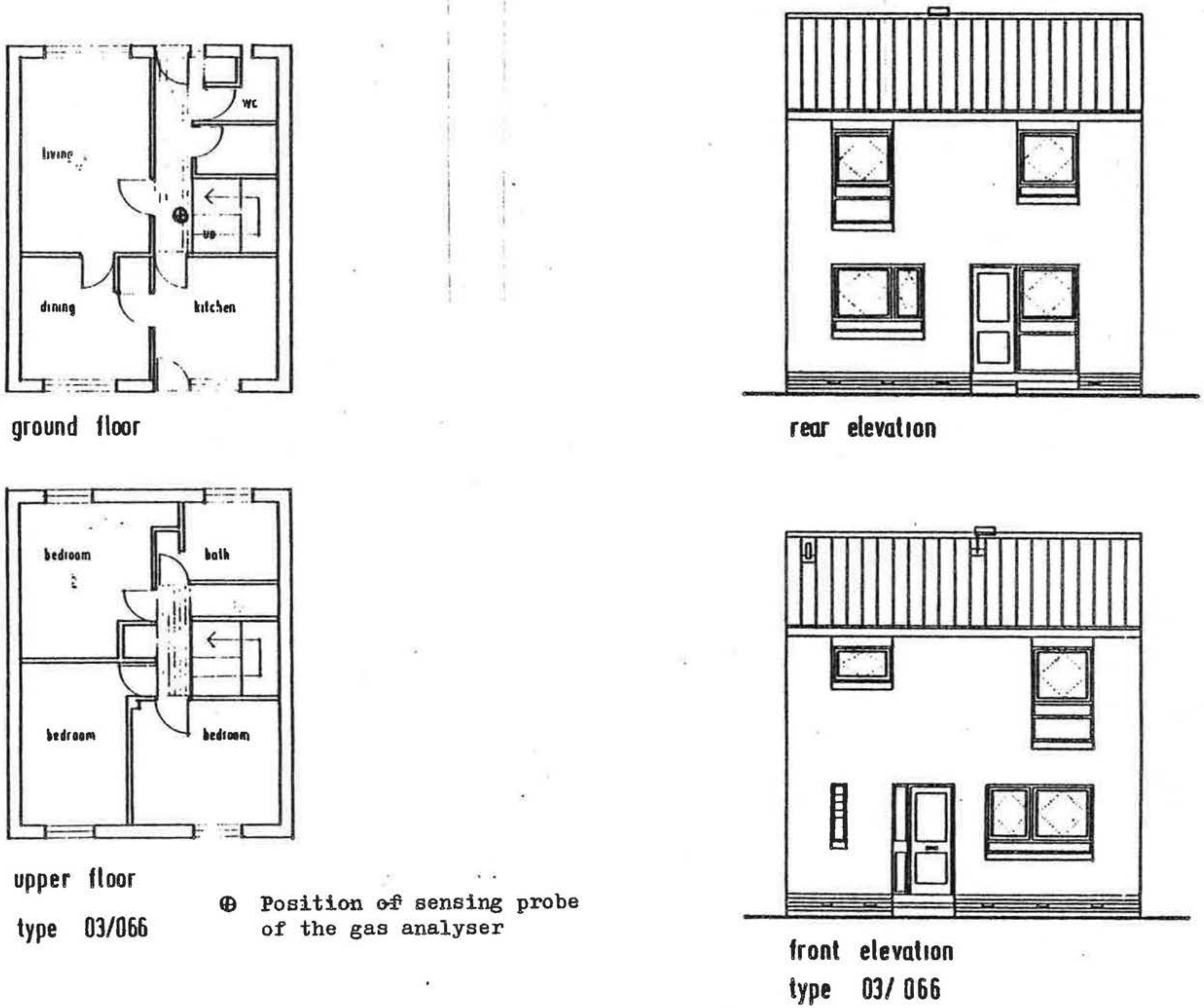


FIG. A.2 (a) PLANS AND ELEVATIONS OF THREE DIFFERENT HOUSE TYPES

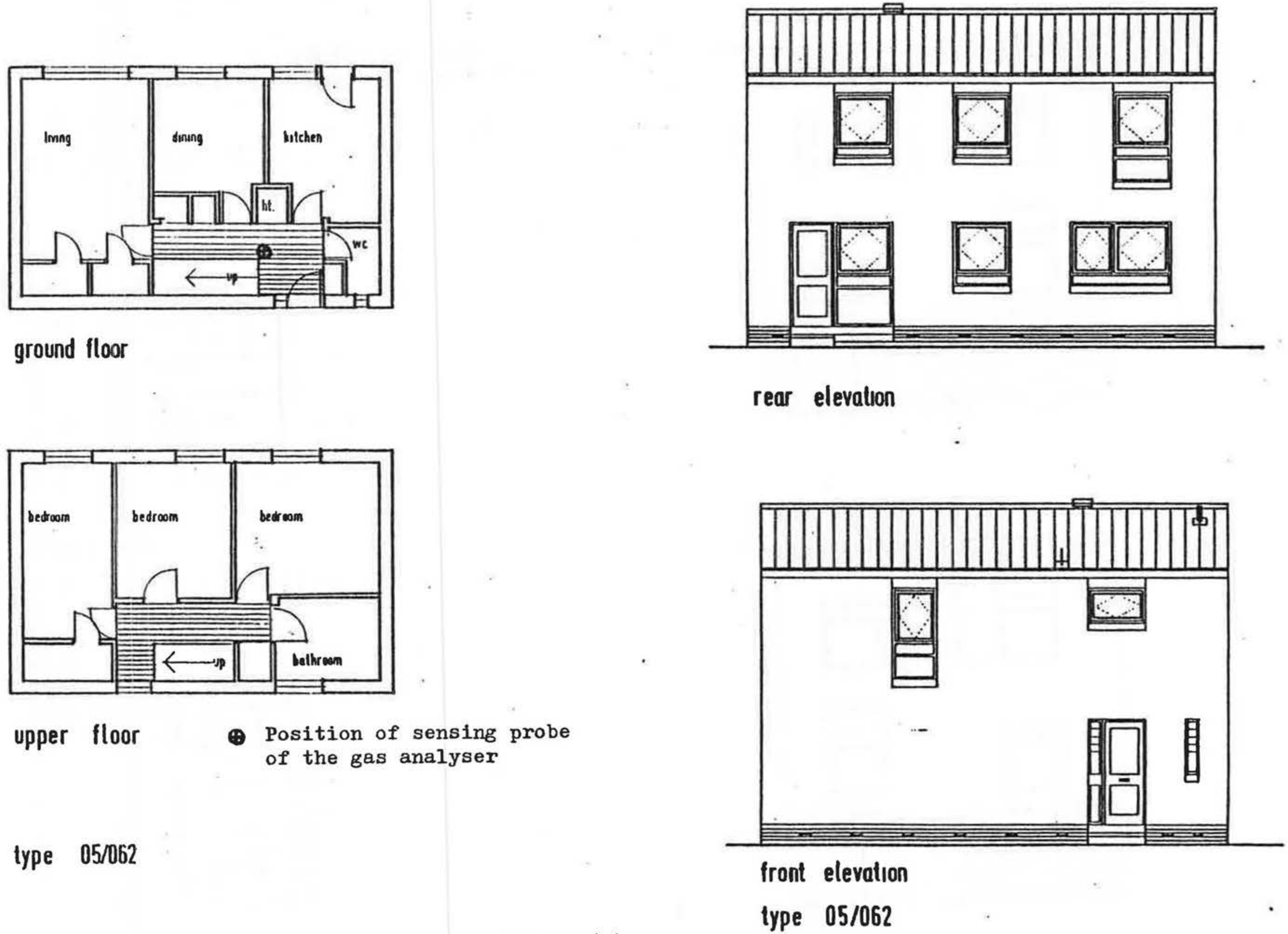
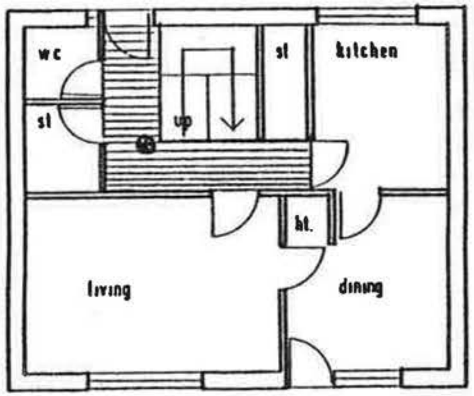
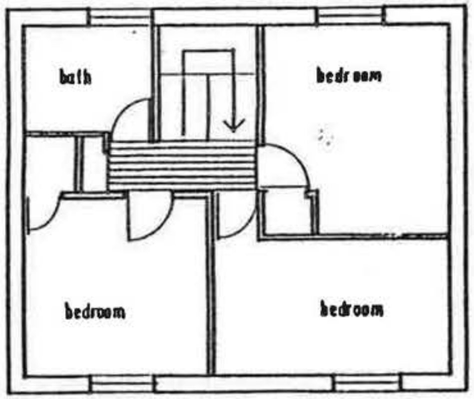

living
dining
kitchen
ht.
wc
up
ground floor
bedroom
bedroom
bedroom
up
bathroom
upper floor
Position of sensing probe of the gas analyser
type 05/062
rear elevation
front elevation
type 05/062

FIG. 2A (b)



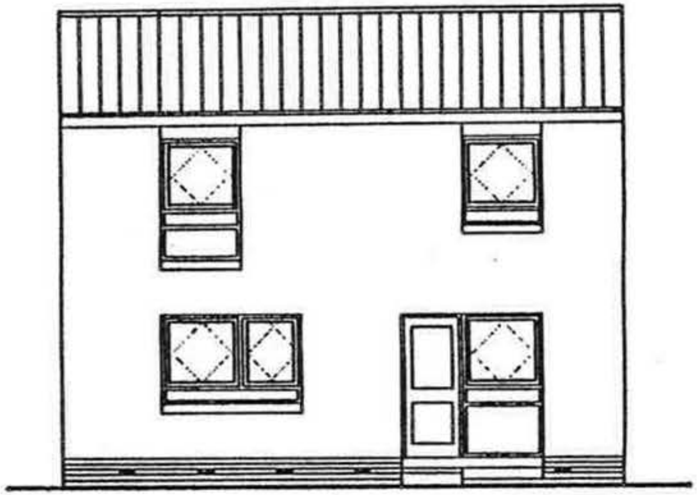
ground floor



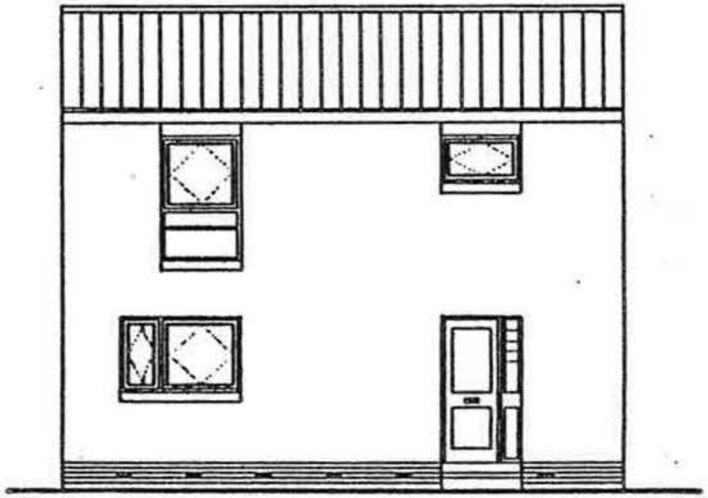
upper floor

type 03/065

● Position of sensing probe of the gas analyser



rear elevation



front elevation
type 03/065

FIG.2A (c)

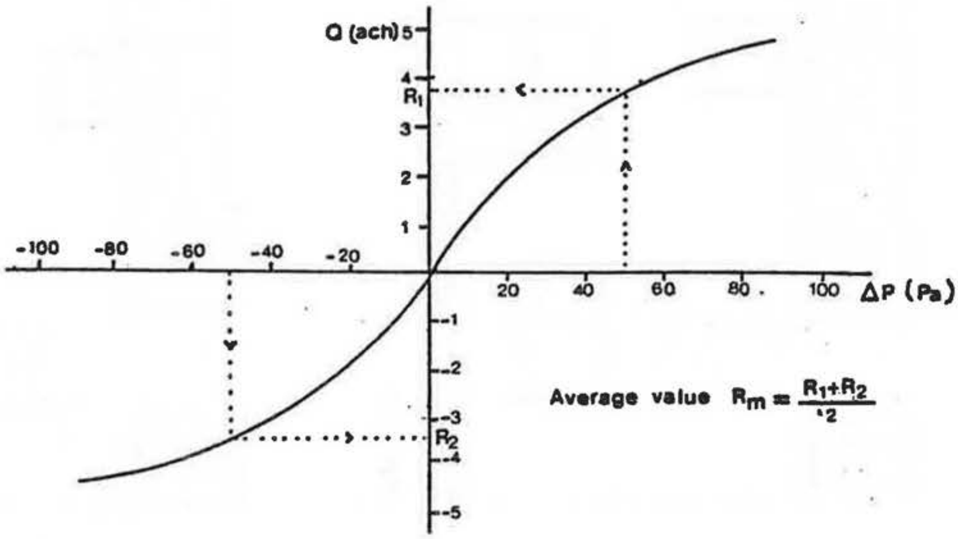


Fig. A.3 Example of test results in linear-scale graph form

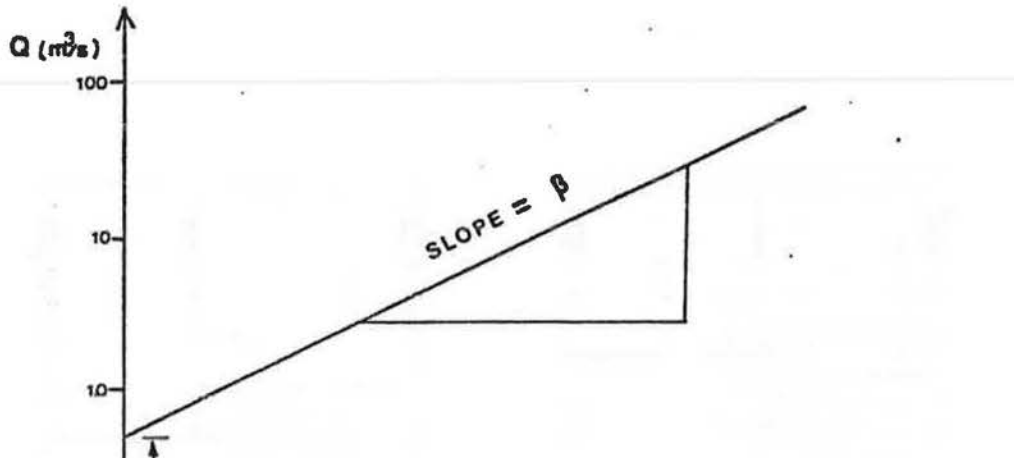


Fig. A.4 Example of test results in log-log scale graph form

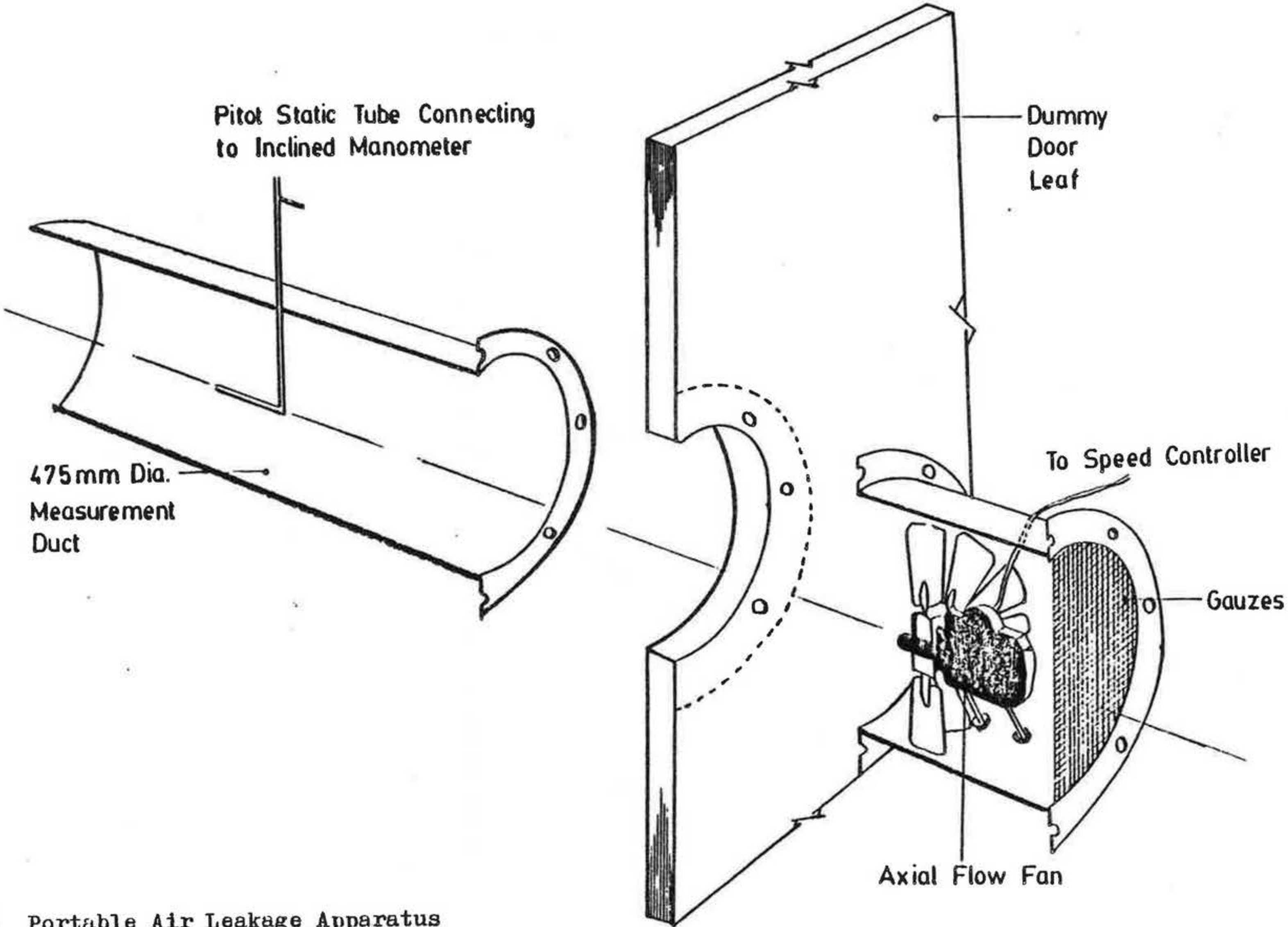


Fig. A.5 Portable Air Leakage Apparatus

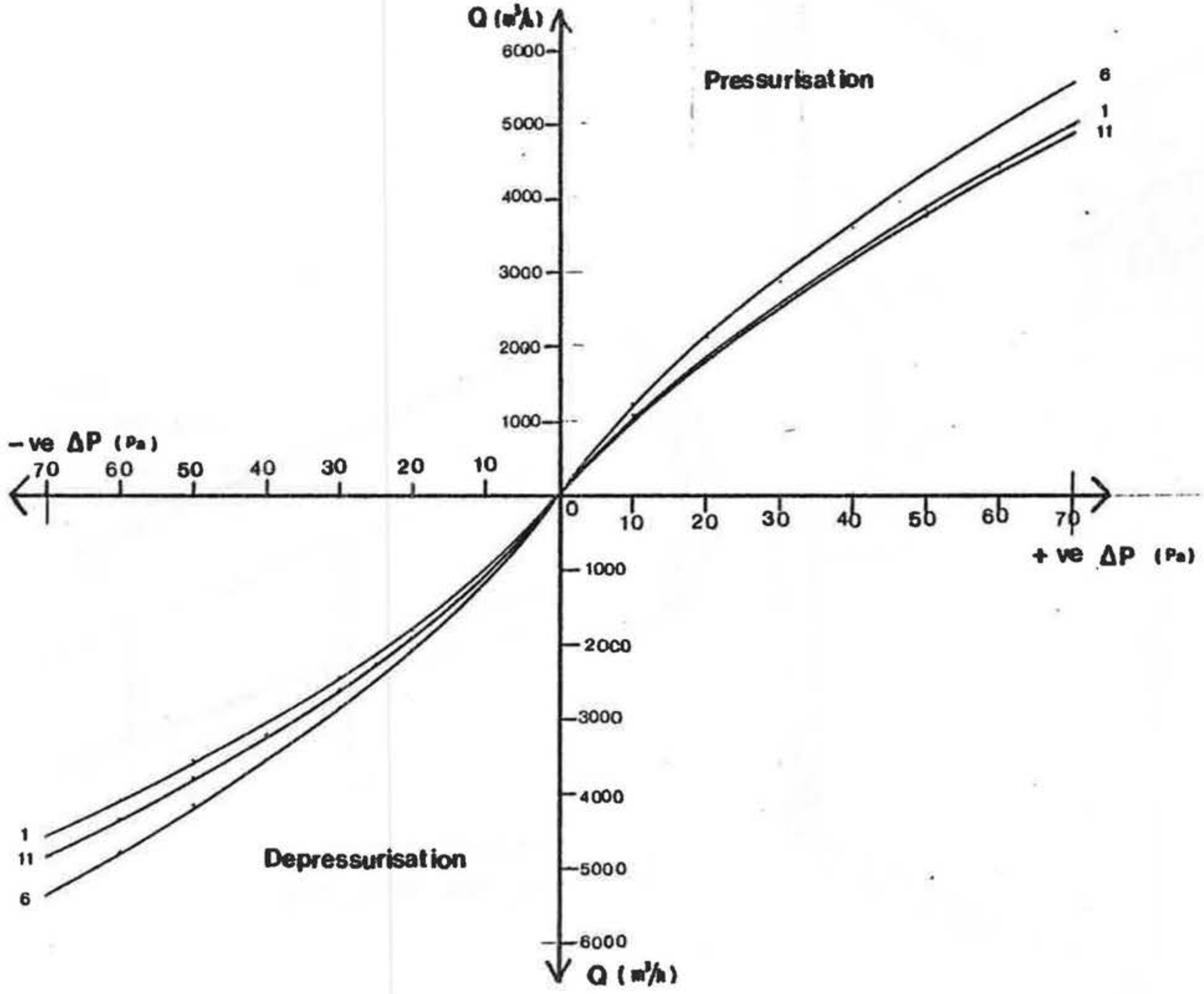


Fig. A.6 Whole house air leakage characteristics of three 'reference houses'

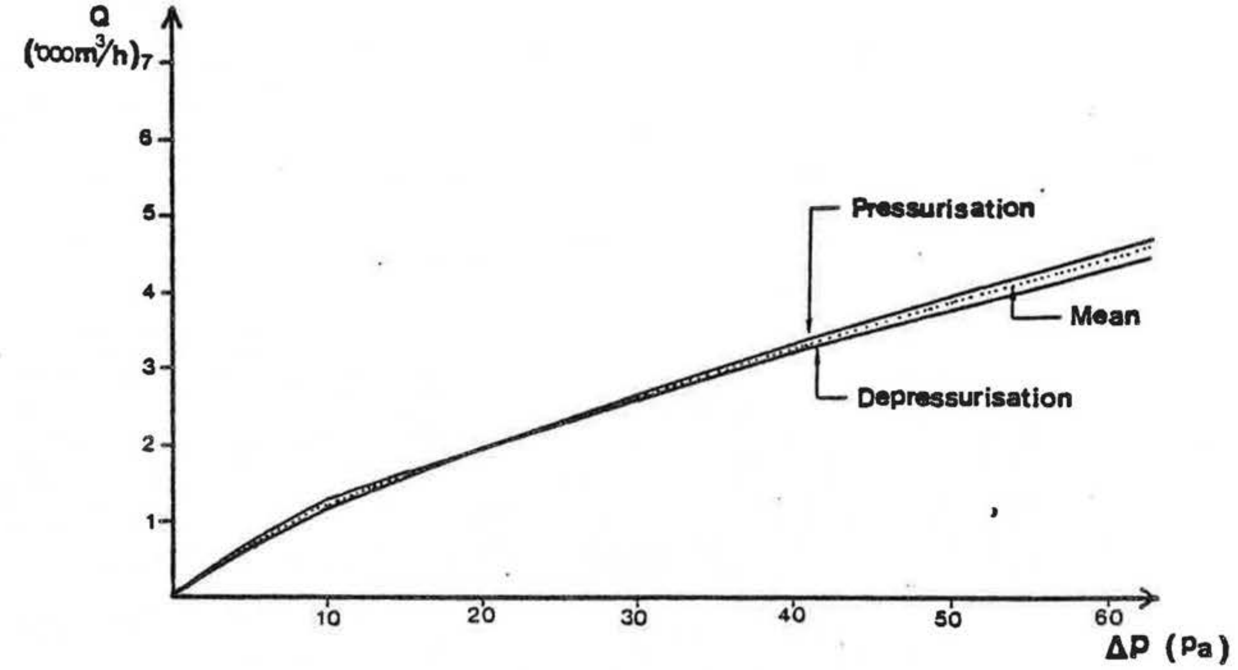


Fig. A.7 Comparison of air leakage measurements made with pressurisation and depressurisation techniques over a range of pressure difference from 0 to 60 Pa for three 'reference houses'

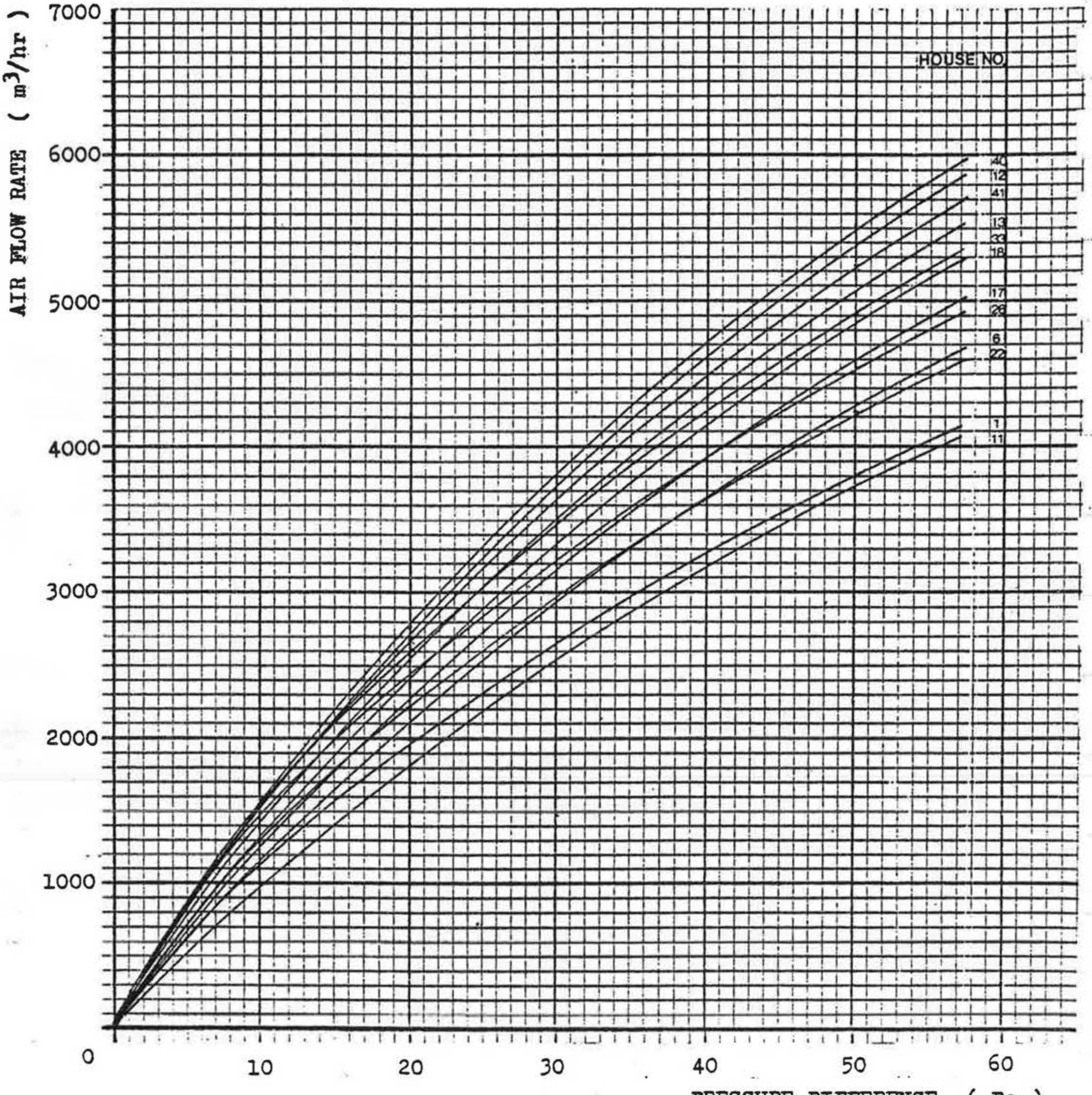


Fig. A.8a Whole house air leakage rates for 12 houses by using Pressurisation technique

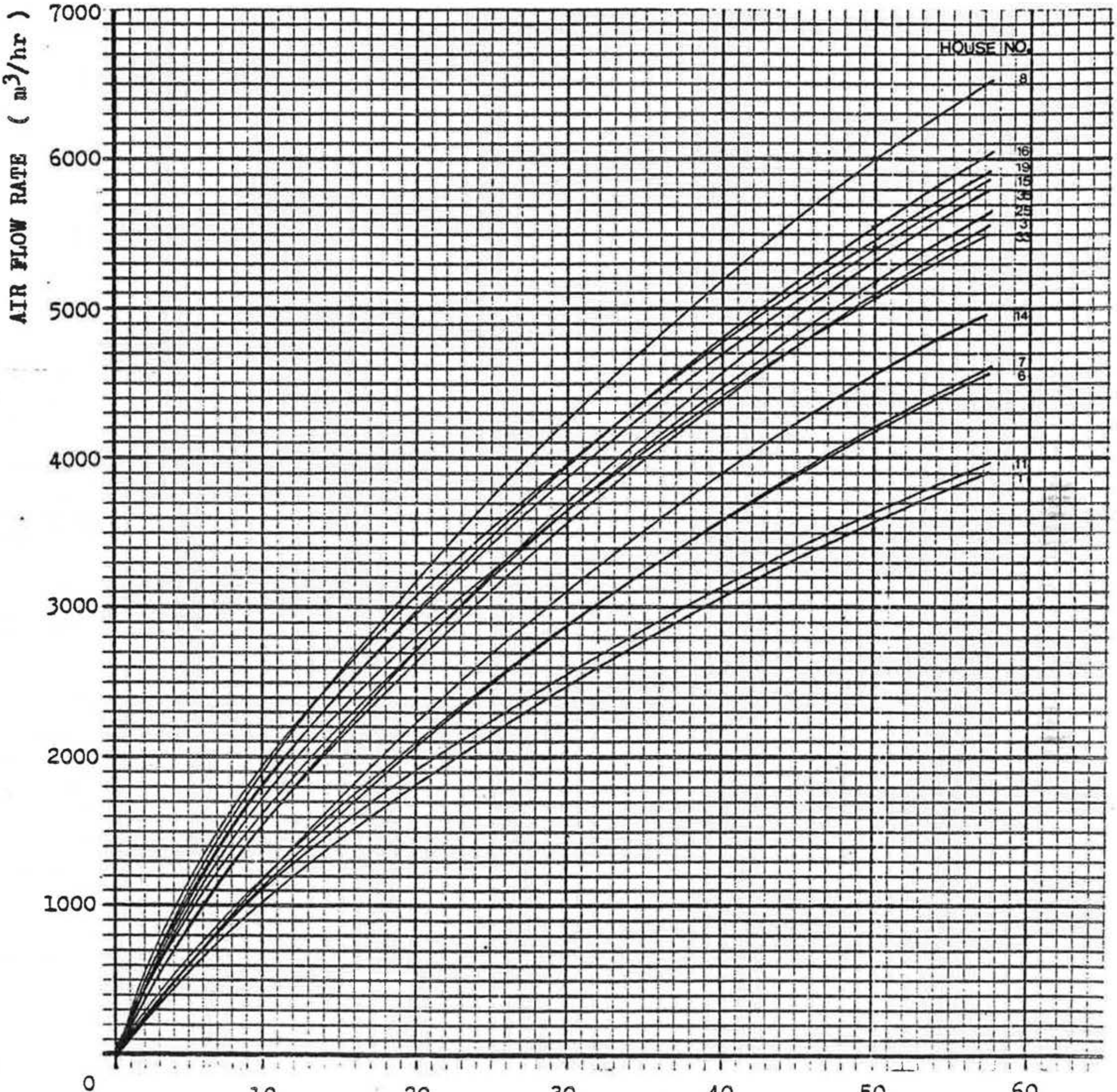


Fig. A.8b Whole house air leakage rates for 13 houses by using Depressurisation technique

BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 6

PRESSURIZATION

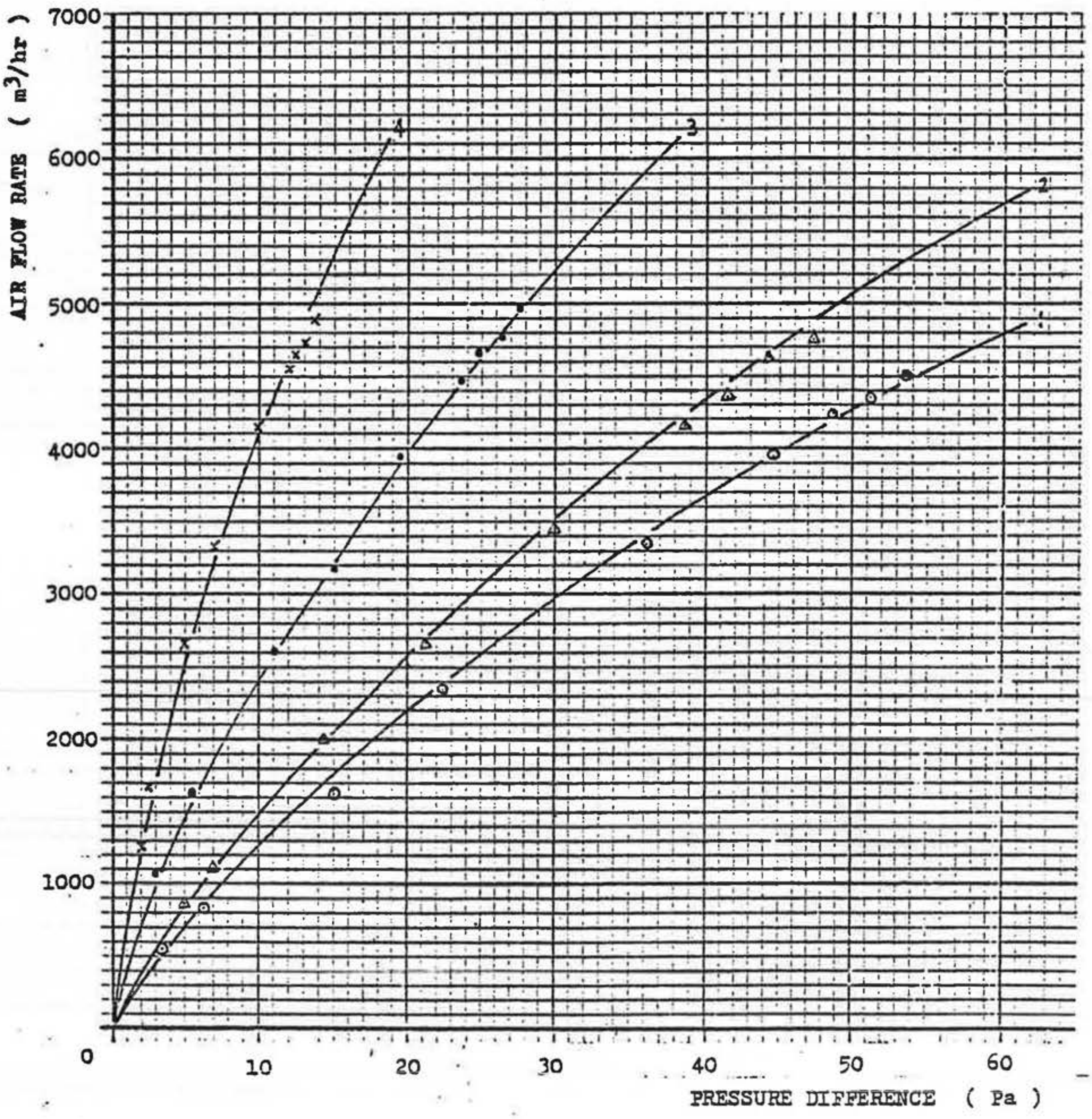


FIG. A.9 AIR LEAKAGE CHARACTERISTICS FOR DIFFERENT OPENING CONDITIONS FOR HOUSE 6

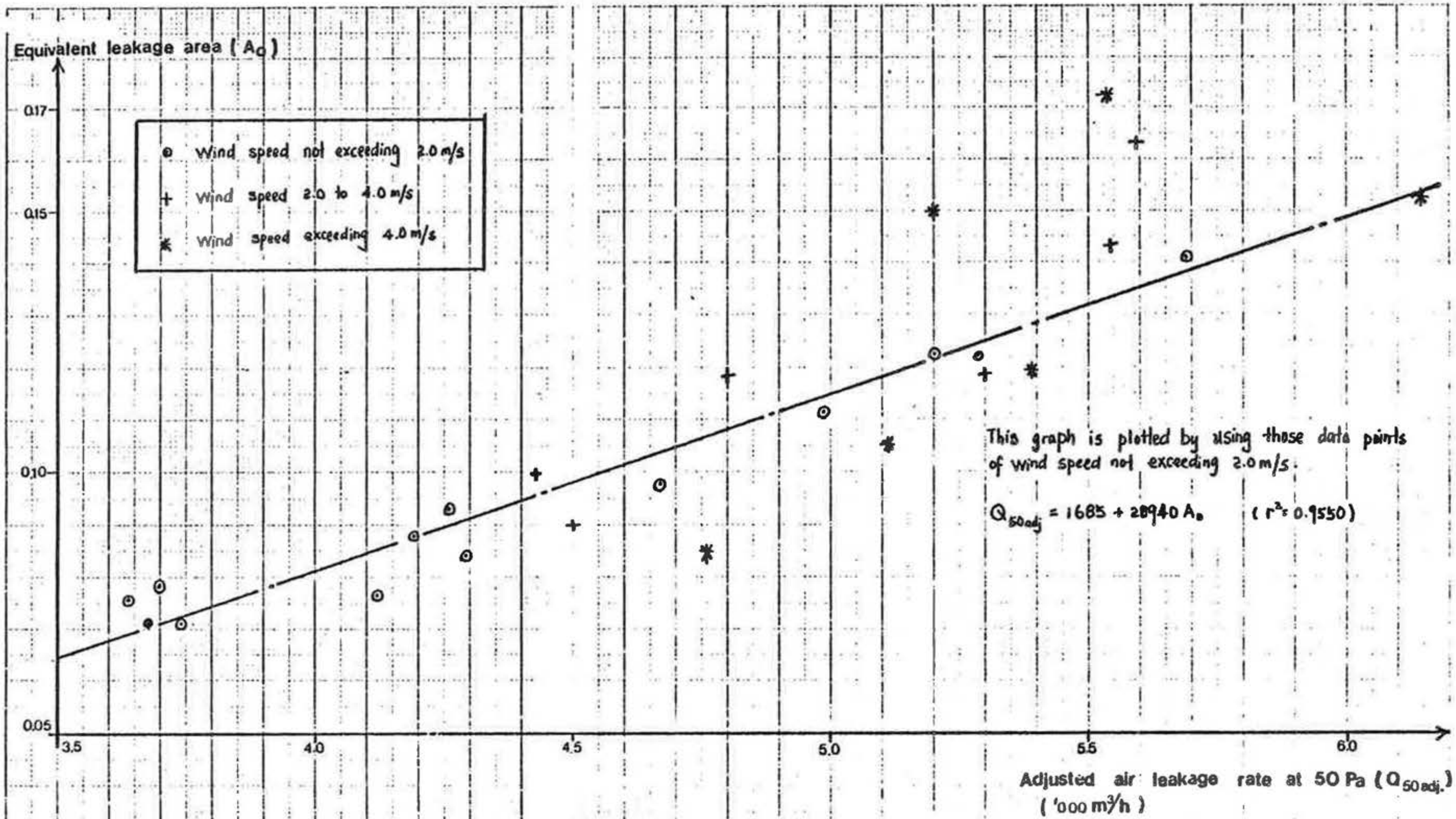


Fig. A10 Relationship between equivalent leakage area and air leakage rate under the influence of wind speed

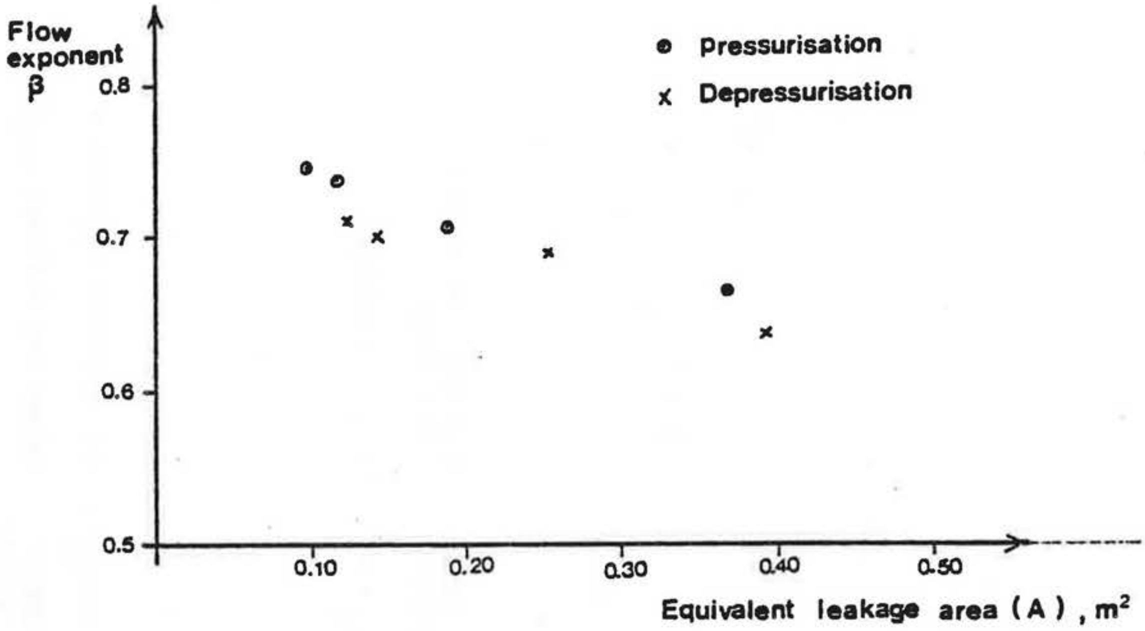


Fig. A.11 The effect of equivalent leakage area (A) on flow exponent β

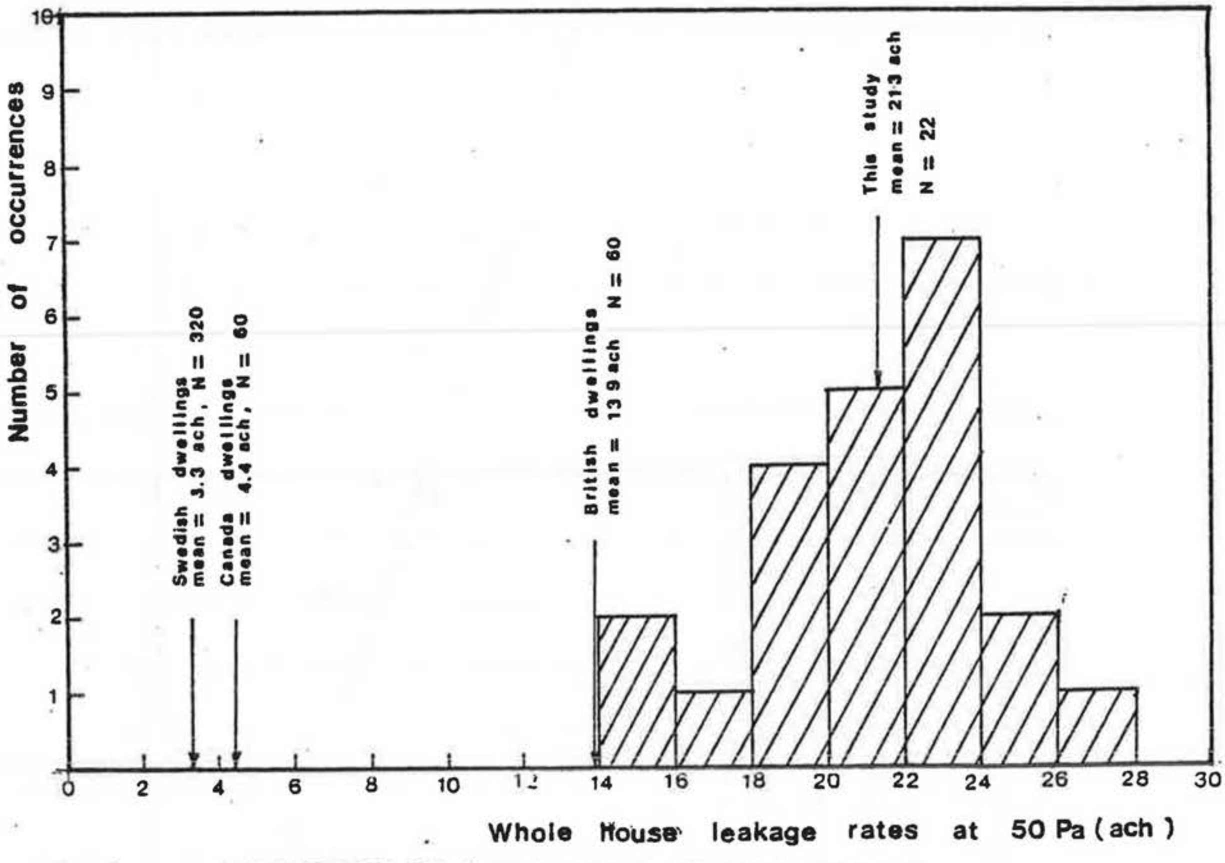


Fig. A.13 Distribution of whole house leakage rates in twenty-two houses of the better insulated houses and compared with other findings (Abstracted from : Warren, 1982).

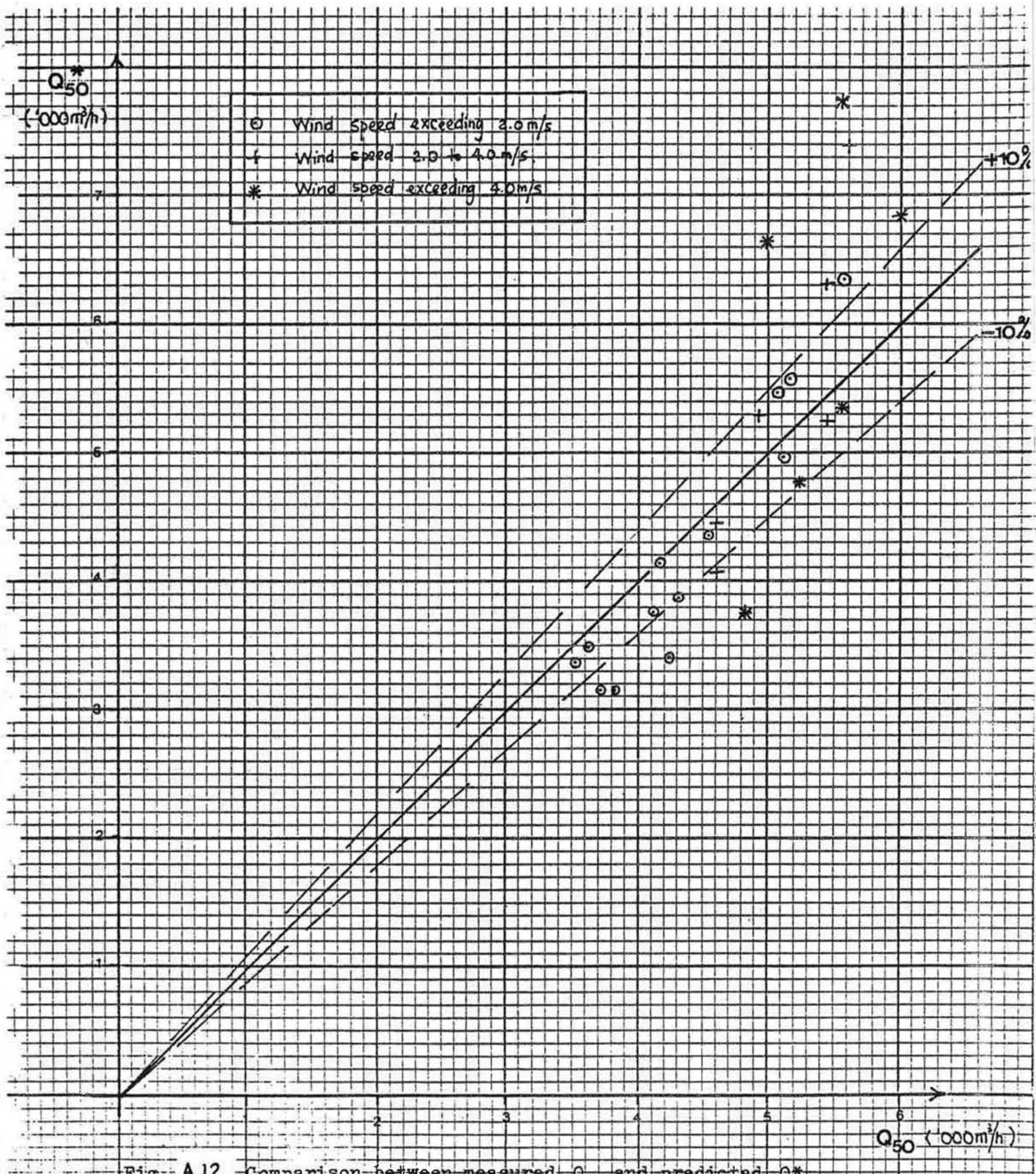


Fig. A.12 Comparison between measured Q_{50} and predicted Q^*_{50}

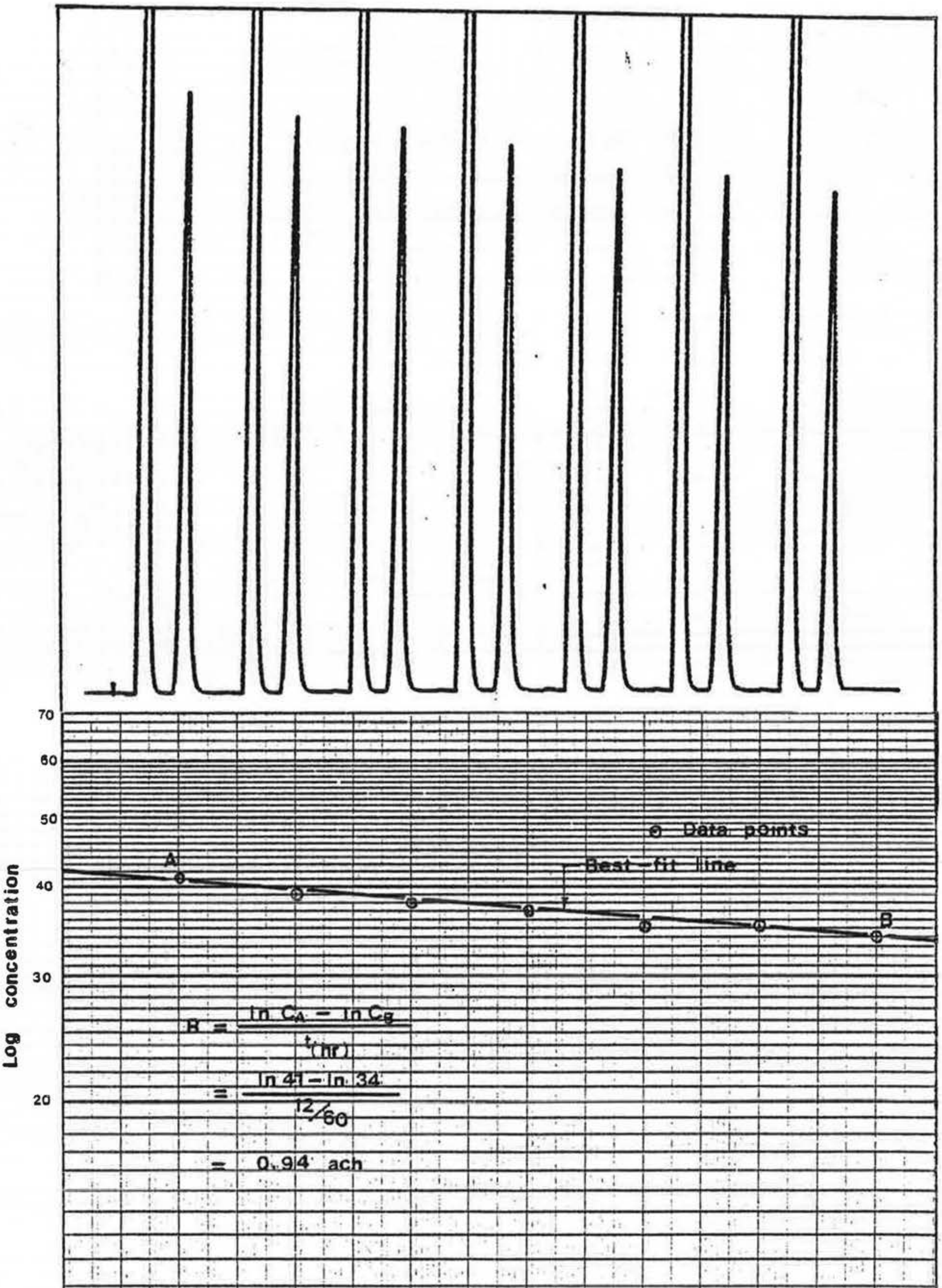


Fig. A.14 Typical result for the decay of tracer concentration and determination of air change rate

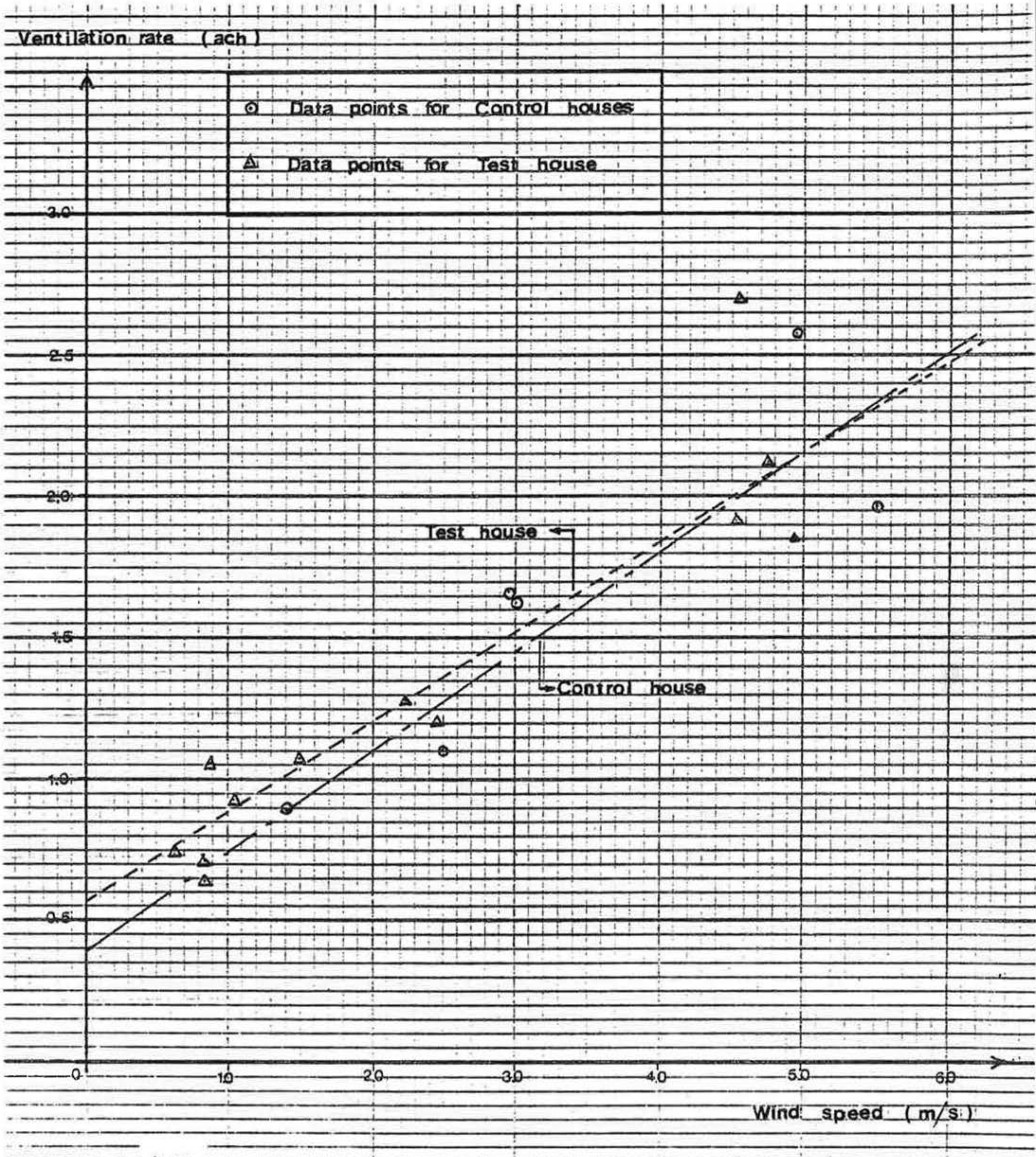


Fig. A.15 Ventilation rate versus wind speed for twenty houses

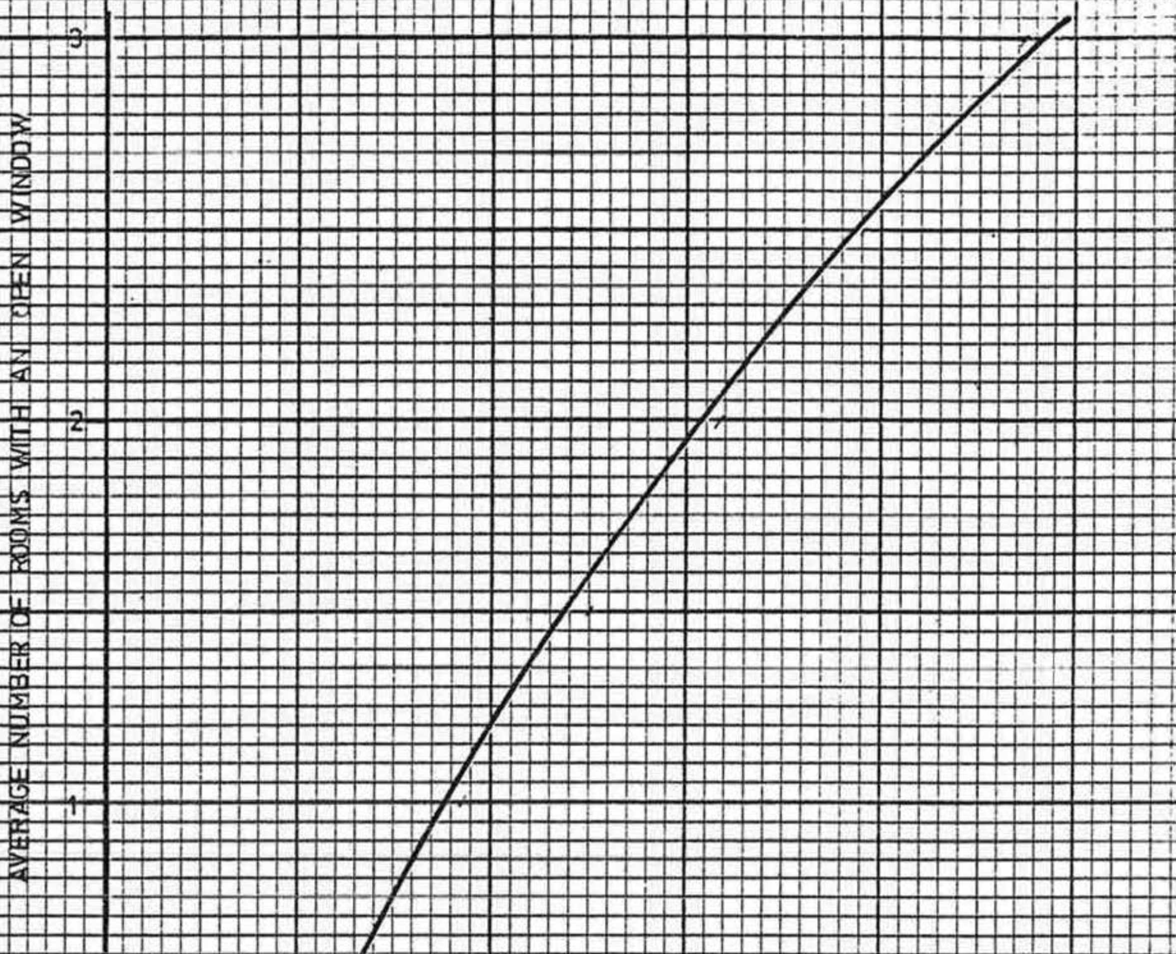


FIG. A.16 EFFECT OF WINDOW-OPENING ON VENTILATION RATE

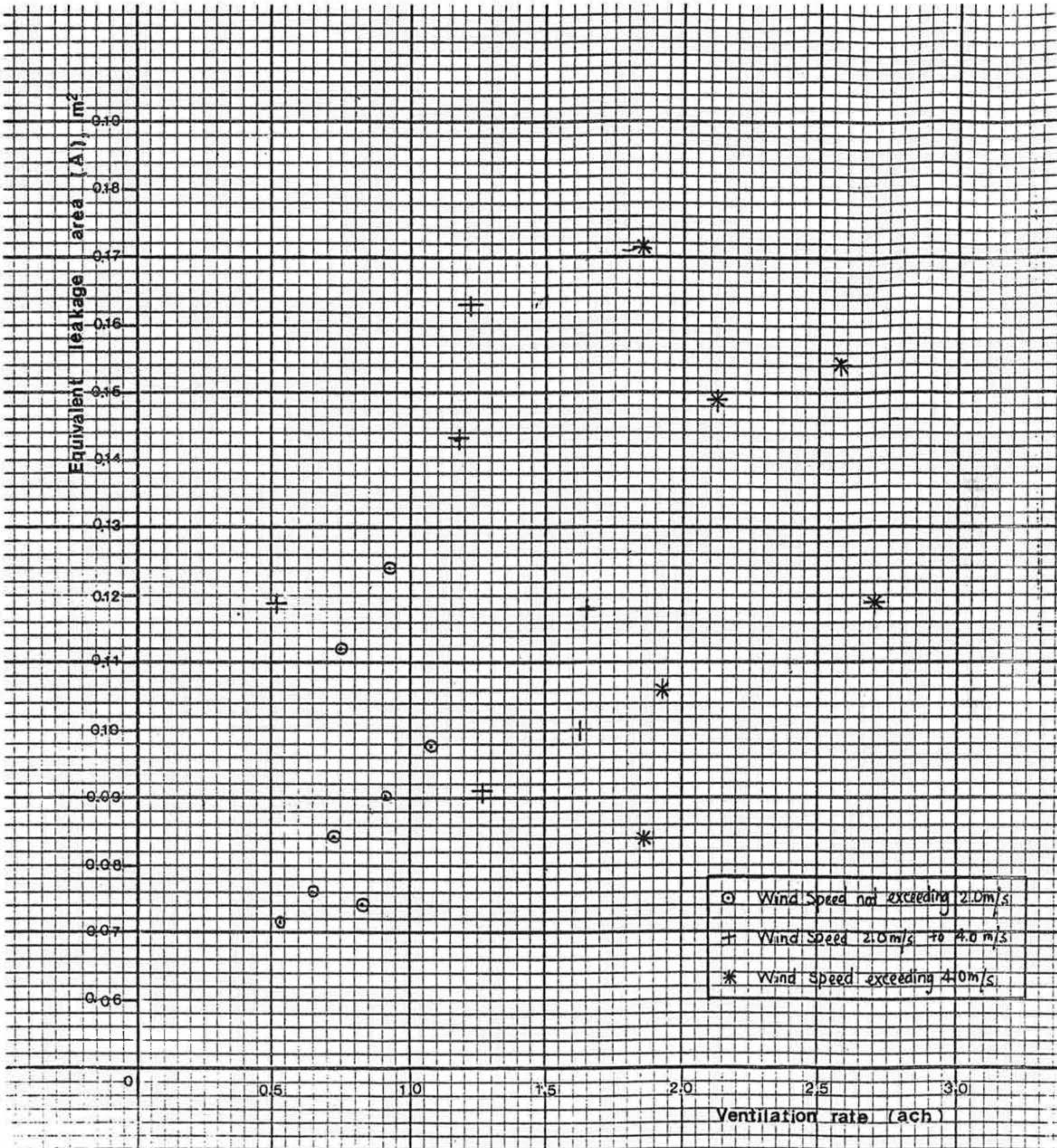


Fig. A.17 Variation of whole house ventilation rates with their equivalent leakage area (A)

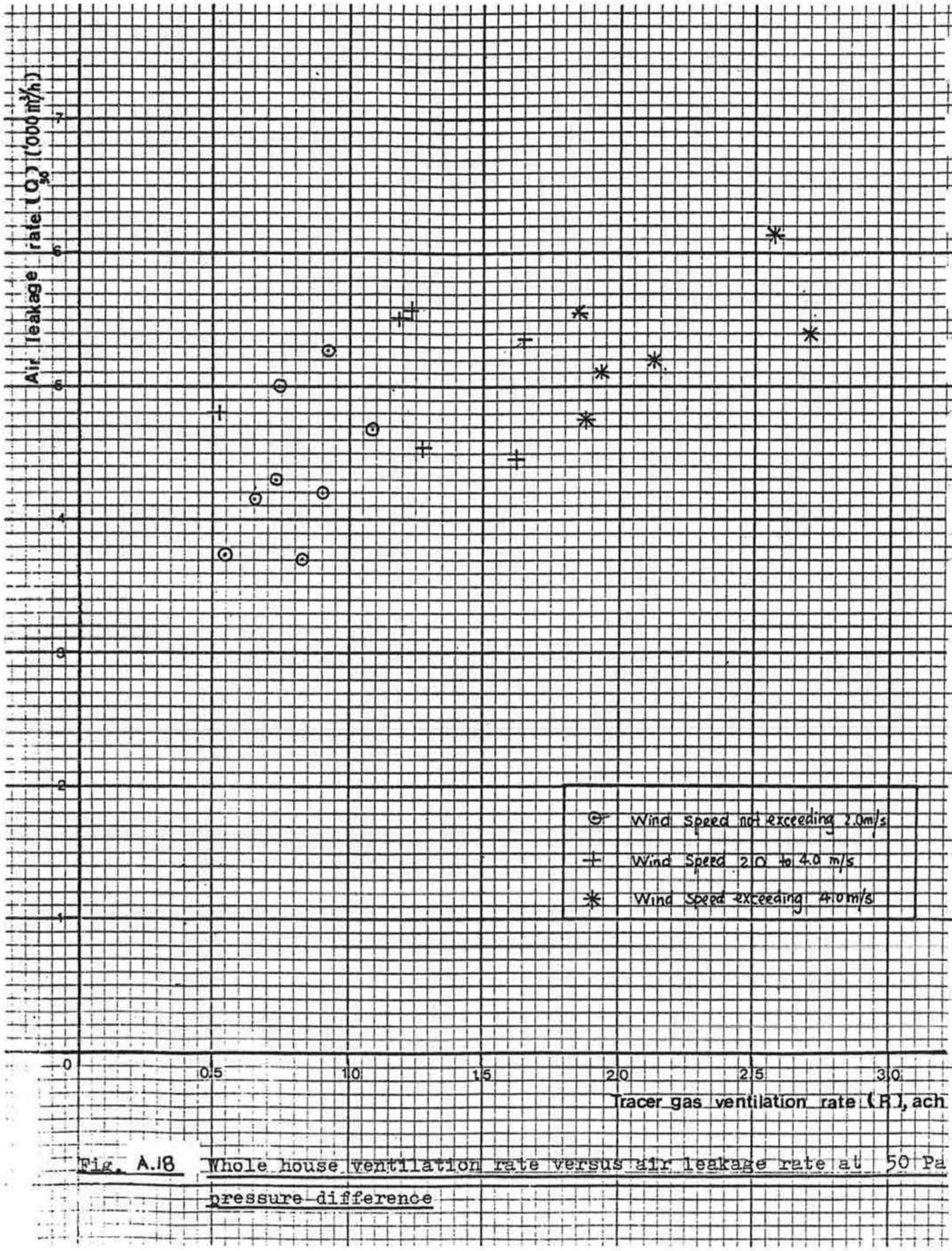


Fig. A.18 Whole house ventilation rate versus air leakage rate at 50 Pa pressure difference

PART B : IMPACT OF WINDOW-OPENING HABITS ON NATURAL VENTILATION RATES

B.1 Introduction

An important aspect of determining actual ventilation rates in houses is the occupant's behaviour in opening windows. The opening of windows by just a small amount can increase the air change rate several times. Unfortunately, this factor has been ignored in existing prediction models for most cases.

Factors which influence occupants to open or close windows can be summarised within four groups (see Fig. B1):

a) External conditions such as wind, temperature, precipitation and noise.

b) Internal conditions such as temperature, humidity and quality of air.

c) Occupancy effects such as size of family, periods of occupancy each day and number of cigarette smokers in family.

d) Psychological factors such as energy-saving consciousness, behaviour learned in early childhood, stress factors and other.

Earlier investigations by the Building Research Station [1] some thirty years ago and recently by Brundrett[2] indicated that housewives systematically opened their windows more as the outdoor temperature increased. The intention of this study is to extend the survey to modern low energy houses in more detail. To identify the main features of weather and psychological factors, three procedures are needed. Firstly, a regular observation of a number of houses over a long period of time; secondly, a systematic recording of the weather data over the same period; and thirdly, a questionnaire or interview with the households in each family. Concurrently, this study also includes measurements of ventilation rates with windows first closed and then adjusted to varying amounts, by tracer gas and pressurisation technique as described in Section A.

B.2 Outline of investigation

B.2.1 Window opening observation

A regular survey had been undertaken over the same group of forty-two houses (one of these houses is unoccupied because of fir damage). All rooms with an open window were observed and recorded for the whole year of 1981. Open window conditions were classified into

Condition 1 - Window tightly closed

Condition 2 - Catch on first notch (approximately $1^{o}30'$ or 10 mm gap)

Condition 3 - Window open to main stop (approximately 6^{o} or 45 mm gap)

Condition 4 - Window open wider than condition 3 (ranging from 10^{o} to 90^{o})

For the sake of convenience, window open to condition 3 is referred to as a standard open window, condition 2 is taken as half and condition 4 as twice the standard open window respectively when the total open windows are added at the end of each observation. This is purely an arbitrary decision.

B.2.2 Weather data

Outdoor air temperature, relative humidity, wind speed and direction and rainfall are monitored continuously with the weather station mounted at a height of approximately four metres above ground level. (Detailed description is given in Section A3.)

B.2.3 Survey of family characteristic and behaviour

Questionnaires were sent to all residents in November 1981. The questionnaire was designed to elicit basic factors such as size of each family, period of occupancy in each day; and records user habits such as smoking and finally to ascertain what the person's own reasons and opinions on window opening were. Twenty-five out of forty-two houses on the site returned their answers within one month. The remaining residents were interviewed on a face-to-face basis.

B.3 Survey results

B.3.1 Window opening observations

The relationship between the number of rooms with an open window and outdoor air temperature derived from the observations over a year is given in Fig. B2 and B3. A definite correlation between window opening and outside air temperature can be established; of even greater significance is the difference between 'test' house and control' house occupants. (See Table B.1). Using regression analysis, the empirical equations for (average) 'test' and 'control' houses are found to be :

for 'test' houses,

$$W = 0.687 + 0.149 \, T_0 \qquad \ldots \quad (B.1)$$

for 'control' houses,

$$W = 0.329 + 0.158 \, T_0 \qquad \ldots \quad (B.2)$$

where W = number of rooms with open windows
T = outside air temperature in ^0C

The distribution of rooms containing open windows is shown in Fig. B4. A close agreement between the results of Brundrett and the present one was found. Bedrooms are the most common rooms for open windows, and other following the same pattern though to a smaller magnitude.

The detail breakdown of relationship between open windows and outside air temperature for bedrooms, w.c., living room, kitchen and dining room are included in Appendix B.

B.3.2 Survey of family characteristics and window-opening habits

Table B.2 shows the three important family characteristics which influenced the number of rooms with open windows. The first characteristic was the size of family. Table B.2a shows that the number of open windows increased with the number of occupants in the family. The second was period of occupancy in the house. About 75% of the houses in this study were occupied continuously; the remainder have been classified as 'split-occupation' where no-one is in the house for any significant time period throughout the working day. Table B.2b shows that 'split-occupation' houses had only about 70% of the window open compared to those houses of continuous occupation. The third characteristic was the number of persons smoking in the family. Table B.2c shows that for any additional smoker in each family the number of the open windows was increased by about 20%.

Fig. B5a, B5b, and B5c show that bedrooms were the rooms most frequently ventilated. Almost 80% of the occupants open their bedroom windows daily and half of this 80% open the windows for more than 8 hours. Although kitchen windows were ranked second after bedroom windows, about half of these were opened for less than 2 hours.

To freshen the room air was ranked as the most likely reason for keeping windows open both in summer and in winter as shown in Fig. B.5d. The majority of the households kept their windows closed in order to save energy and avoid draughts. (See Fig. B.5e).

Table B.3 lists the answers to the questions relating to window-opening habits.

B.4 Discussion of results

The results of this study confirms the findings of two previous studies by Dick and Thomas and Brundrett. The observations showed a strong seasonal pattern with more windows being closed with the approach of winter and then a re-opening of windows with the approach of warmer weather. At the temperature of $0^{o}C$, about half of the houses had one window open. There is a distinctive difference between 'test' house and 'control' house occupants in their window-opening behaviour, approximately twice as many rooms had open windows in the 'test' houses as in the 'control' houses in the heating season. One possible explanation for this is that the 'test' house occupants are running their houses at higher internal air temperatures and are controlling inside temperatures by window opening and hence increasing the space heat consumption and undoubtedly the ventilation heat losses (See Table B.4).

The rate of ventilation heat loss is theoretically given by

$$H_v = C \rho Q \ (T_i - T_o) \qquad \ldots\ldots \quad (B.3)$$

where T_i = indoor air temperature (^oC)

T_o = outdoor air temperature (^oC)

C = specific heat capacity of air (993 J/kg.K)

ρ = density of air (1.25 kg/m^3 at 10^oC)

Q = volume flow rate (m^3/s)

Let v = volume of enclosed space, R = number of air changes per hour (ach). Then

$$H_v = \frac{1.25 \times 993 \times V \times R \times 24}{3600 \times 1000} \text{ kWh/day} \qquad \ldots\ldots \quad (B.4)$$

The effect of window-opening ventilation on daily energy consumption as shown in Fig. B.6 indicated that 'test' houses are consuming 40% more energy than 'control' houses at 0^oC. The percentage difference diminishes as the outdoor air temperature increases. It also showed that the proportion of energy losses through natural ventilation are much greater than the normal assumption of one air change per hour for heat loss calculation for British houses.

Windows in bedrooms are most frequently opened and kept open for longer periods. The survey revealed that the next most popular room to have an open window but of much shorter duration, is the kitchen. No significant difference was found between rooms of 'test' and 'control' houses except bedrooms.

Large variations were found to exist in window opening behaviour from household to household but bascially there are three significant family factors which influence the number of rooms with open windows. The first factor was the size of family. Results showed that the number of open windows for both 'test' and 'control' hosues increased progressively with the number of occupants in the family. The second factor was whether the house was continuously occupied or not. Houses with split-occupation were found to have only about 70% of the window open compared to those houses of continuous occupation. When the houses were to be left unoccupied for a few hours (e.g. for working housewives) 55% of 'test' house occupants as compared to 28% of 'control' house occupants replied that bedroom windows were to be left open on a cold morning while other windows remained tightly closed. The number of persons smoking in the family was the third factor which influenced the number of open windows. Results indicated that for every additional smoker in the family there will be an increase of about 20% of open windows. The most probable reason for this was that more fresh air was needed for odour dilution.

Nearly half of the total forty-one houses kept one or more windows open during the winter night. Of those houses with open windows, about one quarter of them had their internal connecting doors opened. This will most certainly result in tremendous heat loss from the building to the exterior surrounding.

The results of ventilation rate measurement (presented and discussed in Section A.5) showed that opening a window by just a small amount can increase the number of air changes by a factor of 2 to 5. The air change rates from open windows are highly variable due to the complex interaction of many factors. To better understand how these and other factors combined to produce high air change rates requires further research.

B.5 Conclusions

a) The most important contribution to the total air change rate is the effect of open windows. Opening windows just a small amount can increase the number of air changes by several times.

b) The observation has established that there is a definite relationship between the number of rooms with open windows and outdoor air temperatures.

c) There is a significant difference between 'test' house and 'control' house occupants in their window-opening behaviour.

d) 'Test' houses consume more energy than 'control' houses to sustain the higher ventilation rate in the heating season.

e) Bedrooms are the rooms most frequently ventilated and kept open for longer periods.

f) The frequency of open windows increases with growing family size.

g) Houses which are continuously occupied are much more likely to have an open window.

h) The frequency of open windows increases with every additional smoker in the family.

B.6 References

1. Dick, J.B. & Thomas, D.A. Ventilation research of houses, Journal of IHVE, 1951, Vol. 19, October, p. 306.

2. Brundrett, G.W. Ventilation : A Behavioural approach. Energy Research, 1977, Vol. 1, p. 289.

Table B.1 : Detail of the results

Total Houses = Sample of 41 houses

Control Houses = Sample of 23 houses

Test Houses = Sample of 18 houses

Empirical expression :

$$W = A + B\,T_o$$

where W = number of rooms with open windows

T_o = outdoor air temperature in ^oC

a) For all the houses

Room		Value of A	Value of B	Correlation coefficient
Total :	Total	19.929	6.328	0.95
	Control	7.569	3.638	0.94
	Test	12.360	2.690	0.94
Bedrooms :	Total	15.337	2.669	0.94
	Control	5.786	1.535	0.93
	Test	9.551	1.133	0.89
W.C. :	Total	3.368	0.986	0.85
	Control	1.406	0.602	0.87
	Test	1.962	0.384	0.81
Bath :	Total	1.256	0.851	0.86
	Control	0.528	0.521	0.86
	Test	0.728	0.330	0.83
Kitchen :	Total	0.441	0.622	0.91
	Control	0.211	0.347	0.87
	Test	0.230	0.275	0.81
Living :	Total	-0.412	0.892	0.87
	Control	-0.272	0.486	0.83
	Test	-0.140	0.407	0.81
Dining :	Total	-0.141	0.351	0.75
	Control	-0.282	0.191	0.70
	Test	0.140	0.161	0.63

b) For an average house

Room		Value of A	Value of B	Correlation coefficient
Total :	Total	0.486	0.154	0.95
	Control	0.329	0.158	0.94
	Test	0.687	0.149	0.94
Bedrooms :	Total	0.374	0.065	0.94
	Control	0.252	0.067	0.93
	Test	0.531	0.063	0.89
W.C.	Total	0.082	0.024	0.85
	Control	0.061	0.026	0.87
	Test	0.109	0.021	0.81
Bath	Total	0.031	0.021	0.86
	Control	0.023	0.023	0.81
	Test	0.040	0.018	0.83
Kitchen :	Total	0.011	0.015	0.91
	Control	0.009	0.015	0.87
	Test	0.013	0.015	0.81
Living :	Total	-0.010	0.022	0.87
	Control	-0.012	0.021	0.83
	Test	-0.008	0.023	0.81
Dining :	Total	-0.003	0.009	0.75
	Control	-0.012	0.008	0.70
	Test	0.008	0.009	0.63

Table 8.2: Family Characteristics

a) Influence of family size on rooms with open window

Family size	Size of sample	For one whole year			Winter only		
		Total	Test	Control	Total	Test	Control
Two persons	4	1.39 (4)	1.39 (4)	-	0.73 (4)	0.73 (4)	-
Three persons	11	2.03 (11)	1.78 (2)	2.09 (9)	1.10 (11)	1.11 (2)	1.10 (9)
Four persons	20	2.51 (20)	2.52 (8)	2.50 (12)	1.59 (20)	1.60 (8)	1.59 (12)
Five persons	5	3.41 (5)	3.70 (3)	2.99 (2)	2.10 (5)	2.37 (3)	1.69 (2)
Seven persons	1	6.14 (1)	6.14 (1)	-	3.90 (1)	3.90 (1)	-

b) Influence of period of occupancy on rooms with open window

Period of occupation	Size of sample	For one whole year			Winter only		
		Total	Test	Control	Total	Test	Control
Continuous	31	2.72 (31)	3.04 (11)	2.55 (20)	1.66 (31)	1.89 (11)	1.54 (20)
Non-continuous	10	1.86 (10)	1.87 (7)	1.83 (3)	1.09 (10)	1.16 (7)	0.94 (3)

c) Influence of number of persons smoking on room with open window

No. of smokers	Size of sample	For one whole year			Winter only		
		Total	Test	Control	Total	Test	Control
No	14	1.98 (14)	1.84 (5)	2.06 (9)	1.14 (14)	1.19 (5)	1.11 (9)
One	14	2.35 (14)	2.68 (5)	2.16 (9)	1.53 (14)	1.69 (5)	1.44 (9)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table B3: Survey of questions relating to window-opening habits, and of answers to these

Questions and Answers	% Responce		
	Total N=41	Test N=18	Control N=23
Q. 3a) In the winter, how often are one or more windows kept opened during the night ?			
Answers :			
a) Every night/most nights	44	44	44
b) Sometimes	17	17	17
c) Never	39	39	39
Q. 3b) When windows are kept open during the winter, are doors to those rooms usually closed, or usually opened ?			
Answer :			
a) Usually closed	68	55	78
b) Sometimes shut, sometimes not	12	17	9
c) Usually opened	20	28	13
Q. 3c) Would you consider opening a window when heating is on ?			
Answer :			
a) Yes	65	56	73
b) No	35	44	27
Q. 3d) Does the daily outdoor temperature influences the number of windows you open each day ?			
Answer :			
a) Yes	73	61	83
b) No	24	33	17
c) Not sure	3	6	-

Table 83 (cont'd)

Questions and Answer	% Response		
	Total N=41	Test N=18	Control N=23
Q. 3e) Does the increase of wind speed influence the number of windows you open each day ?			
Answer :			
a) Yes	56	67	48
b) No	41	33	48
c) Not sure	3	-	4
Q. 3f) What will you do if you were about to go for a holiday of not less than one week duration ?			
Answer :			
a) Close all the windows tightly	78	82	76
b) Leave all the windows open slightly	8	6	8
c) Open all upstair windows slightly	10	12	8
d) Only bedroom windows are to be left opened	2	-	4
e) Only W.C. window is to be left opened	2	-	4
f) Only living room windows are to be left opened	-	-	-
Q. 3g) If you are the last person in the house, what will you do before you go out to work on a cold morning ?			
Answer :			
a) Close all the windows tightly	38	20	52
b) Only bedroom windows are to be left opened	40	55	28
c) Only W.C. window is to be left opened	11	15	8
d) Only Living room windows are to be left opened	4	5	4
e) Open all windows slight	-	-	-
f) Do not bother about the windows at all	7	5	8

Table B.4 Energy consumption for space heating (Dec.1979 / Dec.1980)
(Average consumption per house)

House type	Electricity + paraffin + colar gas consumption	Electricity + paraffin + colar gas consumption + other gains*
Total	8297 kW	12249 kW
Control	8001 kW	11842 kW
Test	8675 kW	12741 kW

* Excluding solar heat gains and metabolic rates.

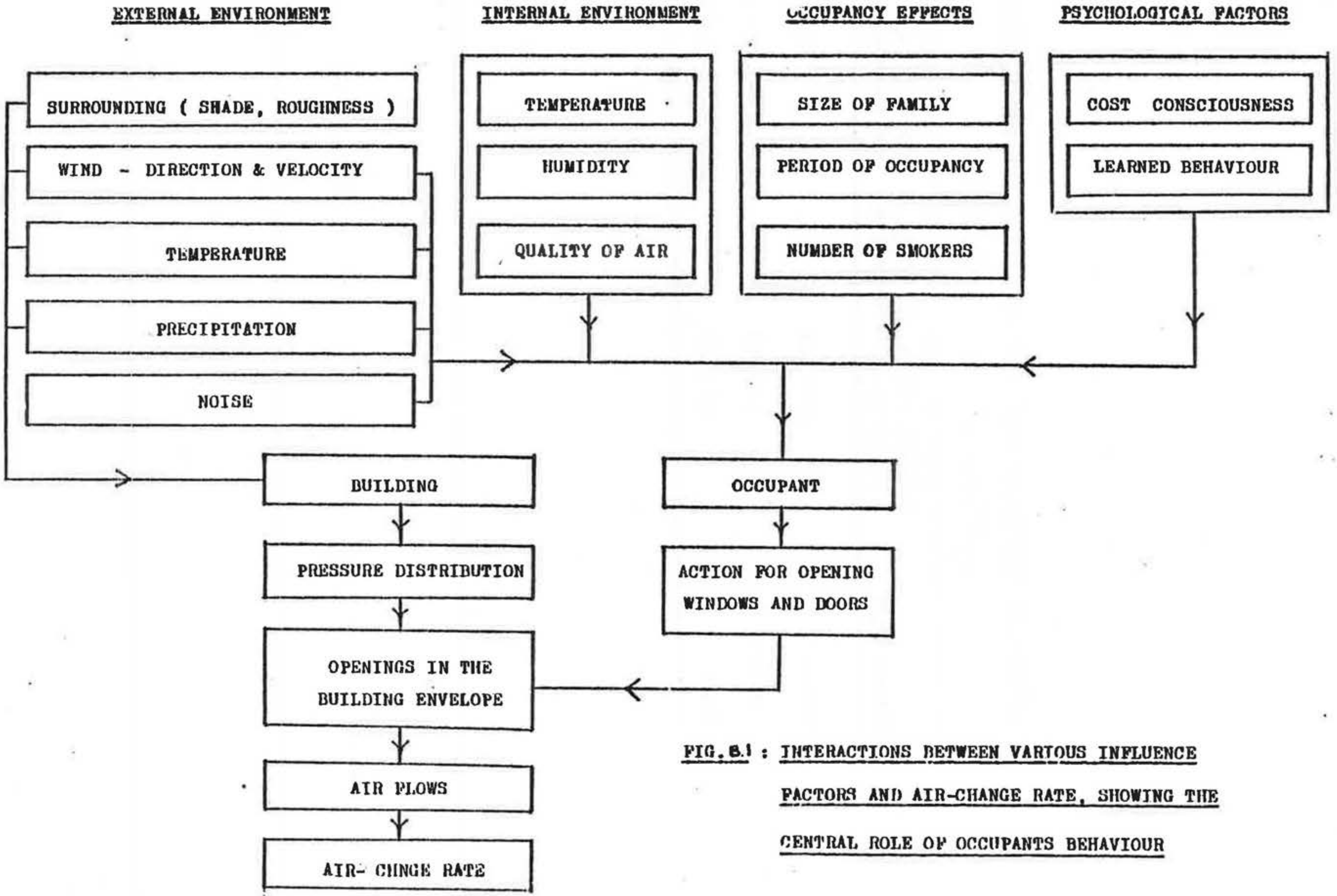


FIG. 8.1 : INTERACTIONS BETWEEN VARIOUS INFLUENCE FACTORS AND AIR-CHANGE RATE, SHOWING THE CENTRAL ROLE OF OCCUPANTS BEHAVIOUR

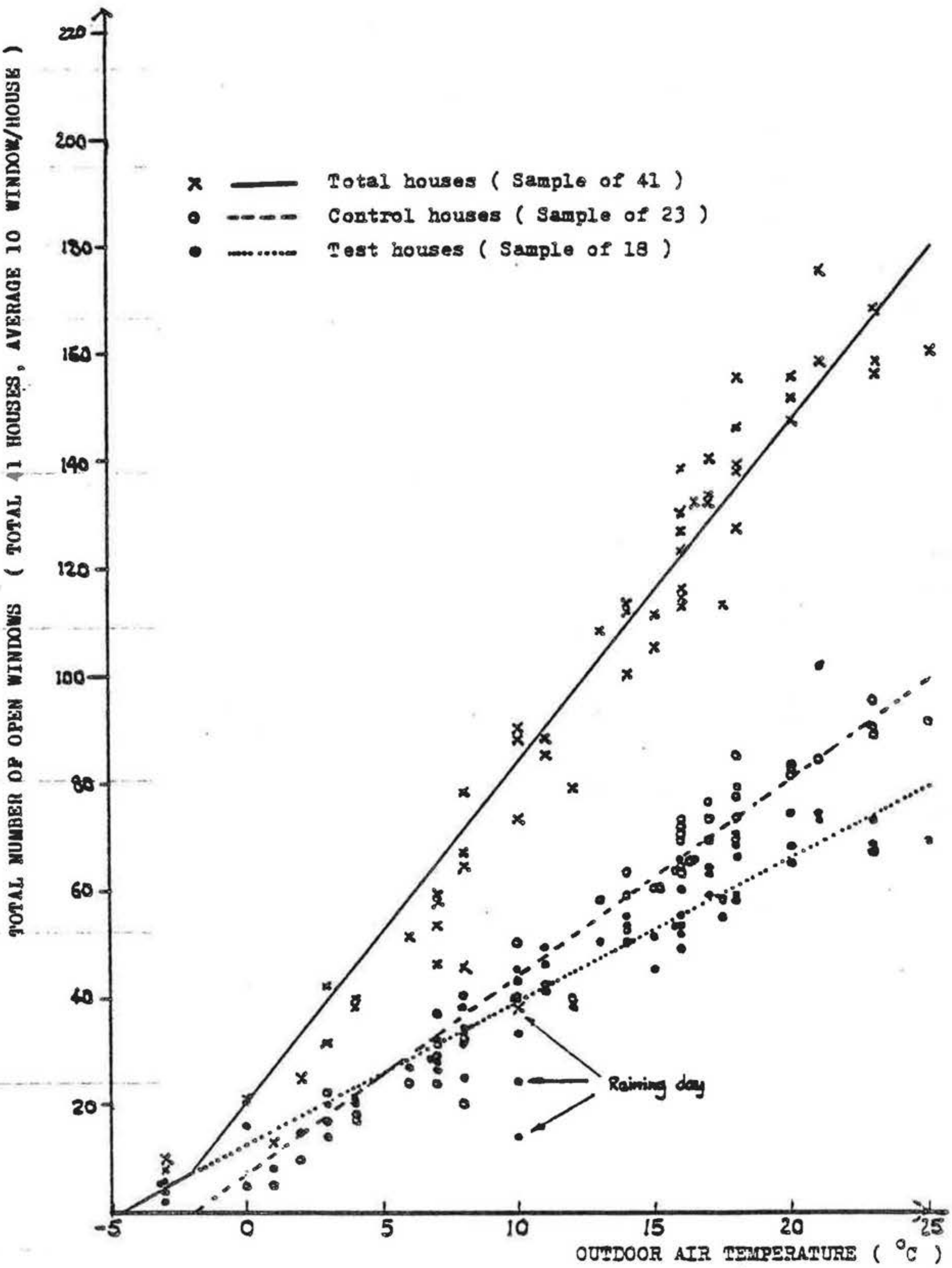


FIG. 82 : RELATIONSHIP BETWEEN WINDOWS OPEN AND OUTDOOR AIR TEMPERATURE

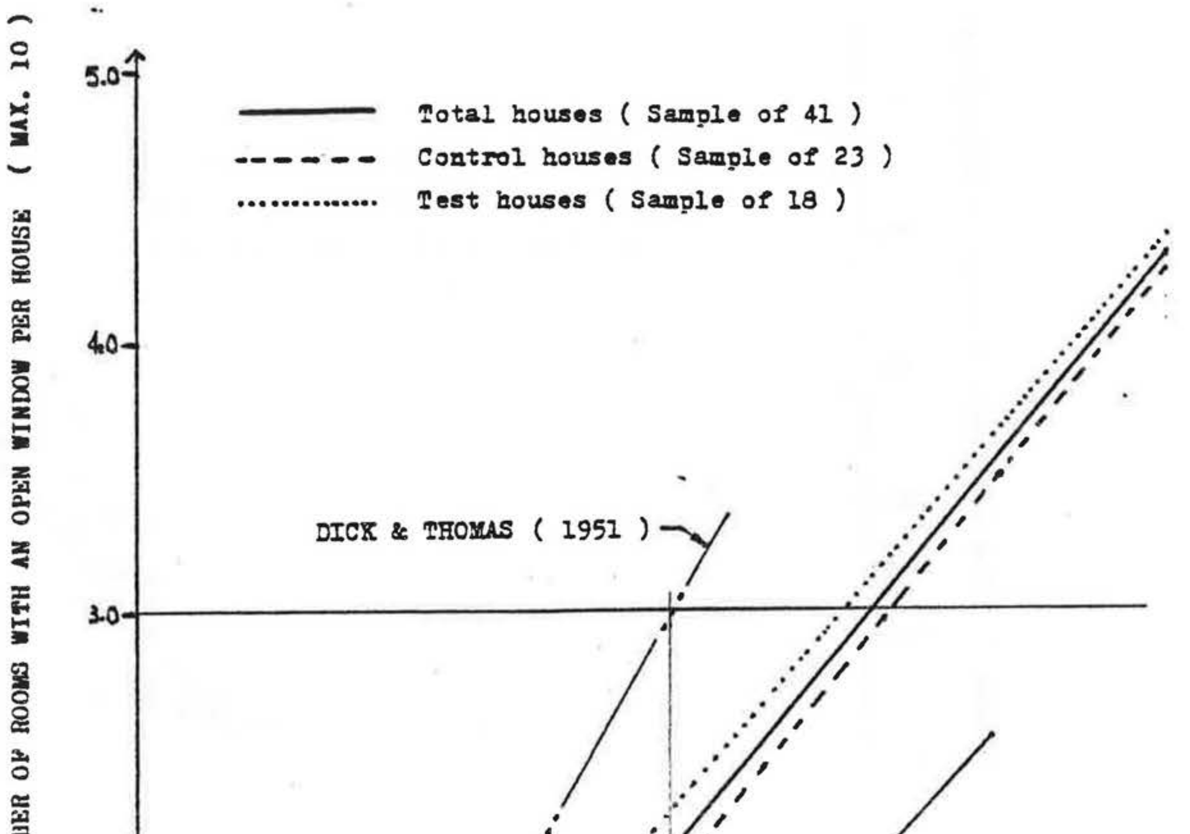


FIG. 8.3 : EFFECT OF OUTDOOR AIR TEMPERATURE ON WINDOW-OPENING BEHAVIOUR

7.83 51.08°F — 3 windows open
8.01 43.25°F — 2 " "
7.70 35.24 — 1 " "
27.5 — 0

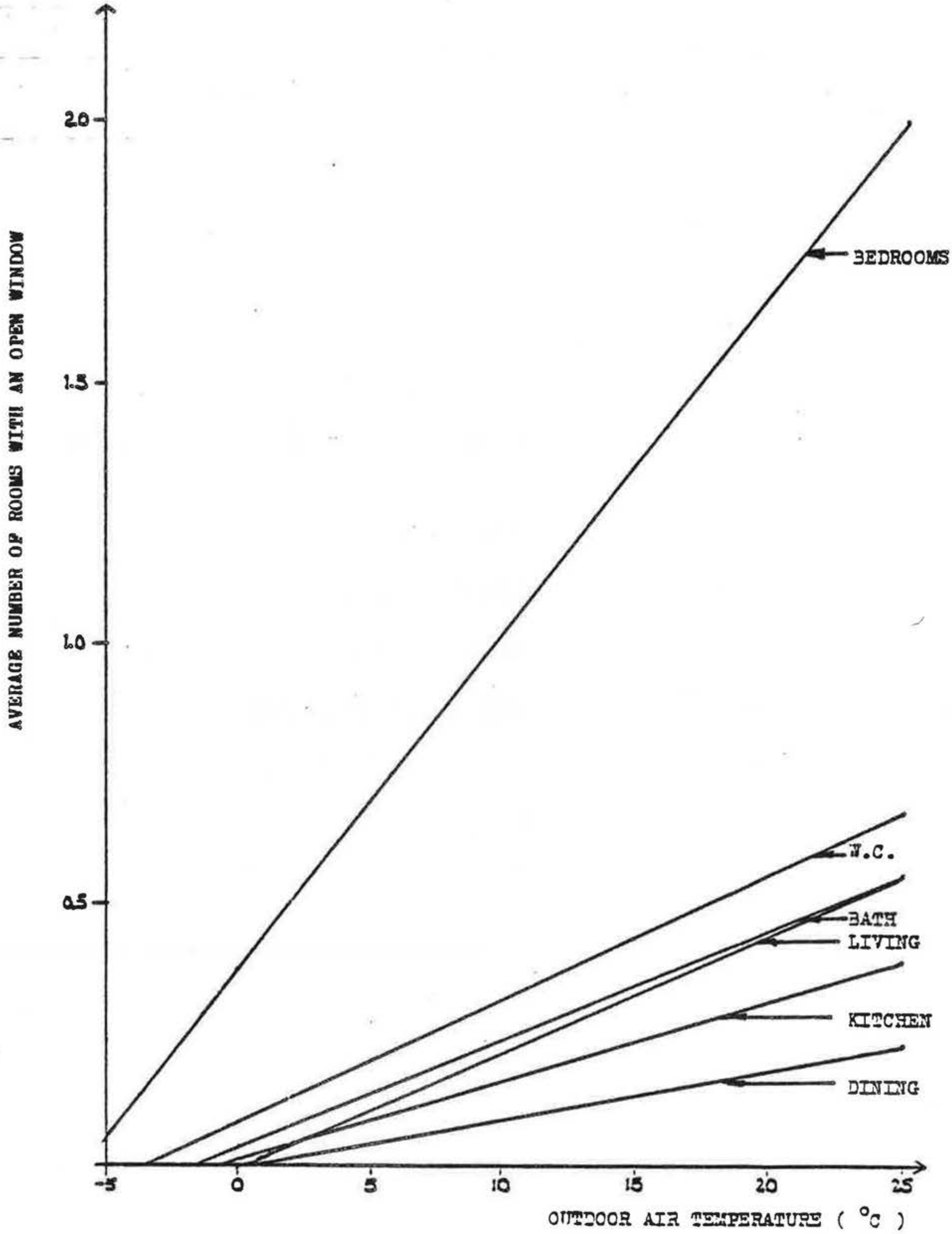


FIG.B4 : ROOMS WITH OPEN WINDOWS

Fig. B.5 : Occupants' Behaviours

a) Q. Which room do you frequently ventilate ?
(Rank 1 to 6, i.e. 1 for most frequently, and 6 for least frequent

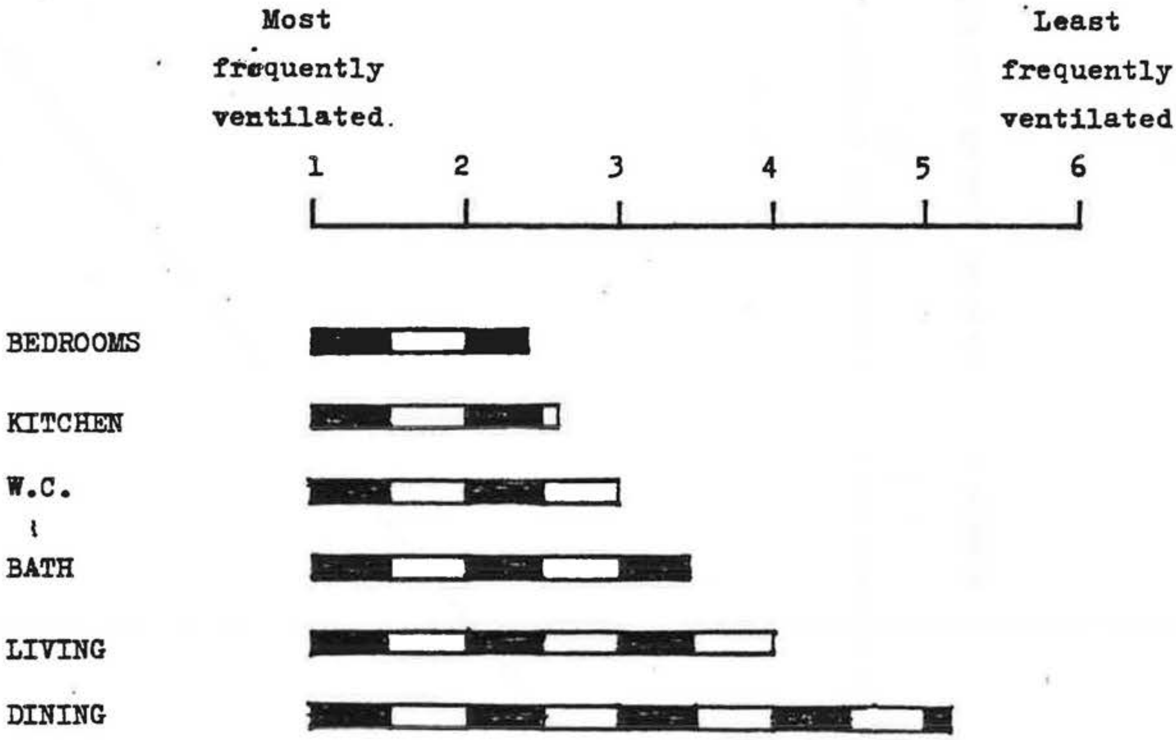
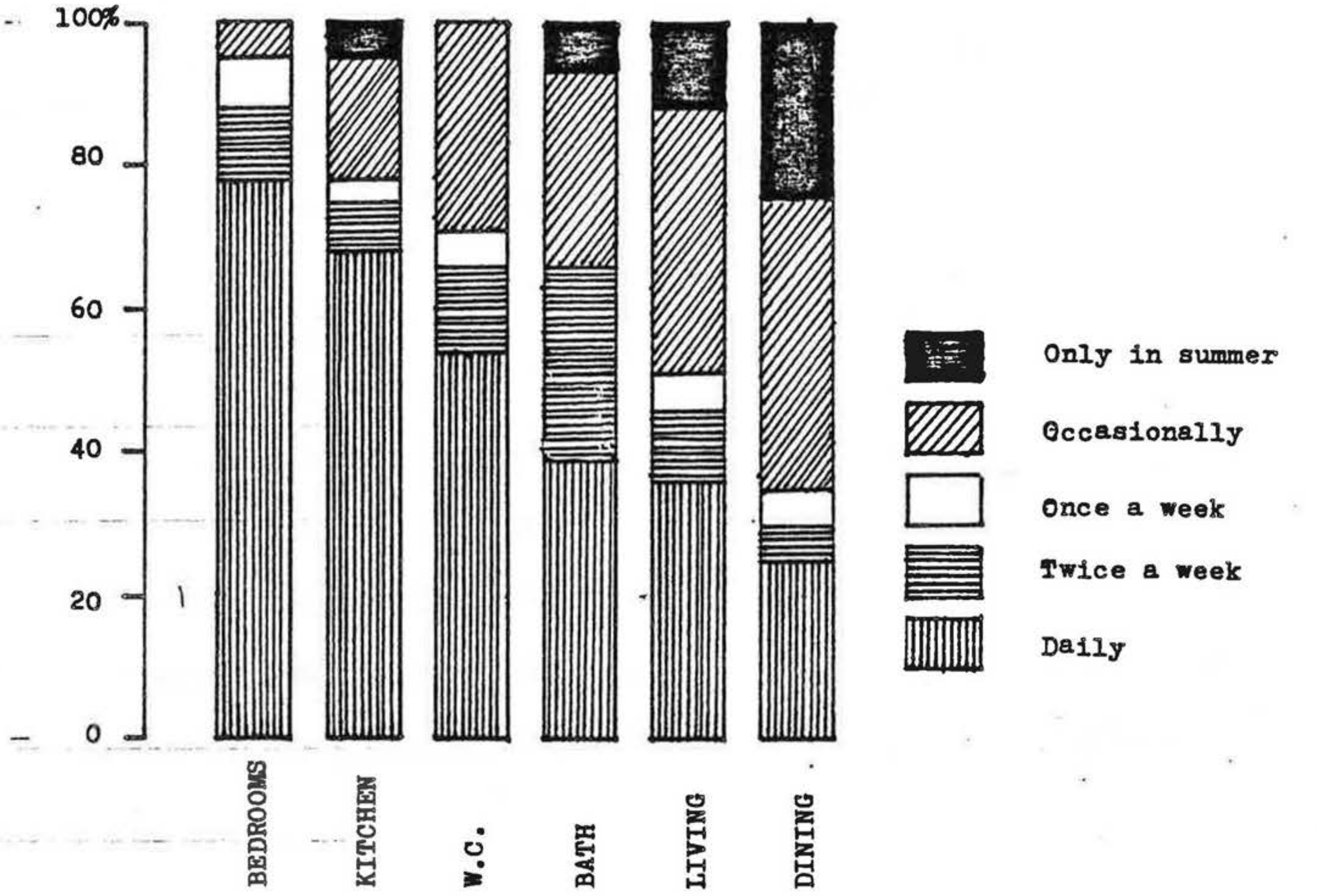


Fig. B5 (cont'd)

b) Q. How often do you open the following windows ?



c) Q. What is the duration of leaving the following windows opened ?

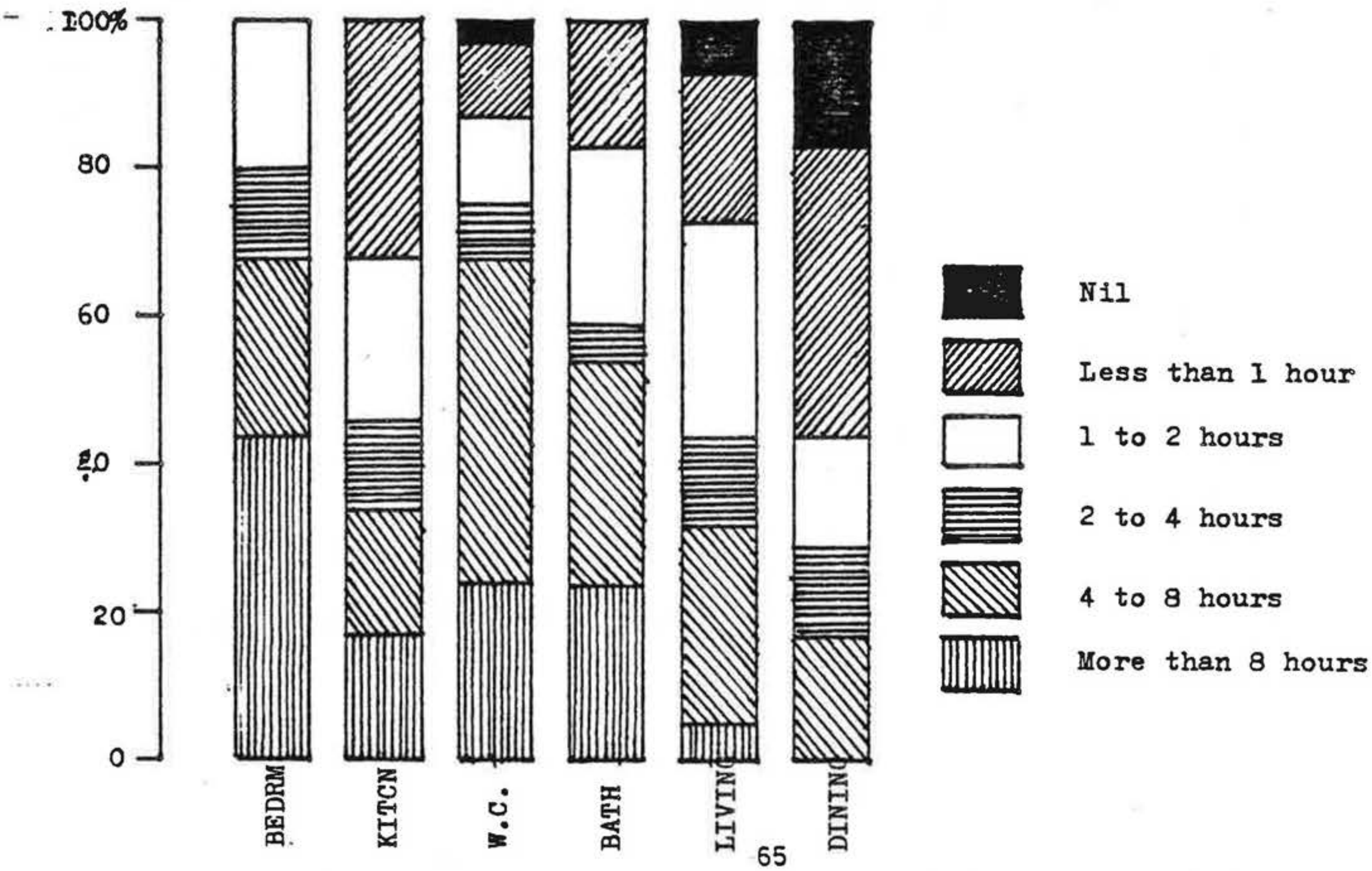
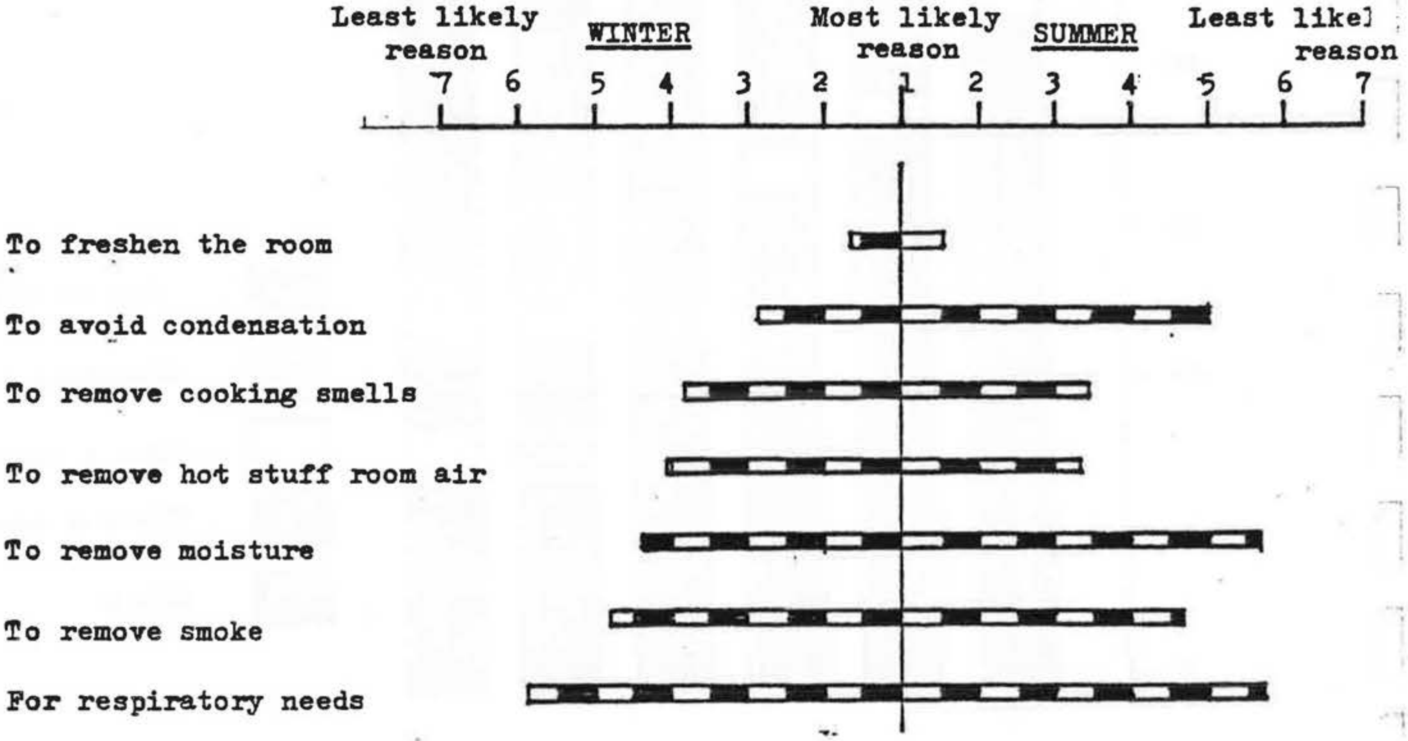


Fig. B5 (cont'd)

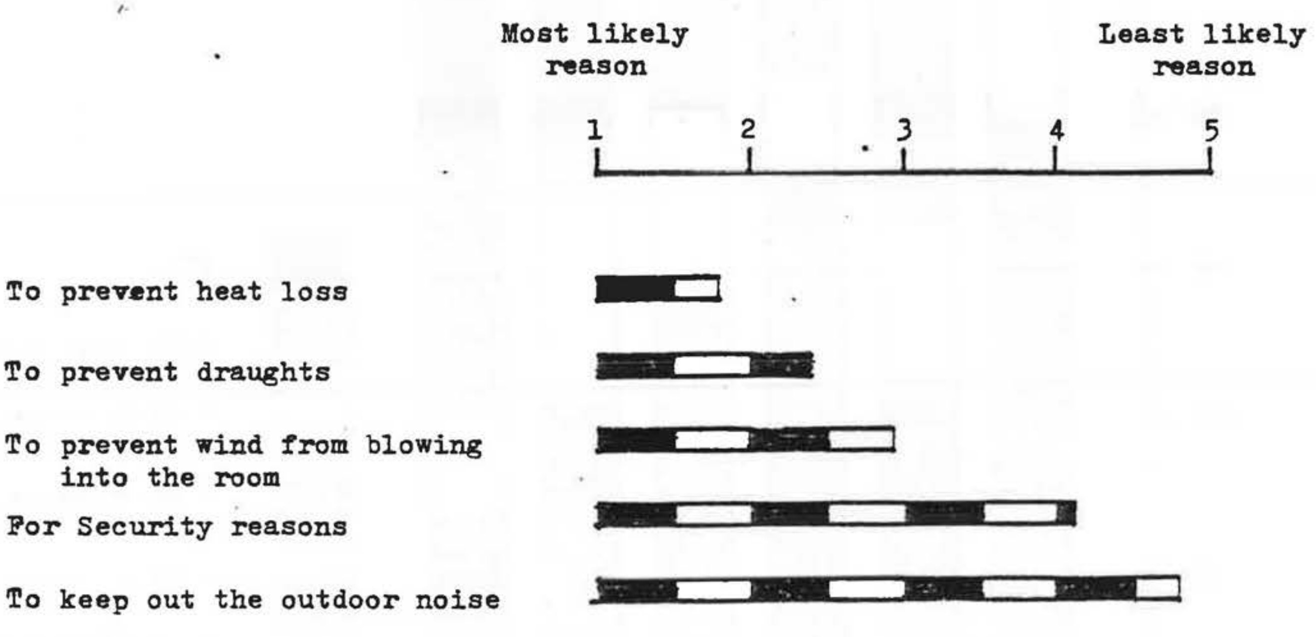
d) Q. What is the reasons for opening windows in winter and in summer ?

(Rank 1 to 7, i.e. 1 for most likely; and 7 for least likely reason).



e) Q. What is the reasons for keeping the windows closed in your house ?

(Rank 1 to 6, i.e. 1 for most likely; and 6 for least likely reason).



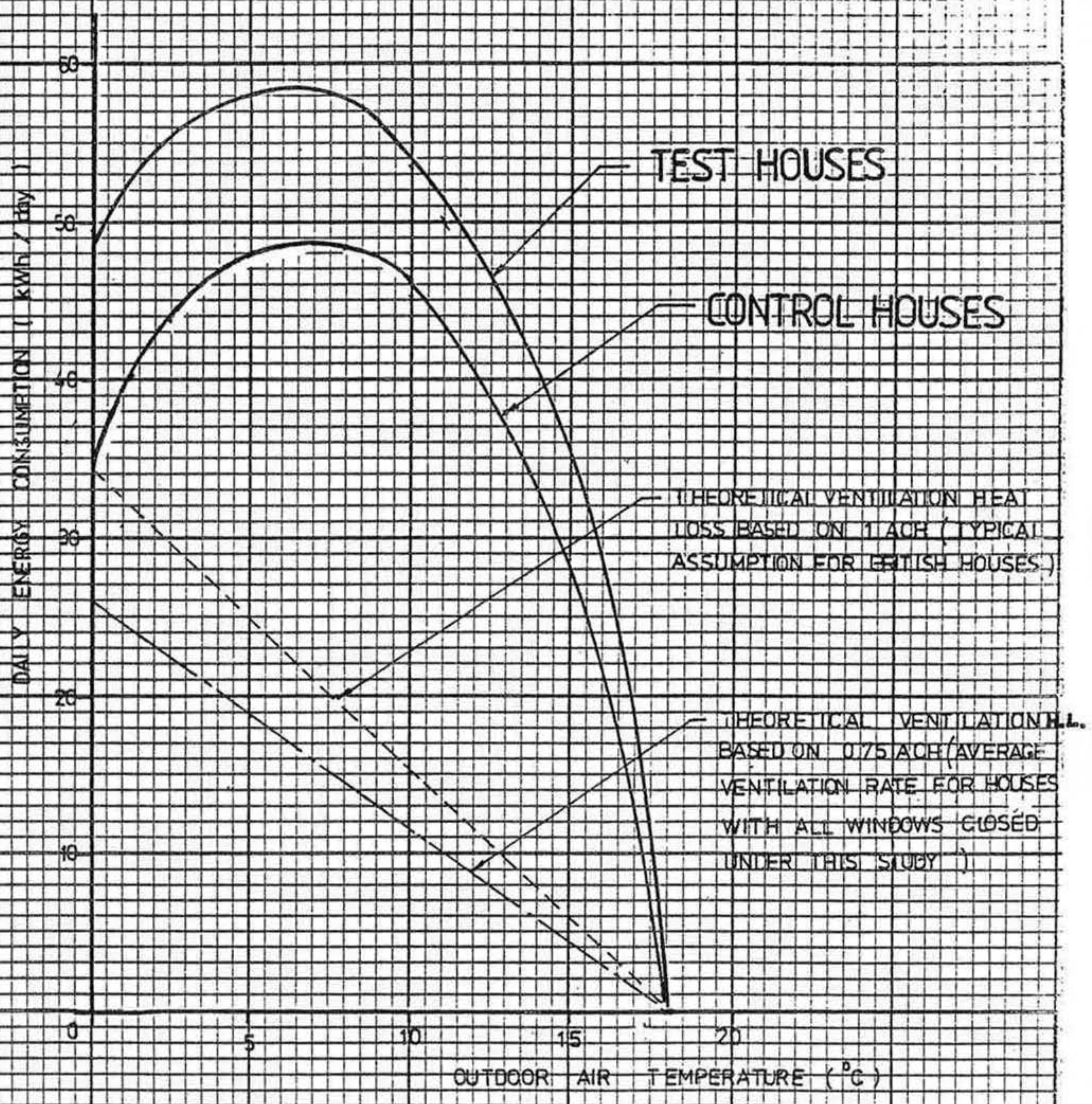
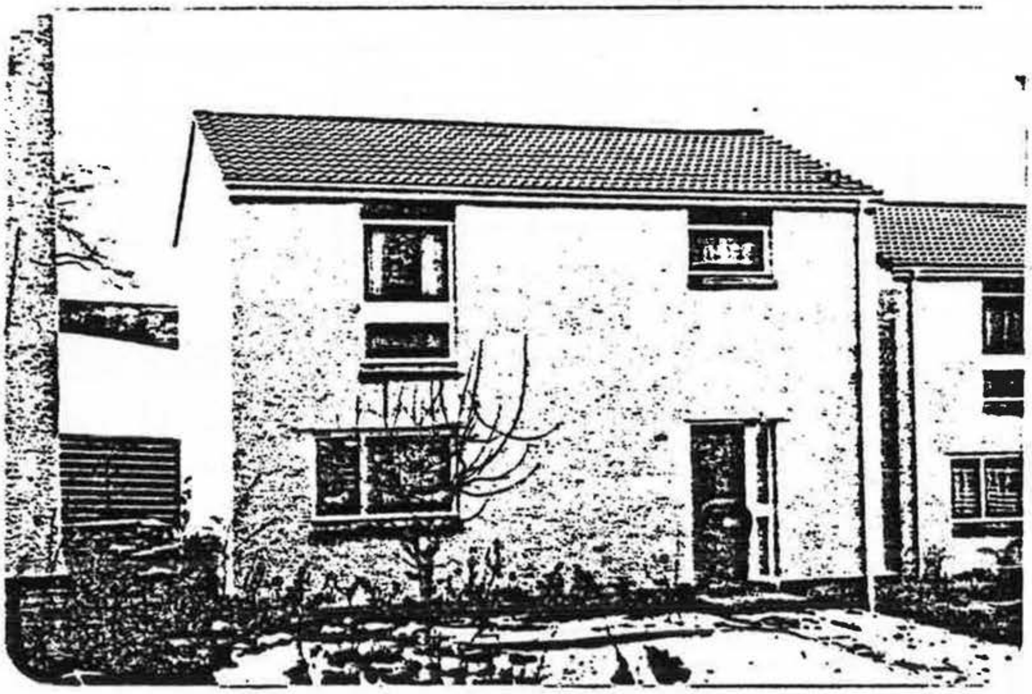


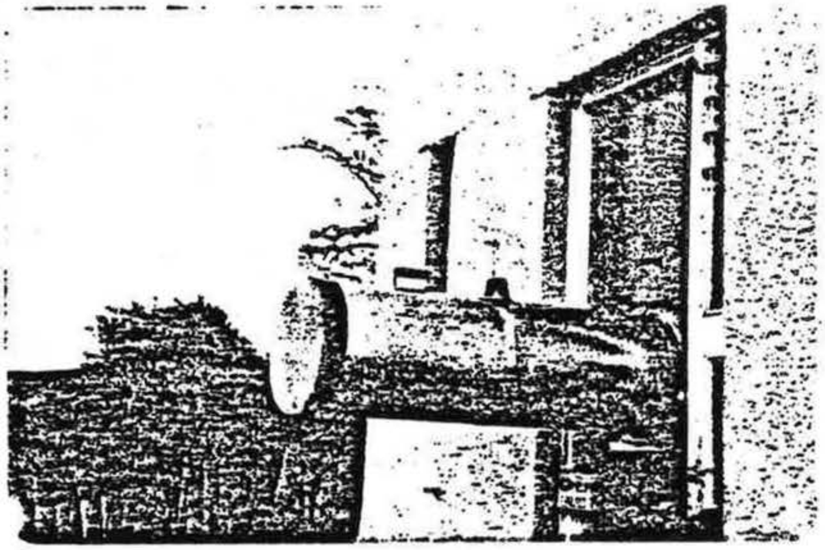
FIG. B.6 IMPACT OF WINDOW OPENING VENTILATION ON DAILY ENERGY CONSUMPTION



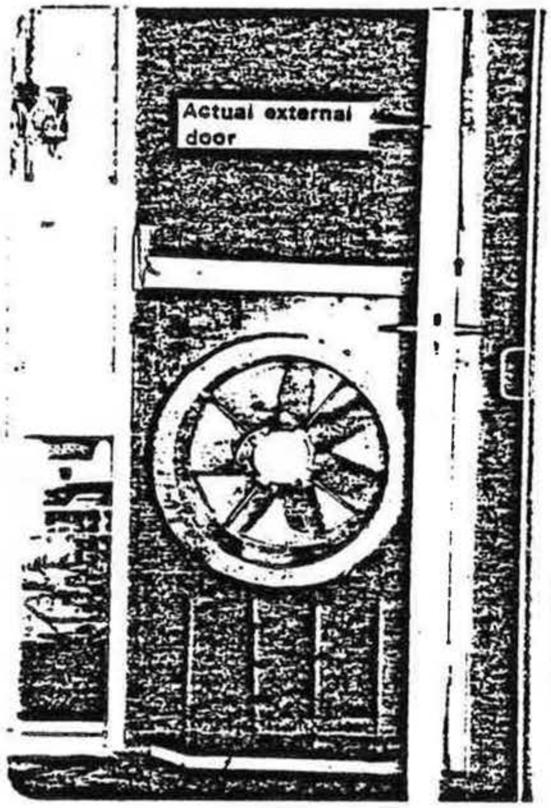
(a) Detached House

(b) End Terrace House

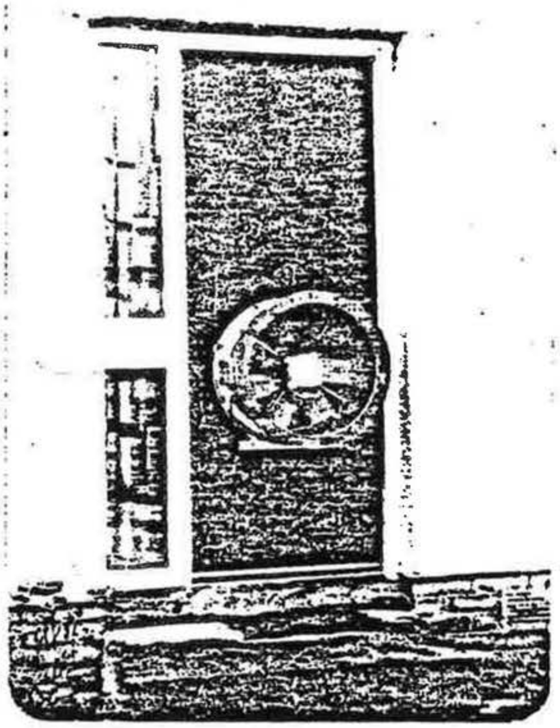
PLATE 1 : TEST HOUSES



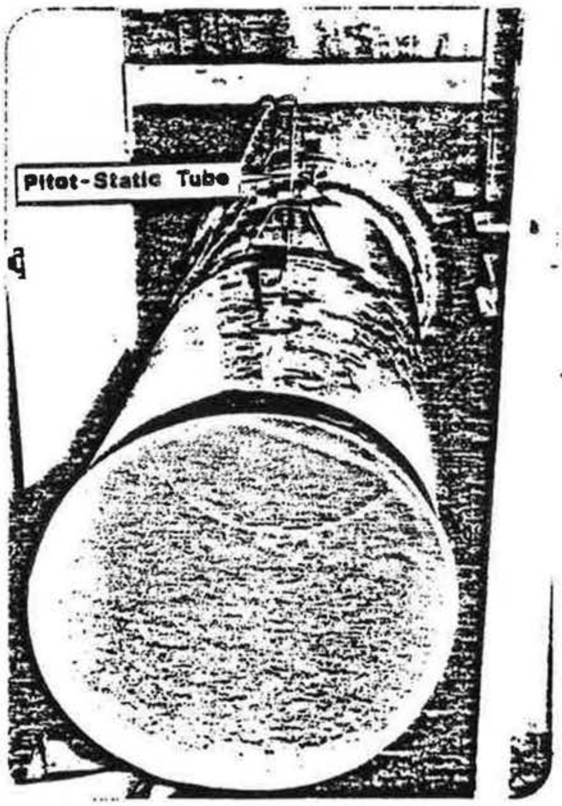
Pressurisation : External view



Pressurisation : Internal view

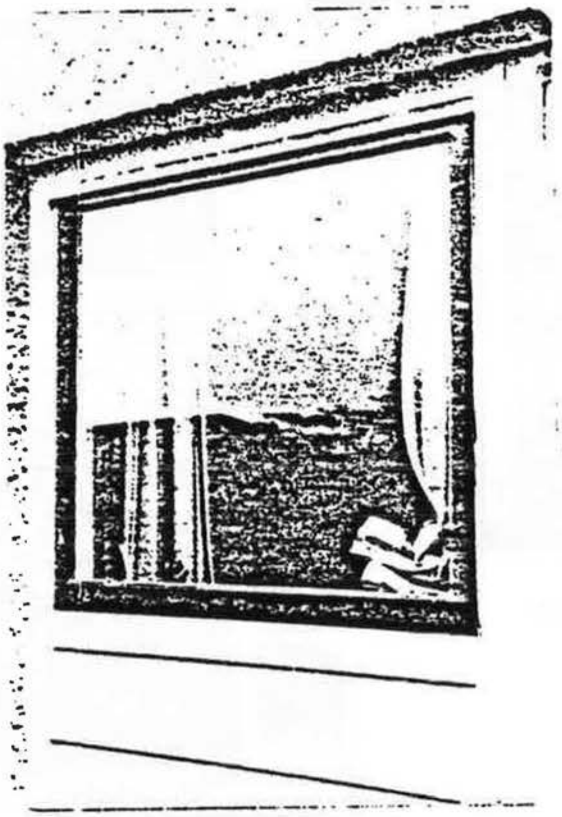


Depressurisation : External view

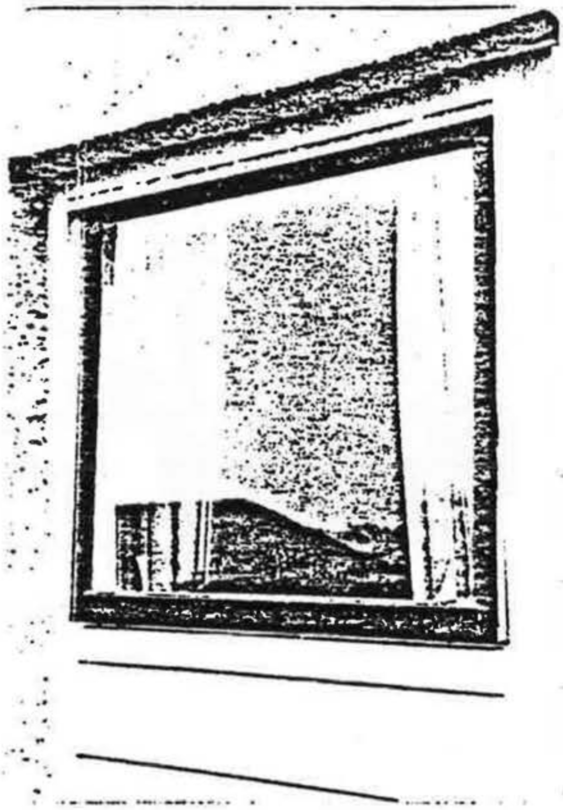


Depressurisation : Internal view

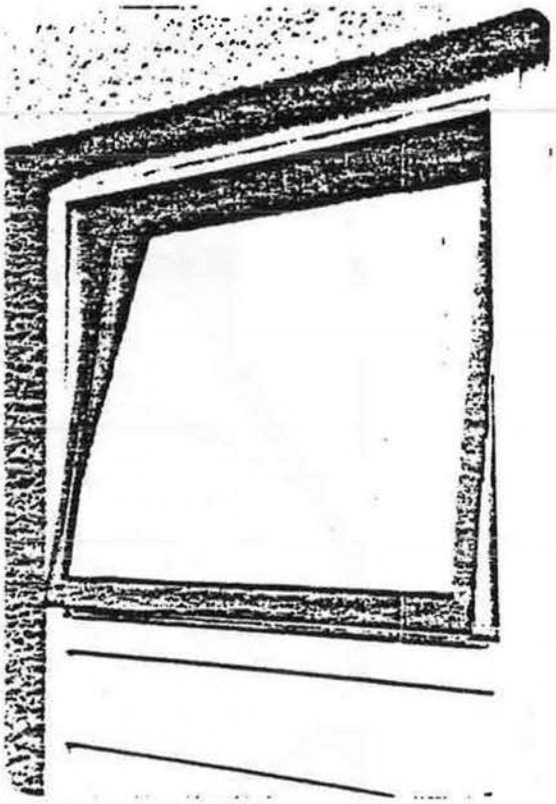
Plate 2 Pressurisation and depressurisation tests



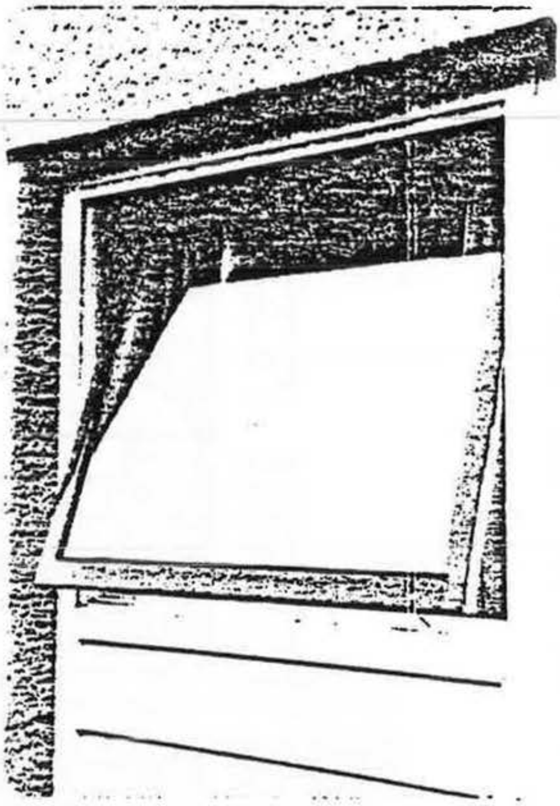
Condition 1



Condition 2

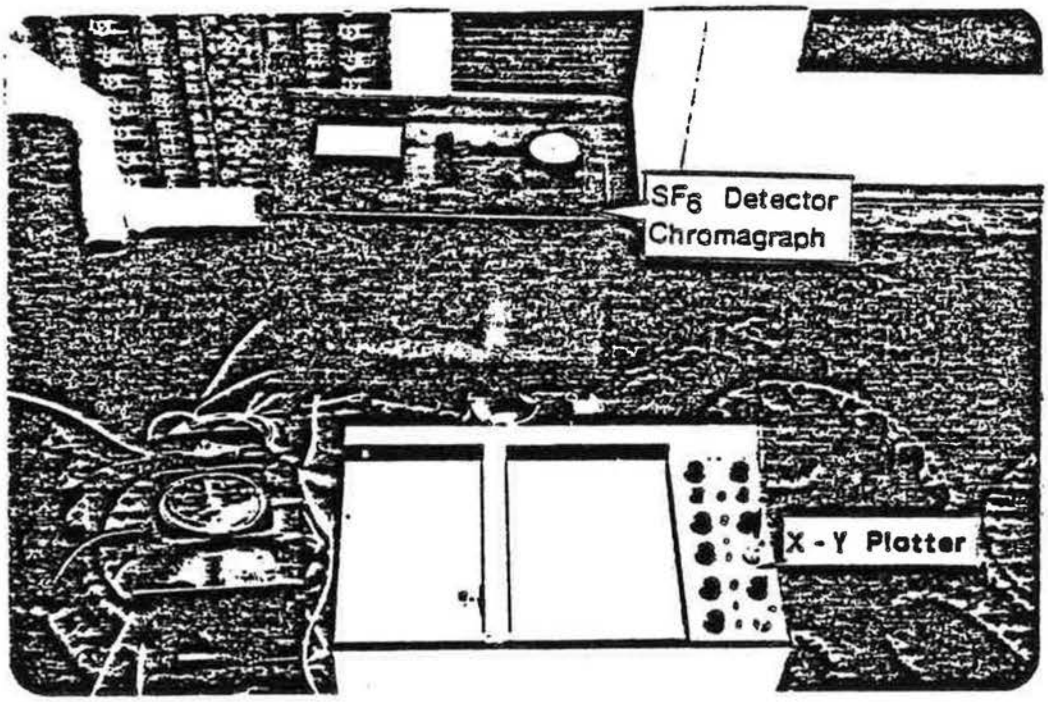


Condition 3



Condition 4

Plate 3 Conditions of window opening sequence



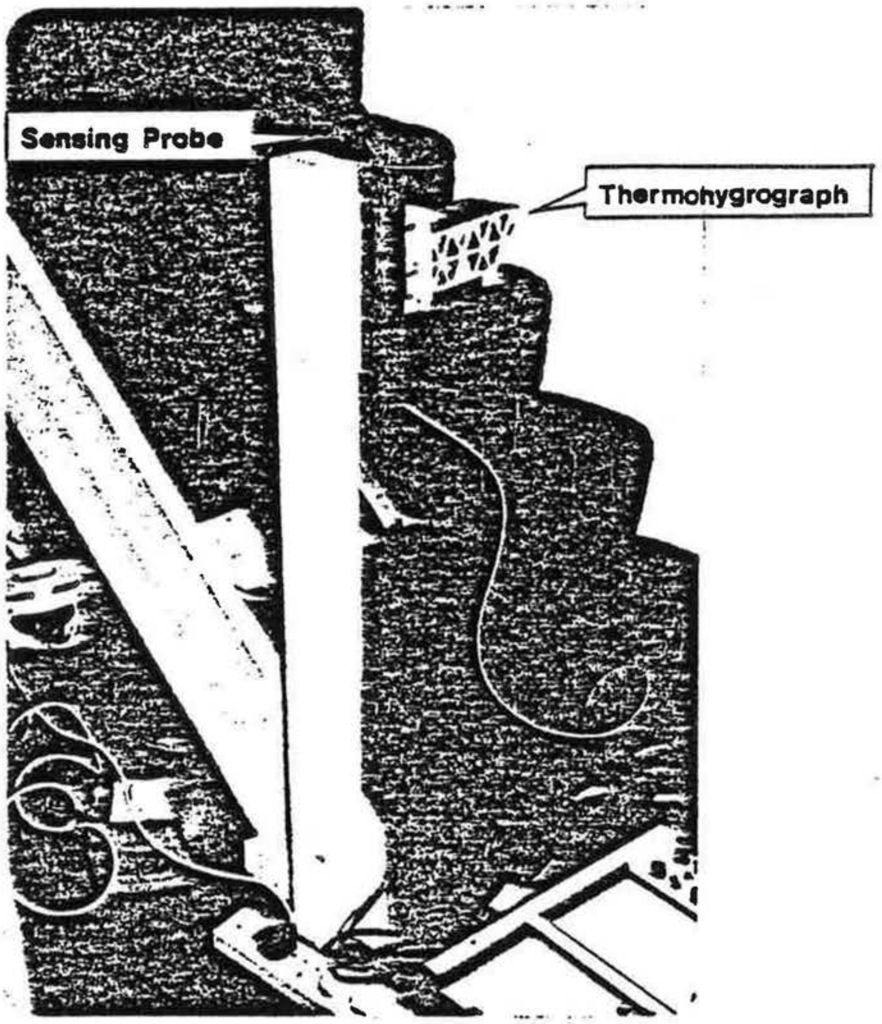


Plate 4 Instrumentation used for ventilation rate measurement

APPENDIX A1 : PRESSURISATION TESTS : RESULTS ANALYSIS

House No	Test No	Pressurisation Test				Depressurisation Test			
		α	β	R^2	Q_{50}	α	β	R^2	Q_{50}
1	1	197.77	0.782	0.9967	3824.40	195.87	0.742	0.9959	3565.09
	2	233.43	0.773	0.9987	4593.09	232.92	0.736	0.9985	4146.51
	3	401.30	0.751	0.9970	7584.39	347.69	0.739	0.9972	6266.97
	4	961.71	0.733	0.9963	16832.47	1023.22	0.657	0.9990	13361.13
3	1					312.33	0.714	0.9958	5102.50
	2					355.61	0.707	0.9992	5636.00
	3					544.60	0.705	0.9970	8580.00
	4					1138.26	0.671	0.9789	15691.52
6	1	203.96	0.779	0.9995	4287.30	221.44	0.750	0.9991	4165.06
	2	247.47	0.773	0.9988	5088.91	277.86	0.749	0.9994	5196.46
	3	436.09	0.735	0.9988	7712.53	426.92	0.723	0.9935	7215.38
	4	847.30	0.682	0.9924	12233.43	837.82	0.603	0.9971	8872.84
7	1					206.84	0.769	0.9950	4192.91
	2					256.40	0.733	0.9994	4505.08
	3					399.89	0.714	0.9984	6526.37
	4					895.60	0.709	0.9987	14358.45
8	1					411.12	0.685	0.9976	6001.01
	2					460.57	0.691	0.9970	6863.09
	3					653.73	0.688	0.9970	9650.33
	4					1146.23	0.662	0.9790	15264.14
11	1	178.98	0.779	0.9995	3763.72				
	2	233.84	0.792	0.9997	5175.90				
	3	444.44	0.789	0.9976	9741.82				
	4	816.25	0.741	0.9895	14805.69				
12	1	275.16	0.762	0.9978	5431.21				
	2	328.70	0.767	0.9950	6614.30				
	3	446.93	0.766	0.9930	8963.29				
	4	915.35	0.618	0.9990	10253.51				

House No	Test No	Pressurisation Test				Depressurisation Test			
		α	β	R^2	Q_{50}	α	β	R^2	Q_{50}
13	1	262.95	0.757	0.9990	5089.21				
	2	313.42	0.747	0.9995	5831.07				
	3	439.76	0.740	0.9993	7963.45				
	4	827.11	0.653	0.9915	10626.96				
14	1					198.47	0.802	0.9970	4569.[illegible]
	2					246,91	0.769	0.9950	4996.[illegible]
	3					373.36	0.745	0.9760	6893.[illegible]
	4					732.20	0.599	0.9960	7633.[illegible]
15	1					417.89	0.655	0.9960	5408.[illegible]
	2					461.40	0.671	0.9960	6370.31
	3					715.91	0.670	0.9980	9872.[illegible]
	4					1012.37	0.615	0.9560	11245.[illegible]
16	1					393.44	0.677	0.9990	5557.[illegible]
	2					443.89	0.666	0.9990	6018.72
	3					662.29	0.654	0.9990	8568.[illegible]
	4					1149.06	0.650	0.9910	14614.[illegible]
17	1	226.07	0.771	0.9989	4610.29				
	2	269.57	0.762	0.9962	5305.25				
	3	424.72	0.768	0.9880	8556.44				
	4	955.83	0.725	0.9949	16300.79				
18	1	234.84	0.775	0.9996	4875.04				
	2	292.16	0.749	0.9992	5474.74				
	3	501.13	0.730	0.9995	8723.90				
	4	981.30	0.699	0.9935	15101.60				
19	1					438.31	0.645	0.9971	5467.9[illegible]
	2					512.82	0.641	0.9918	6289.5
	3					756.11	0.610	0.9993	8235.1
	4					1004.28	0.602	0.9922	10564.4[illegible]
22	1	264.09	0.708	0.9971	4220.40				
	2	329.73	0.673	0.9918	4588.46				
	3	593.43	0.604	0.9993	6295.84				
	4	1204.93	0.605	0.9922	12862.48				

House No.	Test No.	Pressurisation Test				Depressurisation Test			
		α	β	R^2	Q_{50}	α	β^2	R	Q_{50}
23	1	327.97	0.692	0.9993	4918.84				
	2	395.29	0.666	0.9988	5344.66				
	3	574.14	0.653	0.9990	7400.60				
	4	1036.44	0.623	0.9945	11845.59				
25	1					314.90	0.715	0.9973	5165.41
	2					357.36	0.702	0.9960	5567.74
	3					559.84	0.718	0.9958	9303.31
	4					1016.58	0.622	0.9976	11597.12
26	1	331.21	0.669	0.9800	4538.83				
	2	398.12	0.656	0.9988	5183.58				
	3	597.02	0.657	0.9988	7794.66				
	4	1213.78	0.630	0.9986	14255.37				
33	1					404.09	0.647	0.9986	5087.09
	2					484.55	0.624	0.9990	5571.51
	3					695.55	0.611	0.9947	7598.28
	4					985.30	0.990	0.9947	9913.26
35	1					285.29	0.752	0.9917	5415.39
	2					311.18	0.746	0.9972	5755.72
	3					500.26	0.718	0.9980	8300.84
	4					846.49	0.715	0.9970	13829.61
40	1	279.13	0.763	0.9974	5515.54				
	2	356.99	0.759	0.9978	6944.68				
	3	483.91	0.745	0.9984	8913.89				
	4	797.96	0.666	0.9996	10783.42				
41	1	294.83	0.735	0.9973	5231.99				
	2	364.16	0.745	0.9949	6715.09				
	3	519.58	0.691	0.9992	7747.37				
	4	953.66	0.622	0.9975	10856.61				

HOUSE NO. 1

DATE OF TEST : 5.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~
HOUSE GROUP : CONTROL, ~~TEST~~
HOUSE TYPE : ~~DETACHED~~, END-DETACHED, ~~TERRACE~~
HOUSE VOLUME : 230.86 m^3
HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 135.35 m^2
NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 13 °C, OUTDOOR : 9 °C, ΔT : 4 °C
WIND : SPEED : ____ Ft/min OR 1.39 m/s, DIRECTION : W
RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~
HEATING CONDITION DURING TEST : ON / ~~OFF~~
TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	2.5	2.5	1.5	1.0	335	454	502	962
2	4.0	5.8	2.5	2.0	552	903	636	1505
3	12.5	12.0	7.0	4.0	1405	1606	1639	2676
4	21.5	20.4	12.5	6.0	2074	2350	2643	3847
5	34.4	29.9	19.9	8.5	3011	3011	3891	4349
6	51.3	42.8	24.9	9.5	3881	4050	4549	5018
7	55.0	48.3	28.4	10.0	4049	4450	4850	5185
8	59.2	49.5	29.9	10.5	4216	4499	4917	5352
9	63.3	52.3	30.4	11.5	4383	4683	5018	5781
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 179.700 β_1 = 0.7816 r^2 = 0.9967 α_1 = 2183.00
2. $\alpha . (A + 0.02)$ = 223.430 β_2 = 0.7728 r^2 = 0.9987 α_2 = 2541.03
3. $\alpha . (A + 0.09)$ = 401.302 β_3 = 0.7513 r^2 = 0.9966 α_3 = 3113.06
4. $\alpha . (A + 0.27)$ = 961.706 β_4 = 0.7325 r^2 = 0.9963 α_4 = 2896.06

$\alpha_{av.}$ = 2683.36

CONSIDER CONDITION 1 ONLY:

Q_5 = 632.2
Q_{10} = 1086.8
Q_{20} = 1868.2
Q_{30} = 2564.9
Q_{40} = 3211.0
Q_{50} = 3823.5

A = EQ. LEAKAGE AREA
= 0.0670 m^2

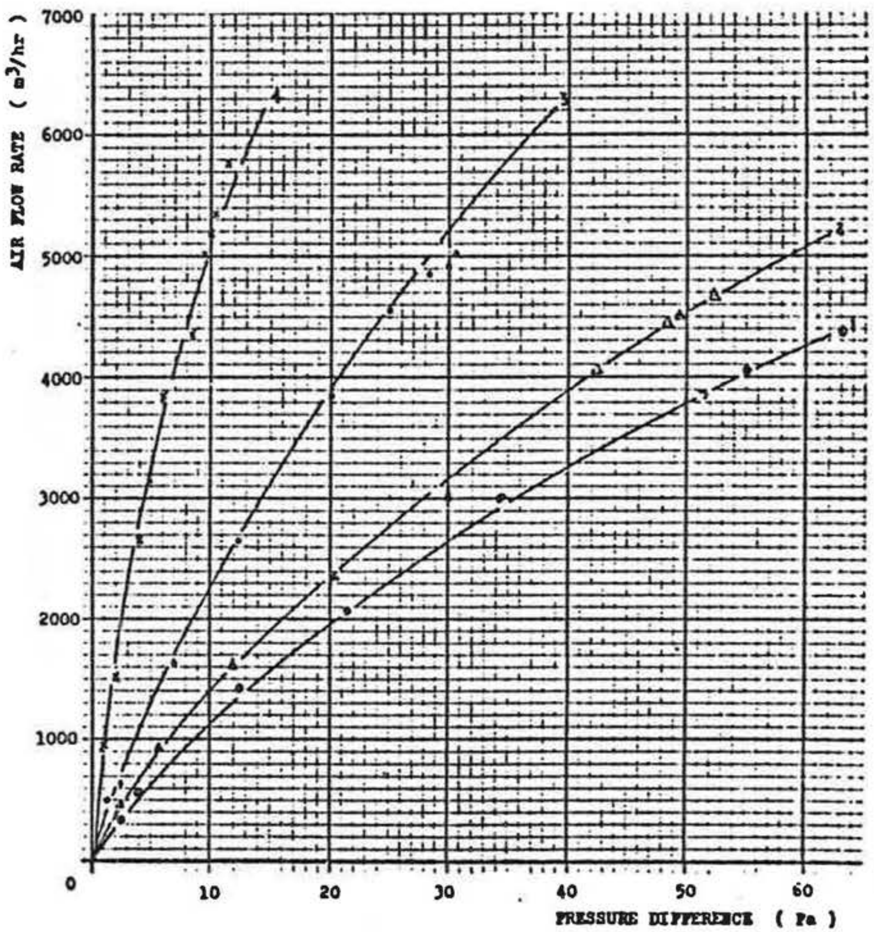
GEN. EQ. : $Q = 0.067 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 1

PRESSURIZATION



HOUSE NO. 1

DATA OF TEST : 5.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED~~, END-DETACHED, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVELOPE (EXPOSED SURFACE) WALL AREA : 133.35 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 13 °C, OUTDOOR : 9 °C, ΔT : 4 °C

WIND : SPEED : ____ Ft/min OR 1.39 m/s, DIRECTION : W

RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	6.5	5.6	2.8	1.0	750	800	700	1000
2	9.1	7.2	4.5	2.0	1040	1000	1140	1670
3	18.4	17.5	10.5	4.0	1840	2010	2010	2510
4	27.4	26.0	16.7	6.0	2340	2610	2710	3350
5	41.0	37.0	29.2	7.9	3180	3350	3680	4010
6	51.8	45.2	28.7	9.0	3680	3850	4150	4350
7	57.7	50.1	31.1	9.9	3910	4080	4380	4680
8	61.4	51.0	32.4	10.6	4010	4150	4550	4750
9	64.2	53.2	34.3	11.2	4150	4280	4750	4880
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 195.871 β_1 = 0.7417 r^2 = 0.9959 α_1 = 1882.55
2. $\alpha .(A + 0.02)$ = 232.922 β_2 = 0.7360 r^2 = 0.9985 α_2 = 1639.51
3. $\alpha .(A + 0.09)$ = 347.688 β_3 = 0.7390 r^2 = 0.9972 α_3 = 3752.93
4. $\alpha .(A + 0.27)$ = 1023.315 β_4 = 0.6568 r^2 = 0.9990 α_4 = 3095.11

$\alpha_{av.}$ = 2592.53

CONSIDER CONDITION 1 ONLY:

Q_5 = 646.2
Q_{10} = 1080.6
Q_{20} = 1806.9
Q_{30} = 2440.9
Q_{40} = 3021.5
Q_{50} = 3565.3

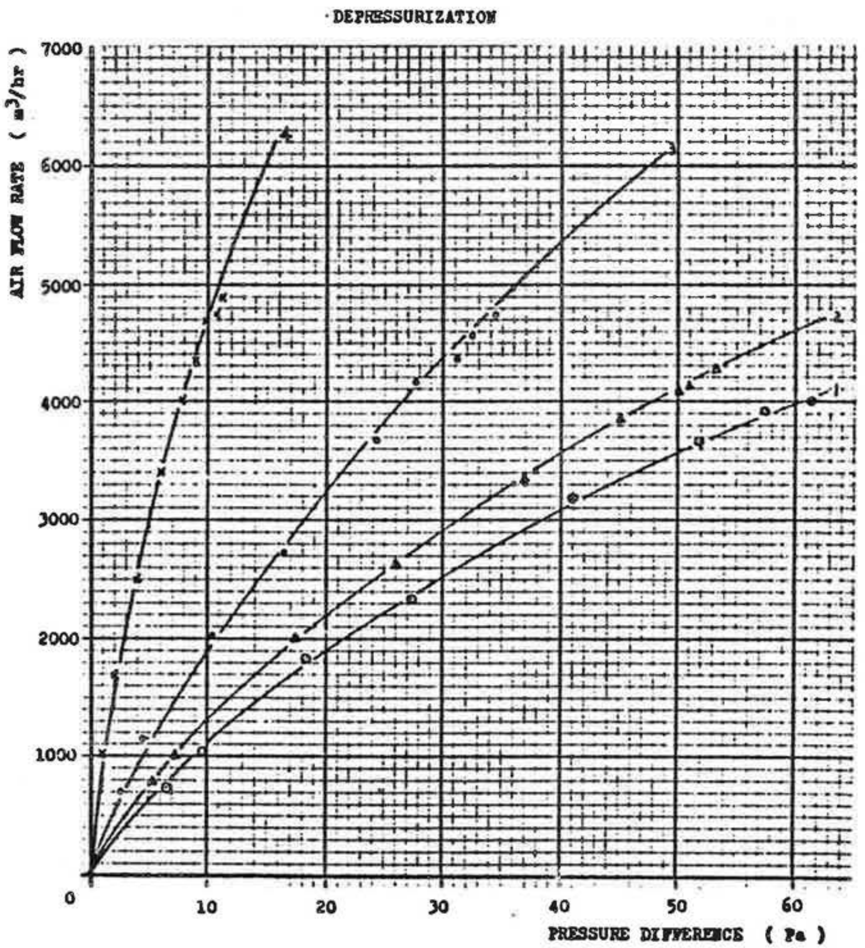
A = EQ. LEAKAGE AREA
= 0.0757 m^2

GEN. EQ.: $Q = 0.0757 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 1



HOUSE NO. 3

DATA OF TEST : 17.12.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED~~, END-DETACHED, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 183.35 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 7 °C, OUTDOOR : -8 °C, ΔT : 15 °C

WIND : SPEED : ______ Ft/min OR 0.65 m/s, DIRECTION : Varies

RELATIVE HUMIDITY : INDOOR : 60 %, OUTDOOR : 90 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	5.5	4.3	2.5	1.0	1000	1000	1000	1000
2	11.0	12.0	6.5	3.0	1840	2010	2170	2170
3	19.9	23.5	15.7	6.0	2680	3350	3750	3850
4	32.5	30.9	19.4	8.0	3850	4110	4530	4520
5	39.6	39.4	22.4	9.5	4350	4760	4850	5120
6	47.8	42.3	24.9	10.5	4820	5020	5180	5350
7	51.8	45.8	26.9	11.0	5080	5180	5420	5590
8								
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 312.325 β_1 = 0.7140 r^2 = 0.9958 α_1 = 2164.40
2. $\alpha .(A + 0.02)$ = 355.613 β_2 = 0.7067 r^2 = 0.9992 α_2 = 2699.86
3. $\alpha .(A + 0.09)$ = 544.603 β_3 = 0.7048 r^2 = 0.9970 α_3 = 3298.01
4. $\alpha .(A + 0.27)$ = 1138.255 β_4 = 0.6710 r^2 = 0.9789 α_4 = 3059.00

$\alpha_{av.}$ = 2805.32

CONSIDER CONDITION 1 ONLY:

Q_5 = 985.5
Q_{10} = 1616.6
Q_{20} = 2651.8
Q_{30} = 3542.2
Q_{40} = 4349.9
Q_{50} = 5101.2

A = EQ. LEAKAGE AREA = 0.1114 m^2

GEN. EQ.: $Q = 0.1114 \alpha_{av.} \Delta P^{\beta_1}$

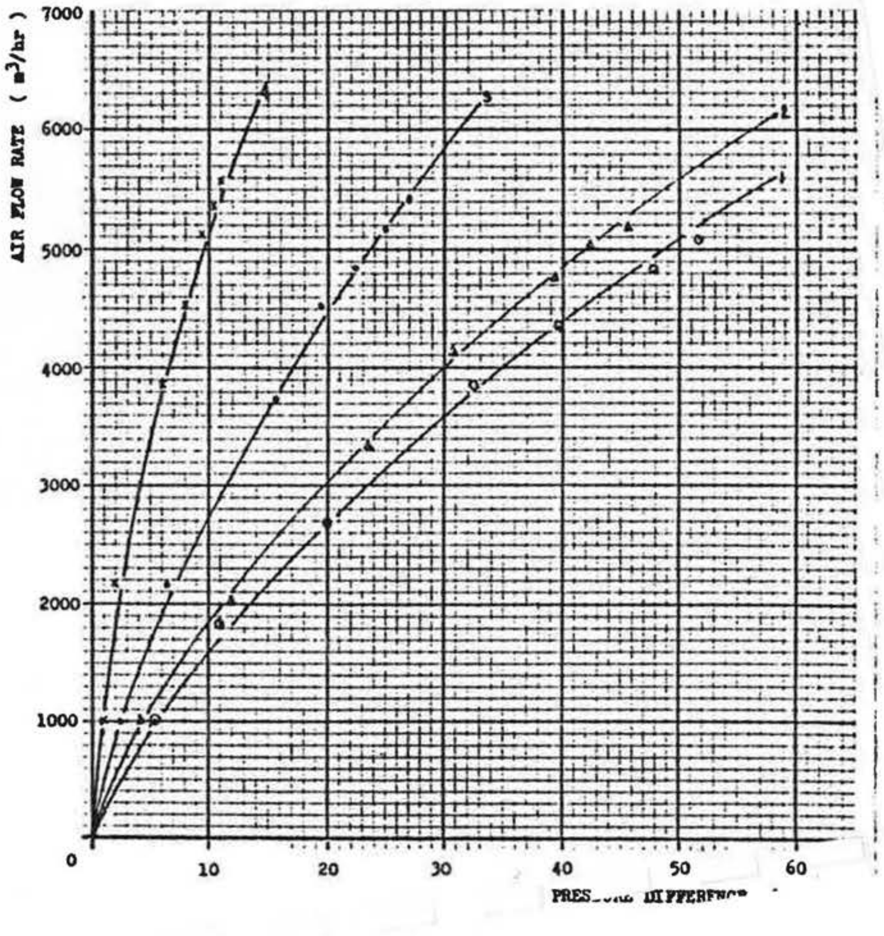
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 3

DEPRESSURIZATION



HOUSE NO. 6

DATA OF TEST : 6.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/062~~

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 163.22 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 11.5 °C, OUTDOOR : 9 °C, ΔT : 2.5 °C

WIND : SPEED : ____ Ft/min OR 1.39 m/s, DIRECTION : W

RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	3.5	5.0	3.0	2.0	550	840	1070	1270
2	6.2	7.0	5.2	2.5	840	1100	1610	1670
3	15.0	14.2	11.0	5.0	1610	2010	2610	2676
4	22.5	21.2	15.0	7.2	2340	2680	3180	3350
5	36.1	29.9	19.4	10.0	3350	3450	3950	4150
6	44.6	38.6	23.7	12.0	3950	4150	4480	4550
7	48.6	41.4	24.9	12.2	4230	4350	4680	4680
8	51.1	44.1	26.2	13.0	4350	4620	4750	4750
9	53.6	47.3	27.9	13.5	4500	4750	4950	4880
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 203.957 β_1 = 0.7785 r^2 = 0.9995 α_1 = 2175.55
2. $\alpha . (A + 0.02)$ = 247.468 β_2 = 0.7729 r^2 = 0.9988 α_2 = 2694.59
3. $\alpha . (A + 0.09)$ = 436.089 β_3 = 0.7345 r^2 = 0.9988 α_3 = 2284.48
4. $\alpha . (A + 0.27)$ = 847.295 β_4 = 0.6820 r^2 = 0.9934 α_4 = 2382.73

$\alpha_{av.}$ = 2384.34

CONSIDER CONDITION 1 ONLY:

Q_5 = 714.0
Q_{10} = 1224.7
Q_{20} = 2100.8
Q_{30} = 2880.6
Q_{40} = 3603.6
Q_{50} = 4287.3

A = EQ. LEAKAGE AREA
= 0.0855 m^2

GEN. EQ.: $Q = 0.0855 \alpha_{av.} \Delta P^{\beta}$

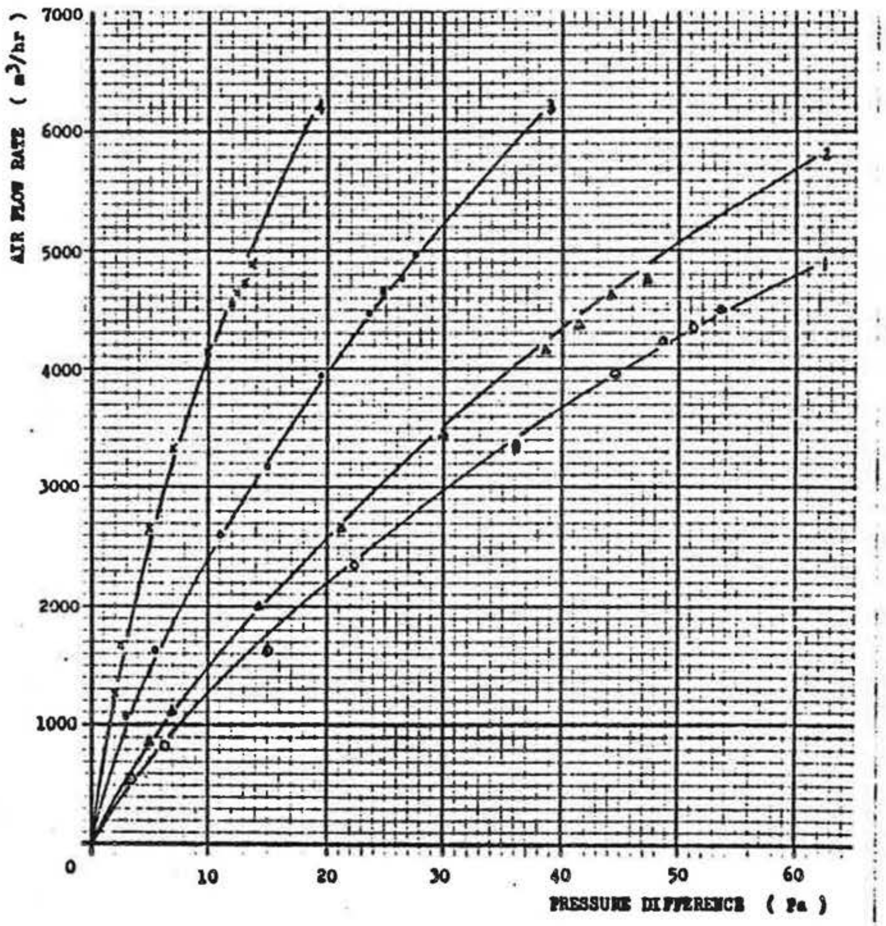
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 6

PRESSURIZATION



HOUSE NO. 6

DATA OF TEST 15.8.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/068~~

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 162.22 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 11.5 °C, OUTDOOR : 9 °C, ΔT : 2.5 °C

WIND : SPEED : _____ Ft/min OR 1.39 m/s, DIRECTION : W

RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED

2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)

3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)

4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	4.5	3.5	2.0	2.0	670	700	650	870
2	7.5	4.8	4.0	4.0	1000	900	1240	1610
3	16.2	14.9	10.5	6.2	1840	2170	2440	2340
4	21.4	22.4	13.0	10.5	2240	2840	2880	3350
5	34.9	27.2	18.7	11.2	3280	3350	3610	3510
6	44.8	30.6	25.7	13.2	3810	3510	4280	3950
7	49.8	39.6	26.2	15.9	4080	4350	4420	4550
8	52.1	42.6	27.4	16.2	4250	4620	4580	4680
9	54.1	46.1	28.7	17.4	4350	4850	4750	4750
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 221.437 β_1 = 0.7501 r^2 = 0.9991 α_1 = 2821.00
2. $\alpha .(A + 0.02)$ = 277.857 β_2 = 0.7486 r^2 = 0.9994 α_2 = 2129.47
3. $\alpha .(A + 0.09)$ = 426.920 β_3 = 0.7230 r^2 = 0.9935 α_3 = 2282.79
4. $\alpha .(A + 0.27)$ = 837.823 β_4 = 0.6030 r^2 = 0.9971 α_4 = 2282.91

$\alpha_{av.}$ = 2379.04

CONSIDER CONDITION 1 ONLY:

Q_5 = 740.5
Q_{10} = 1245.5
Q_{20} = 2094.8
Q_{30} = 2839.5
Q_{40} = 3507.4
Q_{50} = 4165.5

A = EQ. LEAKAGE AREA = 0.0929 m^2

GEN. EQ.: $Q = 0.0929 \alpha_{av.} \Delta P^{\beta_1}$

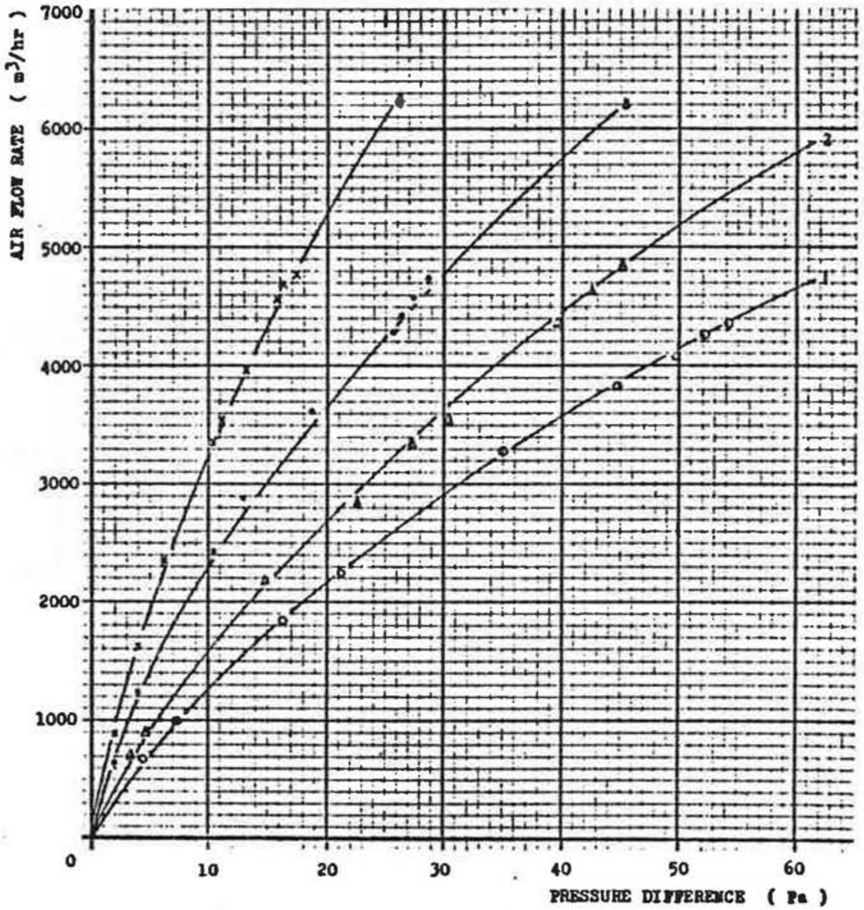
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 6

DEPRESSURIZATION



HOUSE NO. 7
DATA OF TEST : 23.12.81

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/062~~

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : DETACHED, ~~END-DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 163.22 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 8 °C, OUTDOOR : -4 °C, ΔT : 12 °C

WIND : SPEED : ____ Ft/min OR 0.85 m/s, DIRECTION : Varies

RELATIVE HUMIDITY : INDOOR : 70 %, OUTDOOR : 85 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	5.0	3.5	3.8	1.2	669	669	1004	1004
2	8.0	9.0	7.5	2.5	1004	1338	1673	1673
3	14.9	12.5	9.0	3.0	1739	1739	2007	2007
4	18.5	18.9	14.0	4.5	2074	2275	2676	2676
5	29.9	26.4	19.2	6.5	2977	2843	3312	3345
6	39.8	35.9	23.4	7.9	3680	3512	3847	4014
7	49.8	42.3	27.4	10.0	4014	4014	4215	4549
8	57.3	47.3	29.9	12.5	4449	4349	4516	4850
9	61.0	52.3	33.9	13.5	4683	4549	4850	5352
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 206.835 β_1 = 0.7690 r^2 = 0.9950 α_1 = 2478.00
2. $\alpha .(A + 0.02)$ = 256.395 β_2 = 0.7330 r^2 = 0.9994 α_2 = 2049.91
3. $\alpha .(A + 0.09)$ = 399.889 β_3 = 0.7140 r^2 = 0.9984 α_3 = 2753.97
4. $\alpha .(A + 0.27)$ = 895.605 β_4 = 0.7090 r^2 = 0.9987 α_4 = 2550.99

$\alpha_{av.}$ = 2458.22

CONSIDER CONDITION 1 ONLY:

Q_5 = 713.1
Q_{10} = 1215.1
Q_{20} = 2070.7
Q_{30} = 2828.3
Q_{40} = 3528.6
Q_{50} = 4189.2

A = EQ. LEAKAGE AREA
= 0.0841 m^2

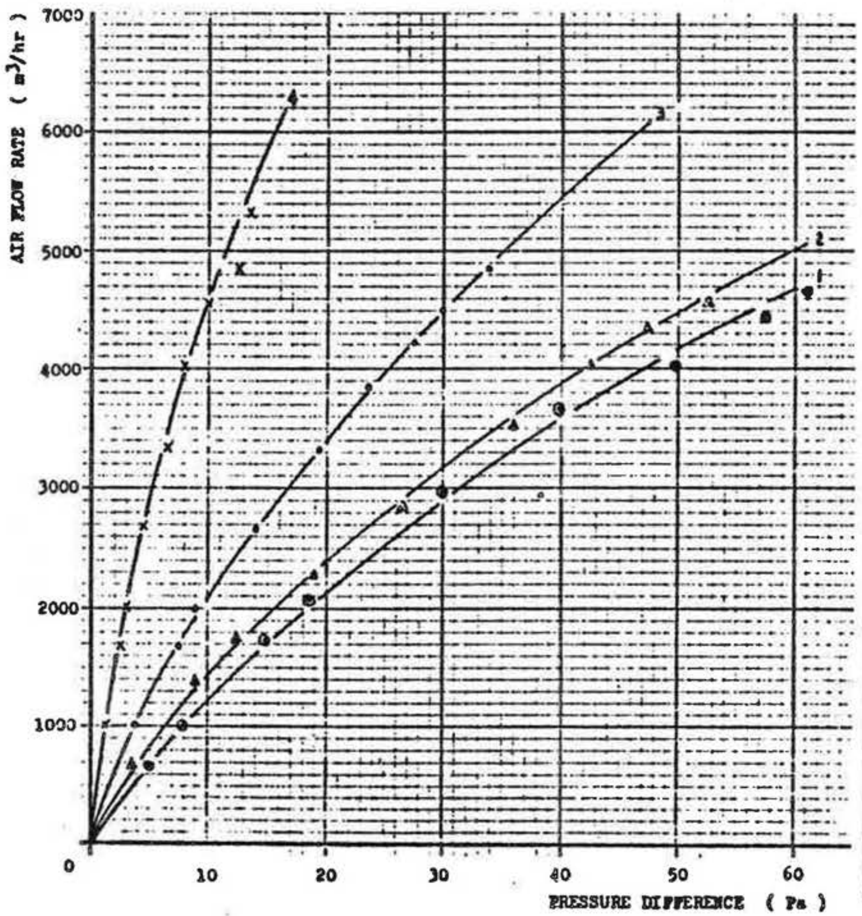
GEN. EQ.: $Q = 0.0841 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 7

DEPRESSURIZATION



HOUSE NO. 8
DATA OF TEST : 27.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/062~~
HOUSE GROUP : ~~CONTROL~~, TEST
HOUSE TYPE : DETACHED, ~~END-DETACHED~~, ~~TERRACE~~
HOUSE VOLUME : 230.85 m^3
HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 163.22 m^2
NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 10 °C, OUTDOOR : 4 °C, ΔT : 6 °C
WIND : SPEED : ____ Ft/min OR 4.99 m/s, DIRECTION : W
RELATIVE HUMIDITY : INDOOR : 48 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO
HEATING CONDITION DURING TEST : ON / ~~OFF~~
TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	1.5	2.5	1.5	1.5	543	836	836	1505
2	2.8	5.0	3.5	2.5	836	1505	1676	1840
3	9.5	9.5	7.5	3.5	2007	2342	2509	3011
4	12.5	14.5	12.0	5.5	2509	3011	3512	3680
5	19.9	21.2	16.0	8.0	3345	3847	4516	4516
6	31.5	30.4	19.4	9.5	4349	4850	5018	5084
7	40.5	32.9	20.2	10.0	5018	5084	5185	5452
8	41.5	34.9	21.0	11.5	5185	5185	5352	5519
9	45.2	35.7	22.4	12.0	5352	5352	5519	5753
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 411.118 β_1 = 0.6850 r^2 = 0.9976 α_1 = 2472.45
2. $\alpha . (A + 0.02)$ = 460.567 β_2 = 0.6910 r^2 = 0.9970 α_2 = 2759.44
3. $\alpha . (A + 0.09)$ = 653.728 β_3 = 0.6880 r^2 = 0.9970 α_3 = 2736.10
4. $\alpha . (A + 0.27)$ = 1146.226 β_4 = 0.6620 r^2 = 0.9790 α_4 = 2722.62

$\alpha_{av.}$ = 2672.65

CONSIDER CONDITION 1 ONLY:

Q_5 = 1238.1
Q_{10} = 1990.5
Q_{20} = 3200.2
Q_{30} = 4224.7
Q_{40} = 5144.9
Q_{50} = 5994.6

A = EQ. LEAKAGE AREA
= 0.1538 m^2

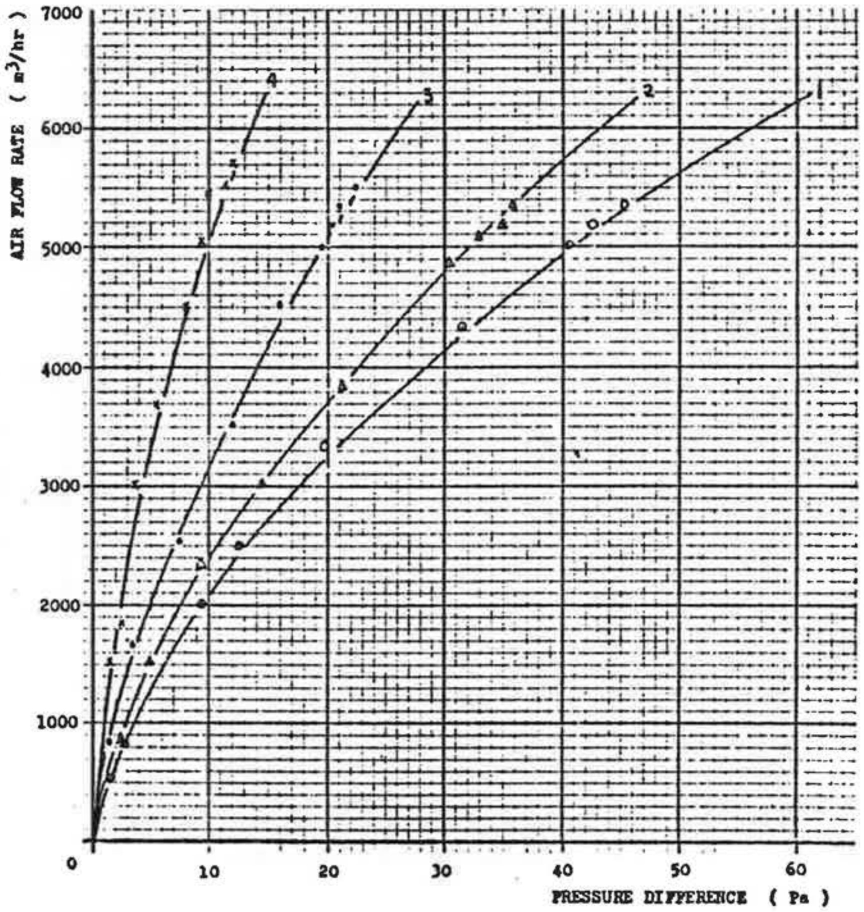
GEN. EQ.: $Q = 0.1538 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 8

DEPRESSURIZATION



HOUSE NO. 11

DATA OF TEST : 18.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/066~~, 05/062

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED~~, ~~END DETACHED~~, TERRACE

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 79.65 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 11 °C, OUTDOOR : 9 °C, ΔT : 3 °C

WIND : SPEED : ____ Ft/min OR 0.09 m/s, DIRECTION : E

RELATIVE HUMIDITY : INDOOR : 56 %, OUTDOOR : 56 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	2.2	2.0	1.5	1.0	335	335	613	815
2	5.5	5.0	3.0	2.0	669	836	1004	1171
3	9.5	7.5	5.0	2.5	1004	1171	1673	1673
4	26.0	21.2	8.5	5.0	2342	2676	2509	2676
5	39.9	32.0	15.0	7.5	3178	3680	3548	3680
6	48.6	36.9	16.3	8.7	3680	4014	4148	4349
7	56.1	41.2	19.9	11.2	4049	4349	4616	4683
8								
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 178.918 β_1 = 0.7786 r^2 = 0.9995 α_1 = 2743.90
2. $\alpha .(A + 0.02)$ = 233.836 β_2 = 0.7917 r^2 = 0.9997 α_2 = 3008.63
3. $\alpha .(A + 0.09)$ = 440.440 β_3 = 0.7892 r^2 = 0.9976 α_3 = 2065.62
4. $\alpha .(A + 0.27)$ = 816.257 β_4 = 0.7408 r^2 = 0.9895 α_4 = 2360.27

$\alpha_{av.}$ = 2544.36

CONSIDER CONDITION 1 ONLY:

Q_5 = 626.6
Q_{10} = 1075.0
Q_{20} = 1844.1
Q_{30} = 2528.6
Q_{40} = 3163.5
Q_{50} = 3763.7

A = EQ. LEAKAGE AREA
= 0.0702 m^2

GEN. EQ.: $Q = 0.0702 \alpha_{av.} \Delta P^{\beta_0}$

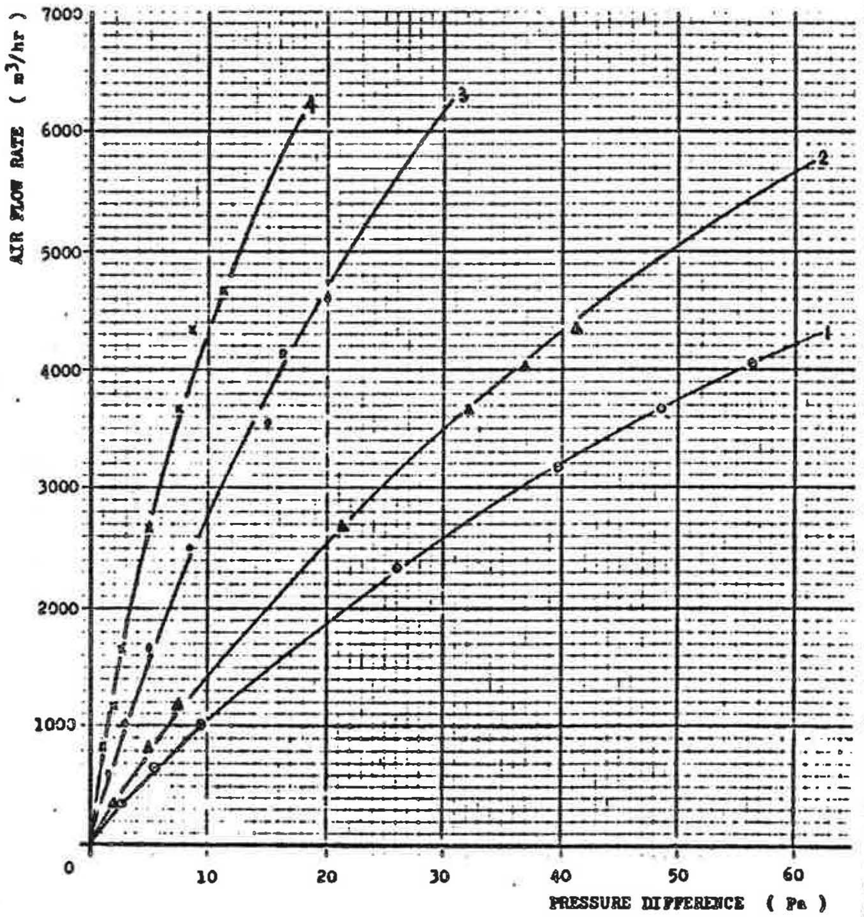
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 11

PRESSURIZATION



HOUSE NO. 11

DATA OF TEST : 18.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/056~~, 05/062

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED~~, ~~END DETACHED~~, TERRACE

HOUSE VOLUME : 230.86 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 79.65 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 11 °C, OUTDOOR : 9 °C, ΔT : 3 °C

WIND : SPEED : ____ Ft/min OR 0.89 m/s, DIRECTION : E

RELATIVE HUMIDITY : INDOOR : 56 %, OUTDOOR : 56 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	40	3.5	30	1.7	600	670	1170	1340
2	82	80	5.2	2.5	990	1340	1670	1670
3	165	14.0	9.7	4.5	1800	2010	2510	2340
4	316	308	13.1	8.0	2760	3350	3180	3350
5	52.2	44.1	207	12.0	3640	4150	4350	4480
6	53.5	468	128	13.2	3700	4350	4680	4600
7	588	51.2	24.2	15.0	3900	4550	4820	4950
8								
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 233.025 β_1 = 0.7011 r^2 = 0.9962 α_1 = 3278.00
2. $\alpha .(A + 0.02)$ = 297.541 β_2 = 0.6998 r^2 = 0.9959 α_2 = 3792.54
3. $\alpha .(A + 0.09)$ = 543.019 β_3 = 0.6854 r^2 = 0.9994 α_3 = 2291.82
4. $\alpha .(A + 0.27)$ = 955.546 β_4 = 0.6096 r^2 = 0.9989 α_4 = 2676.00

$\alpha_{av.}$ = 2996.54

CONSIDER CONDITION 1 ONLY:

Q_5 = 720.2
Q_{10} = 1170.9
Q_{20} = 1903.5
Q_{30} = 2529.4
Q_{40} = 3094.6
Q_{50} = 3618.7

A = EQ. LEAKAGE AREA
= 0.0776 m^2

GEN. EQ.: $Q = 0.0776 \alpha_{av.} \Delta P^{\beta_1}$

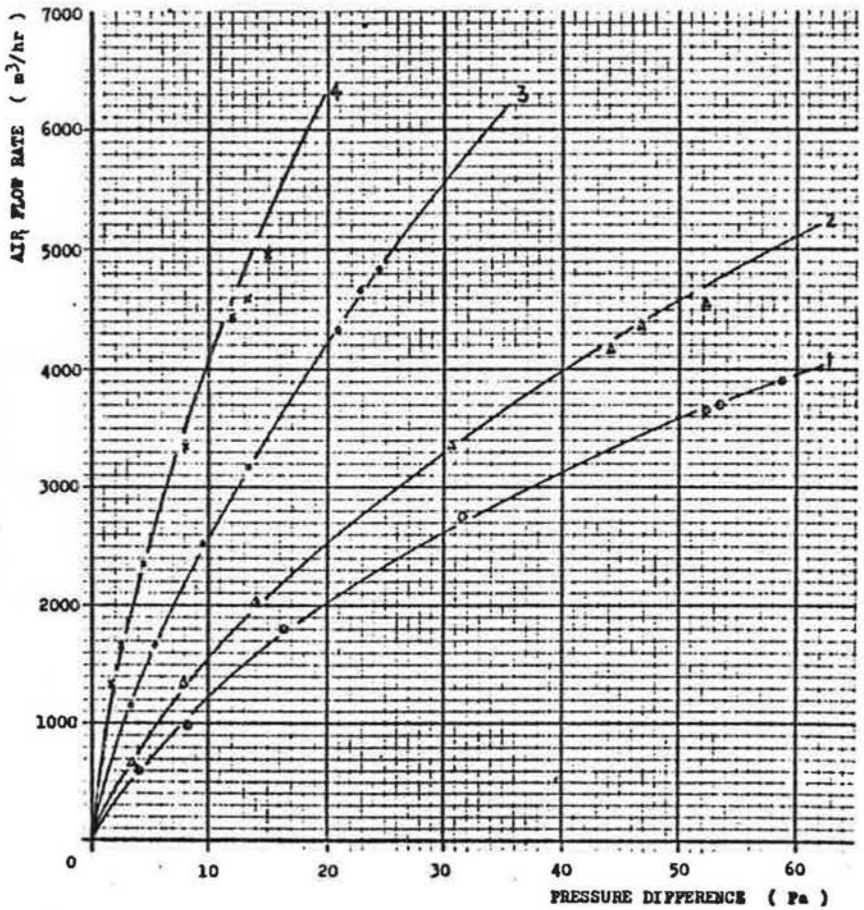
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 11

DEPRESSURIZATION



HOUSE NO. 12

DATA OF TEST : 22.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/066~~, 05/062

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : ~~DETACHED~~, END-DETACHED, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 133.35 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 13 °C, OUTDOOR : 4 °C, ΔT : 9 °C

WIND : SPEED : ____ Ft/min OR 2.98 m/s, DIRECTION : SE

RELATIVE HUMIDITY : INDOOR : 55 %, OUTDOOR : 90 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	2.0	3.5	1.5	1.5	467	669	669	1176
2	3.1	5.0	3.5	2.5	669	1004	1004	1672
3	12.5	8.5	8.4	4.5	2007	1670	2342	2341
4	15.5	10.0	18.4	8.7	2341	2007	4349	3345
5	22.5	24.2	22.4	12.6	3010	3847	5018	4349
6	38.0	31.8	24.9	16.4	4348	4683	5185	5185
7	45.2	34.3	25.5	18.9	4850	5018	5352	5687
8	49.2	36.2	26.2	19.6	5185	5118	5452	5762
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 275.169 β_1 = 0.7624 r^2 = 0.9978 α_1 = 2676.60
2. $\alpha . (A + 0.02)$ = 328.701 β_2 = 0.7673 r^2 = 0.9950 α_2 = 1684.61
3. $\alpha . (A + 0.09)$ = 446.624 β_3 = 0.7675 r^2 = 0.9931 α_3 = 2604.04
4. $\alpha . (A + 0.27)$ = 915.351 β_4 = 0.6176 r^2 = 0.9987 α_4 = 2371.04

$\alpha_{av.}$ = 2334.07

CONSIDER CONDITION 1 ONLY:

Q_5 = 938.6
Q_{10} = 1592.2
Q_{20} = 2700.9
Q_{30} = 3679.2
Q_{40} = 4581.5
Q_{50} = 5431.2

A = EQ. LEAKAGE AREA = 0.1180 m^2

GEN. EQ.: $Q = 0.1180 \alpha_{av.} \Delta P^{\beta_1}$

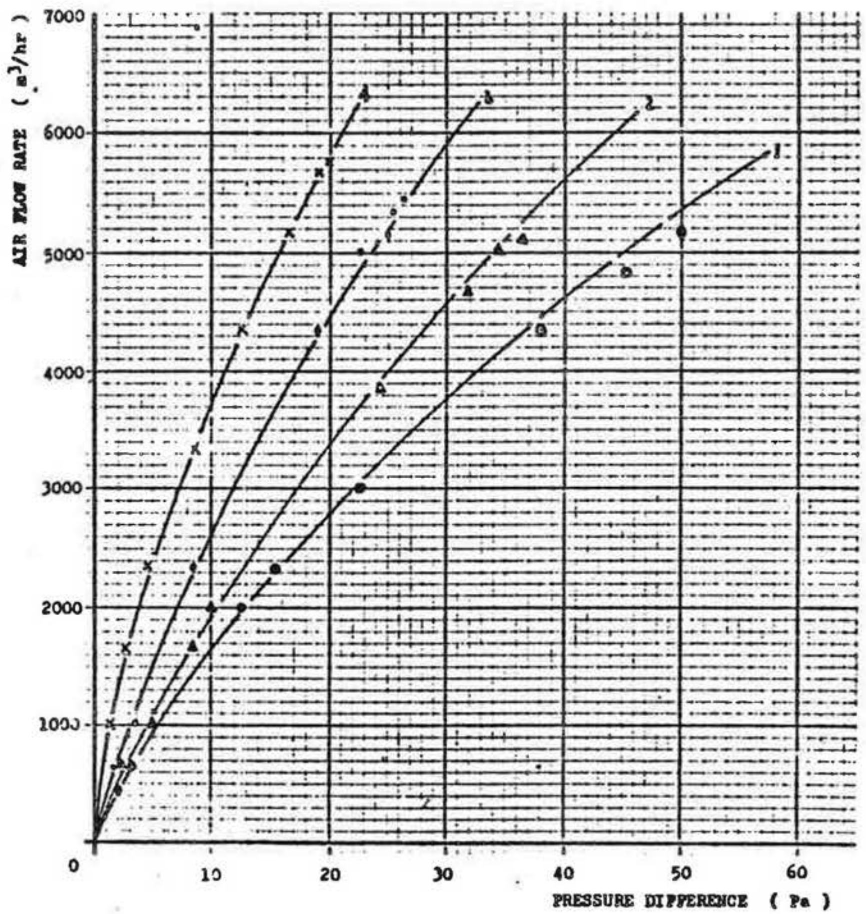
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 12

PRESSURIZATION



HOUSE NO. 13

DATA OF TEST : 6.2.82.

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : DETACHED, ~~END-DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVELOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 10 °C, OUTDOOR : 7 °C, ΔT : 3 °C

WIND : SPEED : ____ Ft/min OR 1.50 m/s, DIRECTION : S

RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 70 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ~~ON~~ / OFF

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	1.5	2.6	2.5	1.5	335	669	836	1004
2	6.0	4.5	6.2	3.5	1004	1004	1673	2007
3	14.2	9.2	11.8	5.8	2007	1673	2776	2676
4	17.5	12.0	16.0	7.5	2342	2007	3479	3178
5	26.0	20.8	20.2	10.0	3178	3010	4148	3880
6	40.2	28.8	22.4	13.2	4349	3880	4415	4349
7	44.0	30.8	23.4	14.2	4549	4081	4549	4549
8	48.3	35.6	25.0	16.0	4816	4549	4683	4817
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 262.948 β_1 = 0.7574 r^2 = 0.9990 α_1 = 2523.40
2. $\alpha .(A + 0.02)$ = 313.416 β_2 = 0.7473 r^2 = 0.9995 α_2 = 1804.97
3. $\alpha .(A + 0.09)$ = 439.764 β_3 = 0.7404 r^2 = 0.9993 α_3 = 2151.93
4. $\alpha .(A + 0.27)$ = 827.111 β_4 = 0.6527 r^2 = 0.9915 α_4 = 2089.49

$\alpha_{av.}$ = 2142.45

CONSIDER CONDITION 1 ONLY:

Q_5 = 889.8
Q_{10} = 1504.1
Q_{20} = 2542.6
Q_{30} = 3456.5
Q_{40} = 4298.0
Q_{50} = 5089.4

A = EQ. LEAKAGE AREA
= 0.1226 m^2

GEN. EQ.: $Q = 0.1226 \alpha_{av.} \Delta P^{\beta_1}$

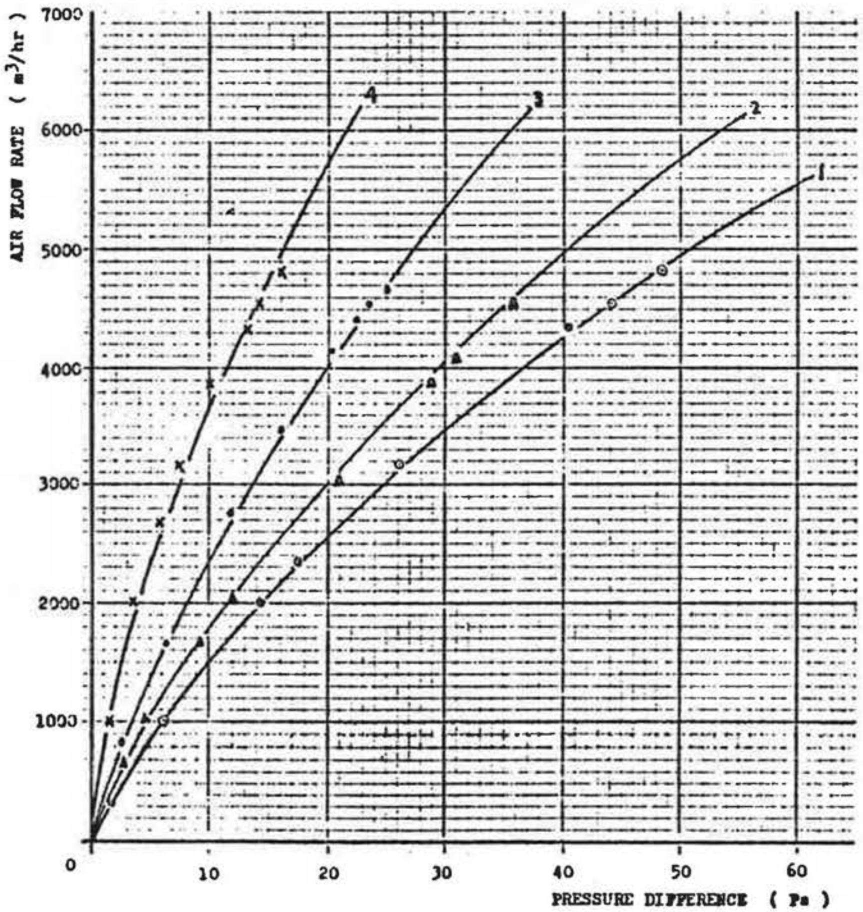
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 13

PRESSURIZATION



HOUSE NO. 16
DATE OF TEST : 4.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/055~~, ~~03/066~~, 05/062
HOUSE GROUP : ~~CONTROL~~, TEST
HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~
HOUSE VOLUME : 230.85 m^3
HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2
NO. OF CRAWLSPACE VENTILATORS : 23

TEMPERATURE : INDOOR : 12 °C, OUTDOOR : 6 °C, ΔT : 6 °C
WIND : SPEED : 331 Ft/min OR 1.69 m/s, DIRECTION : E
RELATIVE HUMIDITY : INDOOR : 62 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~
HEATING CONDITION DURING TEST : ON / ~~OFF~~
TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	2.5	2.0	1.5	1.0	732	704	863	1171
2	8.0	4.0	7.0	1.5	1650	1171	2342	1673
3	12.5	10.0	12.5	3.5	2174	2107	3345	2676
4	23.9	30.9	19.9	9.5	3345	4349	4750	4984
5	40.9	37.4	22.9	10.0	4850	4850	5185	5352
6	43.5	40.9	23.9	13.0	5018	5118	5352	5519
7								
8								
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 393.444 β_1 = 0.6770 r^2 = 0.9990 α_1 = 2522.45
2. $\alpha .(A + 0.02)$ = 443.893 β_2 = 0.6660 r^2 = 0.9990 α_2 = 3119.97
3. $\alpha .(A + 0.09)$ = 663.291 β_3 = 0.6540 r^2 = 0.9990 α_3 = 2704.24
4. $\alpha .(A + 0.27)$ = 1149.055 β_4 = 0.6500 r^2 = 0.9910 α_4 = 2798.56

$\alpha_{av.}$ = 2786.31

CONSIDER CONDITION 1 ONLY:

Q_5 = 1169.7
Q_{10} = 1870.2
Q_{20} = 2990.1
Q_{30} = 3934.5
Q_{40} = 4780.5
Q_{50} = 5560.1

A = EQ. LEAKAGE AREA
= 0.1412 m^2

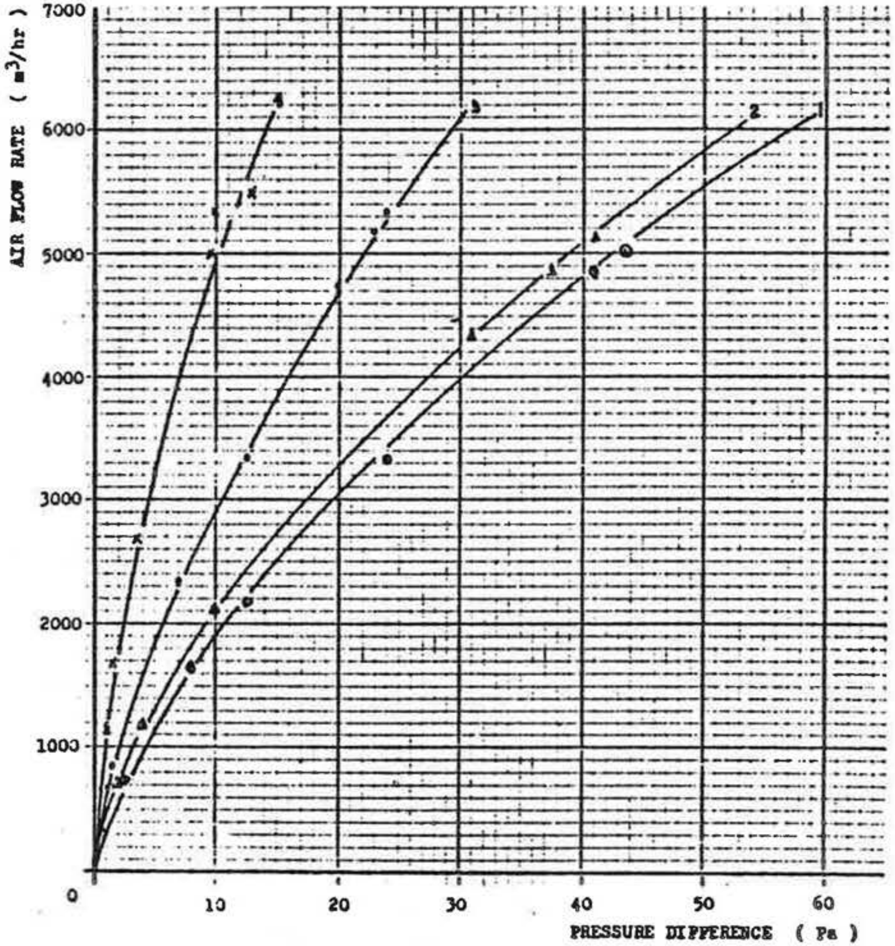
GEN. EQ.: $Q = 0.1412 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 16

DEPRESSURIZATION



HOUSE NO. 17

DATA OF TEST : 23.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/066~~, 05/062

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : DETACHED, ~~SEMI-DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2

NO. OF CRAWLSPACE VENTILATORS : 28

TEMPERATURE : INDOOR : 10 °C, OUTDOOR : 7 °C, ΔT : 3 °C

WIND : SPEED : ____ Ft/min OR 2.26 m/s, DIRECTION : W

RELATIVE HUMIDITY : INDOOR : 80 %, OUTDOOR : 75 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ~~ON~~ / OFF

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	18	15	15	1.0	386	335	669	903
2	38	30	30	1.3	669	669	836	1171
3	68	10.0	6.0	4.0	1003	1673	1673	2843
4	165	17.4	10.0	6.0	2007	2342	2341	3512
5	285	22.4	18.0	9.0	3011	3011	4014	5018
6	473	37.4	21.9	11.5	4349	4014	4516	5452
7	498	42.4	22.9	12.0	4549	4683	4850	5519
8	54.3	46.0	24.9	12.2	4850	4850	5185	5687
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 226.071 β_1 = 0.7708 r^2 = 0.9989 α_1 = 2174.75
2. $\alpha .(A + 0.02)$ = 269.566 β_2 = 0.7617 r^2 = 0.9962 α_2 = 2214.29
3. $\alpha .(A + 0.09)$ = 424.721 β_3 = 0.7680 r^2 = 0.9880 α_3 = 2950.61
4. $\alpha .(A + 0.27)$ = 955.830 β_4 = 0.7350 r^2 = 0.9949 α_4 = 2702.80

$\alpha_{av.}$ = 2510.61

CONSIDER CONDITION 1 ONLY:

Q_5 = 781.6
Q_{10} = 1335.7
Q_{20} = 2275.5
Q_{30} = 3110.4
Q_{40} = 3882.5
Q_{50} = 4611.2

A = EQ. LEAKAGE AREA
= 0.0902 m^2

GEN. EQ.: $Q = 0.0902 \alpha_{av.} \Delta P^{\beta_1}$

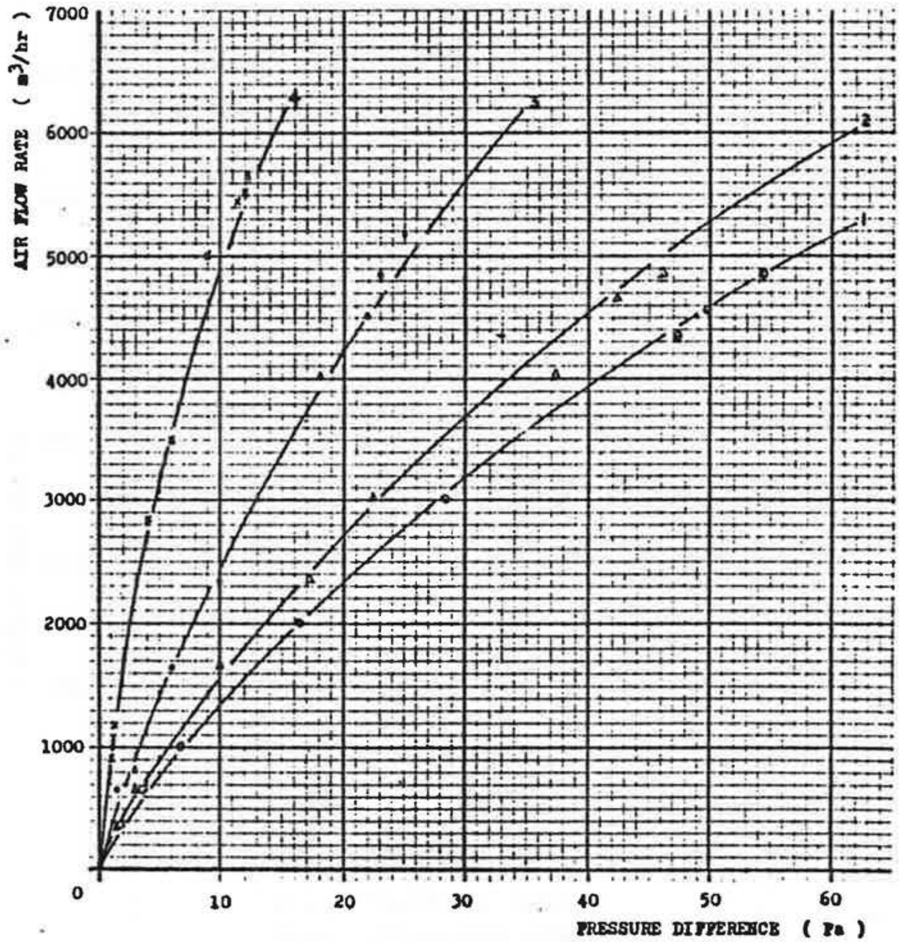
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 17

PRESSURIZATION



HOUSE NO. 18

DATA OF TEST : 17.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/066~~, 05/062

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2

NO. OF CRAWLSPACE VENTILATORS : 23

TEMPERATURE : INDOOR : 9 °C, OUTDOOR : 5 °C, ΔT : 4 °C

WIND : SPEED : ____ Ft/min OR 5.50 m/s, DIRECTION : NW

RELATIVE HUMIDITY : INDOOR : 70 %, OUTDOOR : 80 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	1.6	5.2	2.0	2.5	335	1004	830	1839
2	9.5	10.5	3.5	4.0	1338	1673	1338	2509
3	18.5	18.5	8.8	6.2	2342	2676	2509	3680
4	30.5	31.5	18.6	7.5	3345	3847	4181	4181
5	43.5	39.9	22.5	10.0	4349	4683	4850	4850
6	51.2	45.6	26.4	13.0	4850	5018	5352	5686
7	.	.	.	.				
8	.	.	.	.				
9	.	.	.	.				
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 234.836 β_1 = 0.7753 r^2 = 0.9996 α_1 = 2866.05
2. $\alpha .(A + 0.02)$ = 292.157 β_2 = 0.7491 r^2 = 0.9992 α_2 = 2985.33
3. $\alpha .(A + 0.09)$ = 501.130 β_3 = 0.7300 r^2 = 0.9995 α_3 = 2667.61
4. $\alpha .(A + 0.27)$ = 981.299 β_4 = 0.6990 r^2 = 0.9935 α_4 = 2764.68

$\alpha_{av.}$ = 2820.92

CONSIDER CONDITION 1 ONLY:

Q_5 = 817.9
Q_{10} = 1399.8
Q_{20} = 2395.8
Q_{30} = 3280.8
Q_{40} = 4100.5
Q_{50} = 4875.0

A = EQ. LEAKAGE AREA
= 0.0834 m^2

GEN. EQ.: $Q = 0.0834 \alpha_{av.} \Delta P^{\beta_1}$

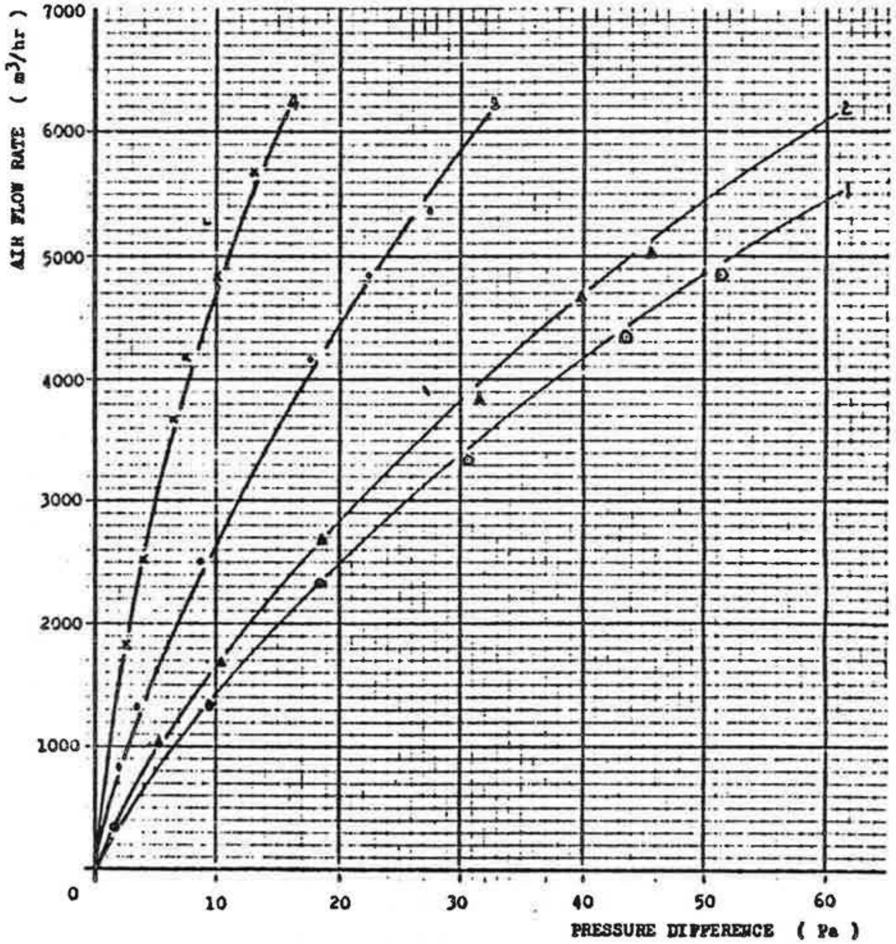
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 18

PRESSURIZATION



HOUSE NO. 19

DATE OF TEST : 21.12.81

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/062~~

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : ~~DETACHED~~, END-DETACHED, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVELOPE (EXPOSED SURFACE) WALL AREA : 133.35 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 5 °C, OUTDOOR : 0 °C, ΔT : 5 °C

WIND : SPEED : ____ Ft/min OR 2.5 m/s, DIRECTION : SE

RELATIVE HUMIDITY : INDOOR : 75 %, OUTDOOR : 90 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED

2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)

3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)

4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	3.7	6.0	3.8	2.2	1004	1673	1739	1673
2	13.0	11.9	7.8	5.5	2342	2442	2676	2676
3	16.2	13.9	11.5	7.8	2676	2676	3178	3345
4	29.9	25.9	18.4	11.0	3914	4181	4349	4248
5	38.9	32.4	22.4	15.2	4683	4917	5185	5251
6	42.1	35.4	22.9	15.8	4850	5018	5218	5352
7	45.6	37.3	24.9	17.0	5084	5185	5419	5586
8								
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 438.390 β_1 = 0.6451 r^2 = 0.9994 α_1 = 3820.00
2. $\alpha .(A + 0.02)$ = 514.790 β_2 = 0.6399 r^2 = 0.9964 α_2 = 3439.00
3. $\alpha .(A + 0.09)$ = 755.520 β_3 = 0.6107 r^2 = 0.9950 α_3 = 1381.22
4. $\alpha .(A + 0.27)$ = 1009.321 β_4 = 0.6015 r^2 = 0.9958 α_4 = 2096.04

$\alpha_{av.}$ = 2684.32

CONSIDER CONDITION 1 ONLY:

Q_s = 1238.1
Q = 1936.2
Q = 3028.0
Q = 3933.3
Q = 4733.3
Q = 5468.5

A = EQ. LEAKAGE AREA
= 0.1634 m^2

GEN. EQ.: $Q = 0.1634 \alpha_{av.} \Delta P^{\beta}$

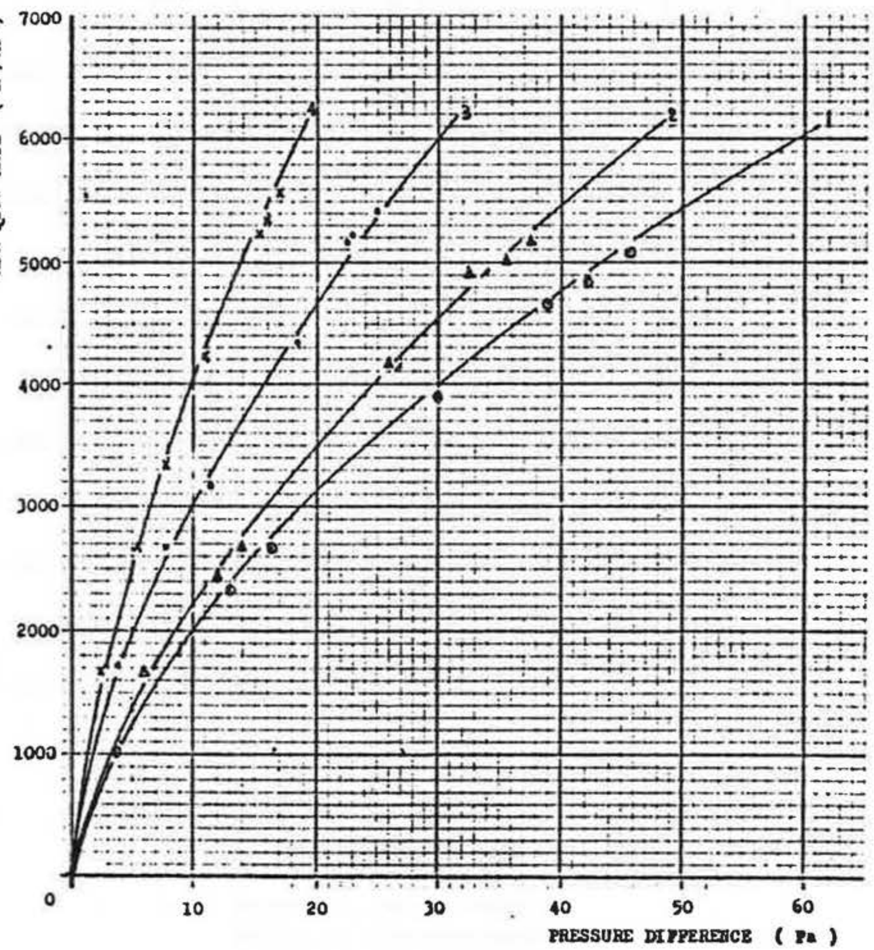
BETTER INSULATED HOUSE PROJECT

BO'NESS INFILL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 19

DEPRESSURIZATION



HOUSE NO. 22

DATA OF TEST : 18.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066, 05/062~~

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED, END-DETACHED,~~ TERRACE

HOUSE VOLUME : 230.85 m³

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 79.65 m²

NO. OF CRAWLSPACE VENTILATORS : 11

TEMPERATURE : INDOOR : 9 °C, OUTDOOR : 6 °C, ΔT : 3 °C

WIND : SPEED : ____ Ft/min OR 0.86 m/s, DIRECTION : E

RELATIVE HUMIDITY : INDOOR : 60 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m²)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m²)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m²)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m³/hr)			
	1	2	3	4	1	2	3	4
1	1.5	8.2	3.2	1.5	335	502	1171	1505
2	2.5	4.5	3.7	2.5	502	1004	1338	2342
3	9.0	14.5	7.5	4.0	1338	2174	2007	2789
4	16.0	29.9	17.0	5.2	2007	3278	3278	3345
5	36.6	41.1	26.2	8.7	3412	3947	4282	4349
6	48.6	44.8	28.7	9.2	4014	4014	4549	4616
7	57.3	47.8	30.4	10.0	4414	4415	4683	4683
8								
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 264.142 β_1 = 0.7084 r^2 = 0.9977 α_1 = 3279.20
2. $\alpha .(A + 0.02)$ = 329.726 β_2 = 0.6781 r^2 = 0.9918 α_2 = 3726.67
3. $\alpha .(A + 0.09)$ = 590.593 β_3 = 0.6068 r^2 = 0.9995 α_3 = 3413.67
4. $\alpha .(A + 0.27)$ = 1205.054 β_4 = 0.6053 r^2 = 0.9921 α_4 = 3484.86

$\alpha_{av.}$ = 3476.10

CONSIDER CONDITION 1 ONLY:

Q_5 = 826.0
Q_{10} = 1349.7
Q_{20} = 2205.4
Q_{30} = 2939.2
Q_{40} = 3603.6
Q_{50} = 4220.7

A = EQ. LEAKAGE AREA
= 0.0761 m²

GEN. EQ.: $Q = 0.0761 \alpha_{av.} \Delta P^{\beta_1}$

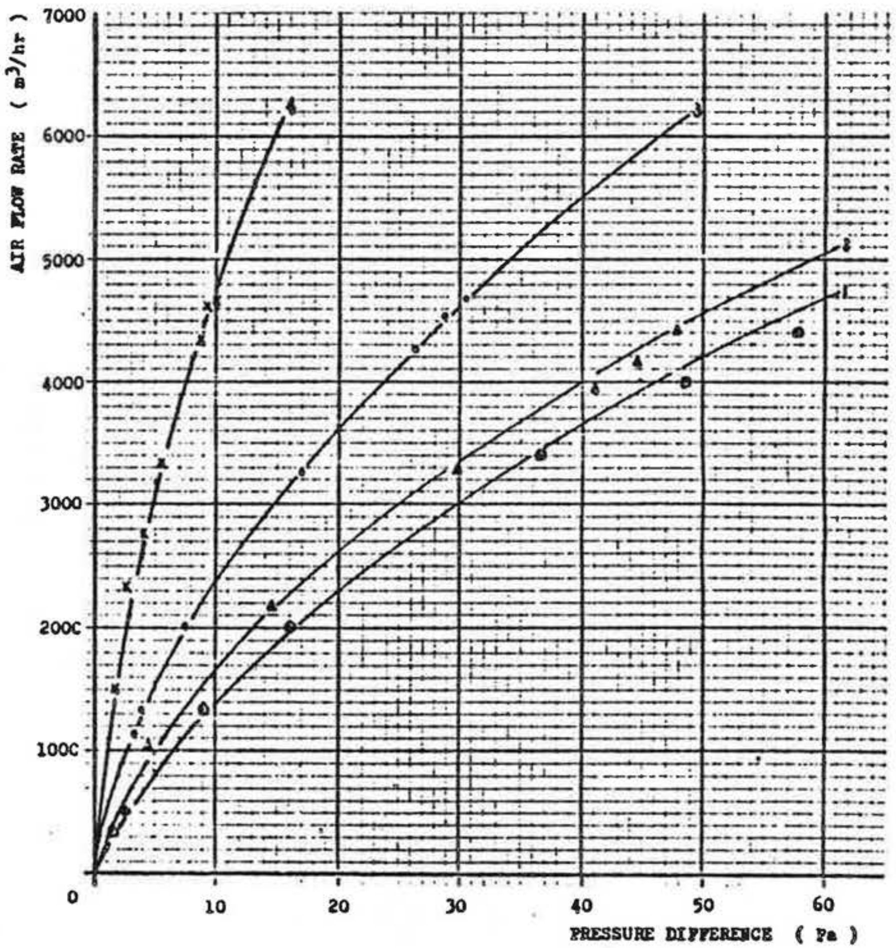
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 22

PRESSURIZATION



HOUSE NO. 23
DATA OF TEST : 18.3.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : 03/065, ~~03/066~~, ~~05/062~~
HOUSE GROUP : CONTROL, ~~TEST~~
HOUSE TYPE : ~~DETACHED~~, END-DETACHED, ~~TERRACE~~
HOUSE VOLUME : 230.85 m^3
HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 133.35 m^2
NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 12 °C, OUTDOOR : 3 °C, ΔT : 9 °C
WIND : SPEED : ____ Ft/min OR 2.51 m/s, DIRECTION : E
RELATIVE HUMIDITY : INDOOR : 60 %, OUTDOOR : 50 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO
HEATING CONDITION DURING TEST : ON / ~~OFF~~
TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	10	15	1.5	1.0	335	502	750	1004
2	30	40	3.2	1.5	669	1004	1171	1438
3	75	100	6.5	3.7	1338	1995	1940	2174
4	182	21.7	12.6	5.0	2509	3100	3010	2843
5	356	32.4	21.7	10.0	3947	4014	4349	4482
6	424	381	24.9	11.2	4349	4382	4683	4616
7	480	44.3	26.2	12.5	4700	4800	4883	5018
8	.	.	.	.				
9	.		.	.				
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 327.971 β_1 = 0.6920 r^2 = 0.9993 α_1 = 3365.95
2. $\alpha .(A + 0.02)$ = 395.290 β_2 = 0.6657 r^2 = 0.9988 α_2 = 2554.94
3. $\alpha .(A + 0.09)$ = 574.136 β_3 = 0.6380 r^2 = 0.9990 α_3 = 2568.38
4. $\alpha .(A + 0.27)$ = 1036.414 β_4 = 0.6230 r^2 = 0.9945 α_4 = 2623.97

$\alpha_{av.}$ = 2778.31

CONSIDER CONDITION 1 ONLY:

Q_5 = 998.9
Q_{10} = 1613.7
Q_{20} = 2607.0
Q_{30} = 3451.5
Q_{40} = 4211.7
Q_{50} = 4915.0

A = EQ. LEAKAGE AREA
= 0.1182 m^2

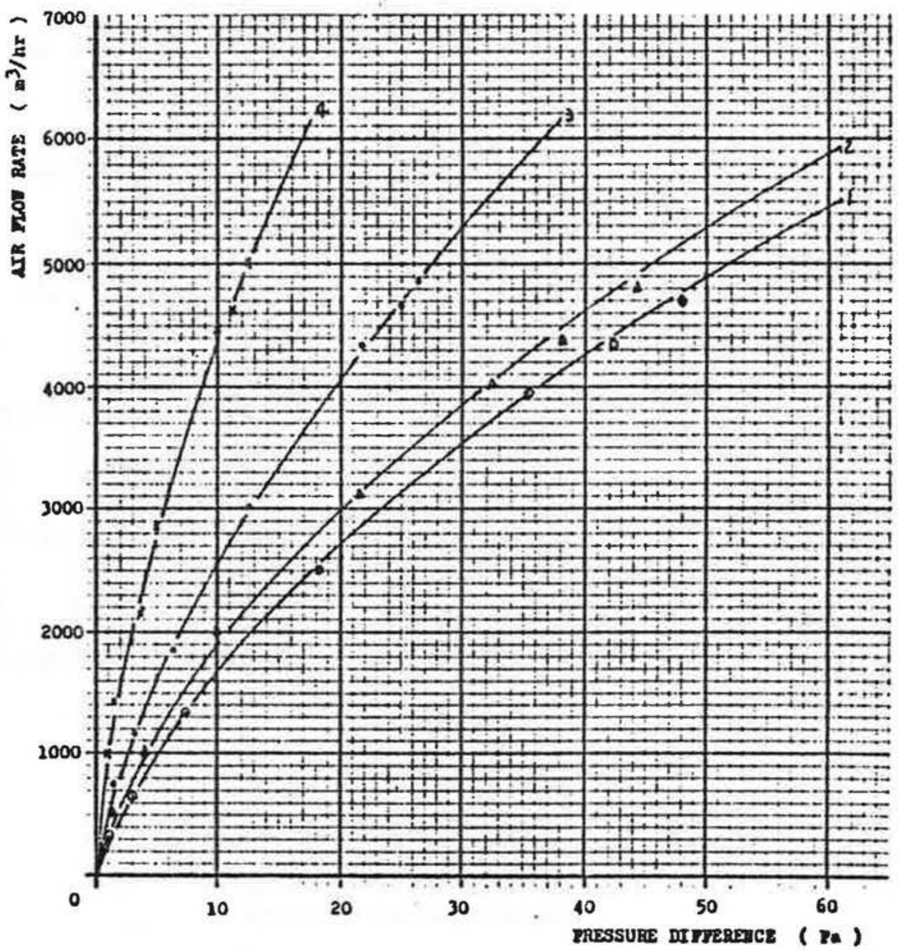
GEN. EQ.: $Q = 0.1182 \alpha_{av.} \Delta P^{\beta}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 23

PRESSURIZATION



HOUSE NO. 25

DATA OF TEST : 21.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 12 °C, OUTDOOR : 8 °C, ΔT : 4 °C

WIND : SPEED : 200 Ft/min OR 1.02 m/s, DIRECTION : NW

RELATIVE HUMIDITY : INDOOR : 70 %, OUTDOOR : 68 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	2.0	1.0	1.8	1.5	517	335	836	1338
2	5.5	7.8	6.0	4.8	1171	1673	2007	2643
3	13.0	13.5	10.0	6.0	2007	2342	3011	3011
4	17.5	17.4	12.9	10.0	2509	2676	3646	4114
5	31.2	29.4	15.9	11.5	3680	3847	4349	4683
6	42.8	39.4	20.0	12.5	4516	4549	4850	5018
7	44.8	41.8	21.5	13.5	4683	4683	5084	5185
8	49.8	44.8	22.5	14.9	5018	4884	5218	5519
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 314.901 β_1 = 0.7151 r^2 = 0.9973 α_1 = 2122.90
2. $\alpha .(A + 0.02)$ = 357.359 β_2 = 0.7025 r^2 = 0.9960 α_2 = 2892.60
3. $\alpha .(A + 0.09)$ = 559.841 β_3 = 0.7185 r^2 = 0.9958 α_3 = 2537.43
4. $\alpha .(A + 0.27)$ = 1016.578 β_4 = 0.6223 r^2 = 0.9976 α_4 = 2598.80

$\alpha_{av.}$ = 2537.93

CONSIDER CONDITION 1 ONLY:

Q_5 = 995.4
Q_{10} = 1634.1
Q_{20} = 2682.5
Q_{30} = 3584.8
Q_{40} = 4403.6
Q_{50} = 5165.4

A = EQ. LEAKAGE AREA
= 0.1240 m^2

GEN. EQ.: $Q = 0.1240 \alpha_{av.} \Delta P^{\beta_1}$

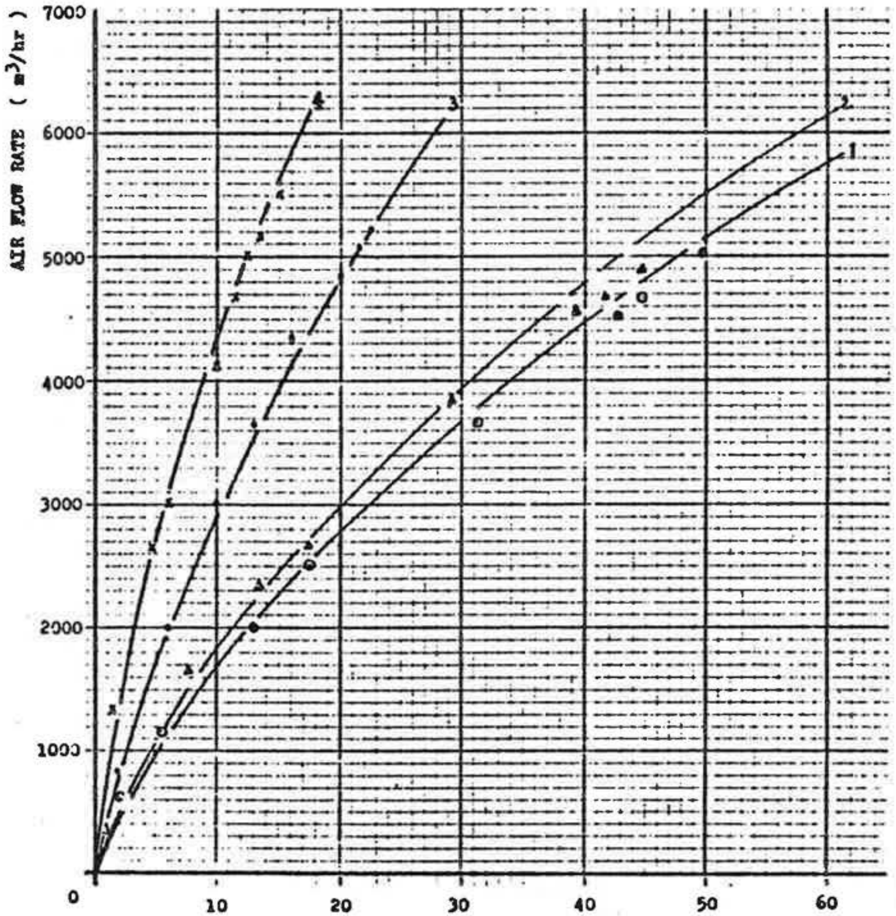
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 25

DEPRESSURIZATION



HOUSE NO. 26

DATA OF TEST : 18.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~

HOUSE GROUP : ~~CONTROL~~, TEST

HOUSE TYPE : DETACHED, ~~END-DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 10 °C, OUTDOOR : 7 °C, ΔT : 3 °C

WIND : SPEED : _____ Ft/min OR 3.0 m/s, DIRECTION : SE

RELATIVE HUMIDITY : INDOOR : 68 %, OUTDOOR : 74 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED

2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)

3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)

4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	5.4	3.2	3.5	1.5	1004	836	1338	1570
2	11.5	11.5	8.5	2.2	1840	2007	2509	2007
3	21.4	17.4	11.0	4.0	2774	2676	3010	3011
4	23.9	27.4	15.4	6.5	3010	3512	3680	3847
5	37.4	34.9	21.4	8.0	3847	4181	4516	4549
6	47.3	42.3	26.4	9.5	4349	4532	5018	5018
7	49.8	43.8	27.4	10.0	4516	4683	5185	5185
8	54.8	48.3	28.4	11.9	4850	5018	5352	5687
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 331.214 β_1 = 0.6691 r^2 = 0.9796 α_1 = 3345.30
2. $\alpha .(A + 0.02)$ = 398.120 β_2 = 0.6560 r^2 = 0.9988 α_2 = 3656.49
3. $\alpha .(A + 0.09)$ = 597.021 β_3 = 0.6568 r^2 = 0.9988 α_3 = 3109.45
4. $\alpha .(A + 0.27)$ = 1213.775 β_4 = 0.6297 r^2 = 0.9986 α_4 = 3268.74

$\alpha_{av.}$ = 3345.00

CONSIDER CONDITION 1 ONLY:

Q_5 = 972.3
Q_{10} = 1546.0
Q_{20} = 2458.3
Q_{30} = 3224.9
Q_{40} = 3908.8
Q_{50} = 4530.3

A = EQ. LEAKAGE AREA = 0.0991 m^2

GEN. EQ.: $Q = 0.0991 \alpha_{av.} \Delta P^{\beta_1}$

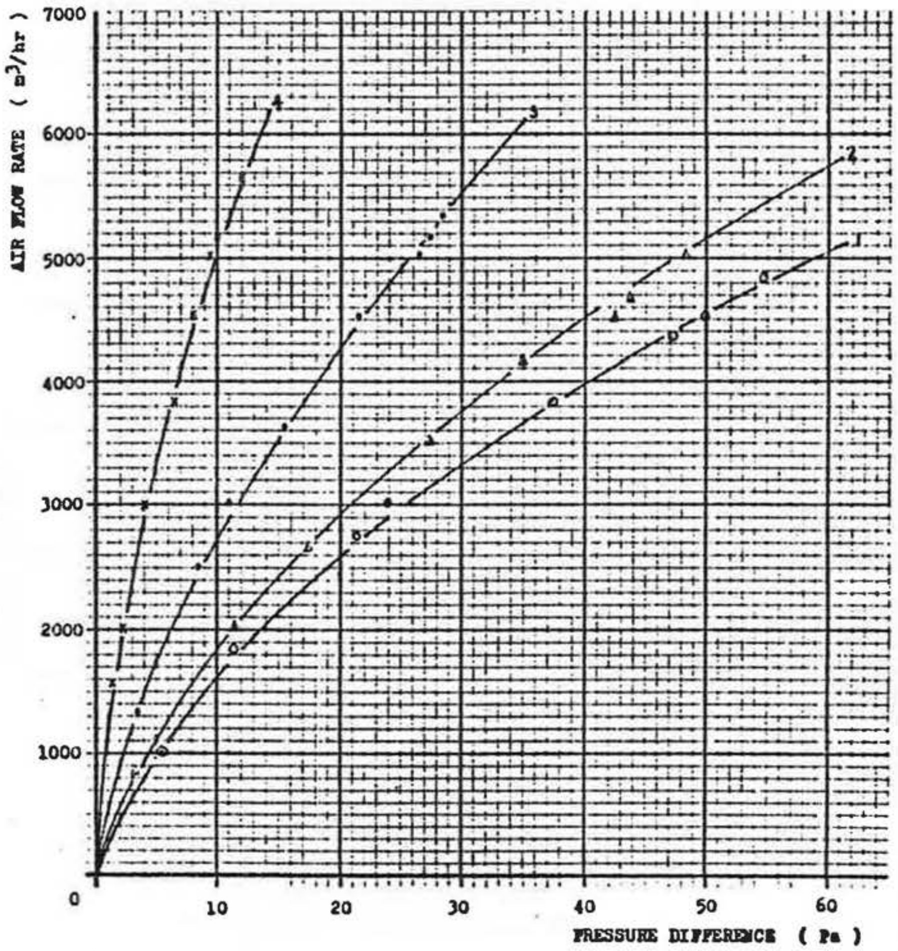
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 26

PRESSURIZATION



HOUSE NO. 33
DATA OF TEST : 10.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~
HOUSE GROUP : CONTROL, ~~TEST~~
HOUSE TYPE : DETACHED, ~~END-DETACHED~~, ~~TERRACE~~
HOUSE VOLUME : 230.85 m^3
HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2
NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 13 °C, OUTDOOR : 9 °C, ΔT : 4 °C
WIND : SPEED : ____ Ft/min OR 4.78 m/s, DIRECTION : E
RELATIVE HUMIDITY : INDOOR : 66 %, OUTDOOR : 58 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~
HEATING CONDITION DURING TEST : ~~ON~~ / OFF
TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	3.2	2.5	1.5	1.5	836	836	836	1253
2	5.2	5.0	2.5	2.5	1170	1338	1338	1673
3	11.2	9.5	6.0	6.0	2007	2041	2040	2676
4	18.7	23.7	11.2	10.5	2776	3546	3010	4148
5	34.3	31.0	18.7	13.5	3947	4148	4148	4349
6	39.9	34.3	22.2	15.0	4349	4349	4549	4750
7	42.4	37.4	22.4	16.5	4482	4549	4750	5018
8	.	.	.	.				
9	.	.	.	.				
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 403.806 β_1 = 0.6476 r^2 = 0.9986 α_1 = 4040.65
2. $\alpha . (A + 0.02)$ = 484.619 β_2 = 0.6243 r^2 = 0.9990 α_2 = 3013.10
3. $\alpha . (A + 0.09)$ = 695.536 β_3 = 0.6112 r^2 = 0.9947 α_3 = 1630.38
4. $\alpha . (A + 0.27)$ = 989.005 β_4 = 0.5837 r^2 = 0.9964 α_4 = 2167.40

$\alpha_{av.}$ = 2712.88

CONSIDER CONDITION 1 ONLY:

Q_5 = 1145.1
Q_{10} = 1793.8
Q_{20} = 2810.1
Q_{30} = 3653.9
Q_{40} = 4402.2
Q_{50} = 5086.6

A = EQ. LEAKAGE AREA
= 0.1489 m^2

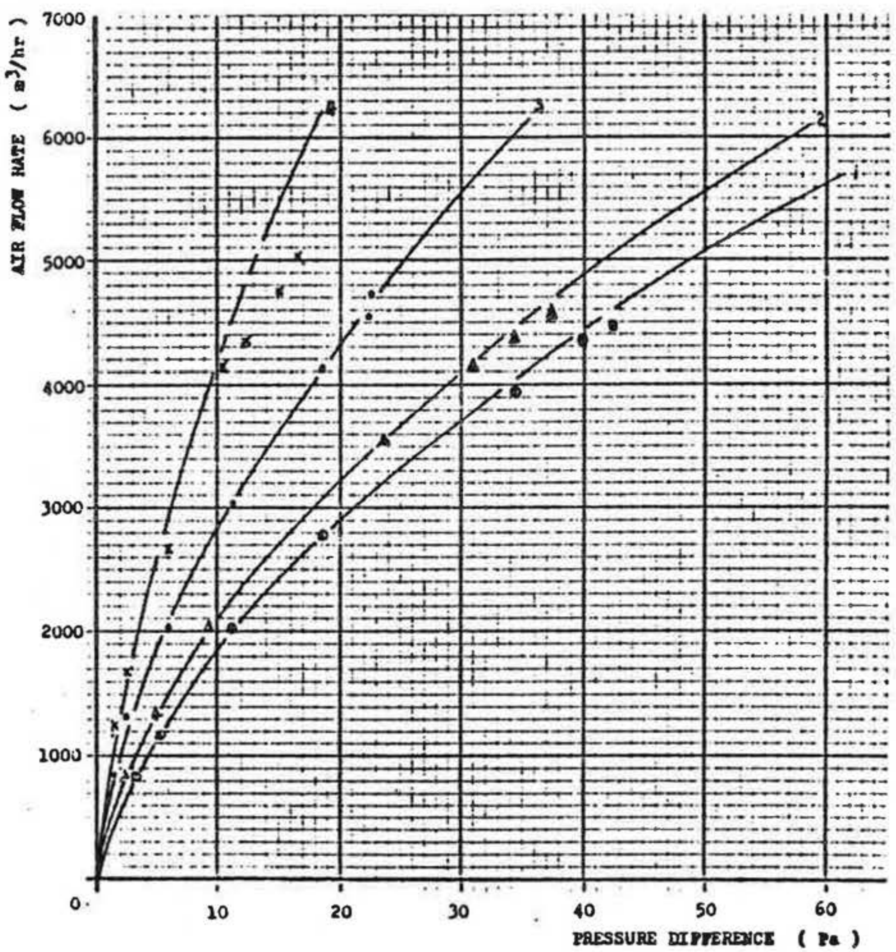
GEN. EQ.: $Q = 0.1489 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 33

DEPRESSURIZATION



HOUSE NO. 36

DATA OF TEST : 3.2.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, 03/066, ~~05/062~~

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : DETACHED, ~~END DETACHED~~, ~~TERRACE~~

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 194.62 m^2

NO. OF CRAWLSPACE VENTILATORS : 21

TEMPERATURE : INDOOR : 9 °C, OUTDOOR : 5 °C, ΔT : 4 °C

WIND : SPEED : 487 Ft/min OR 2.48 m/s, DIRECTION : E

RELATIVE HUMIDITY : INDOOR : 68 %, OUTDOOR : 60 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ~~ON~~ / OFF

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED

2. ONE WINDOW OPEN TO APPROX. 10mm GAP (0.02m^2)

3. ONE WINDOW OPEN TO APPROX. 45mm GAP (0.09m^2)

4. ONE WINDOW OPEN TO APPROX. 135mm GAP (0.27m^2)

TEST RESULTS (~~PRESSURIZATION~~ / DEPRESSURIZATION)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	1.5	2.8	1.5	1.0	335	669	669	836
2	3.8	6.2	3.2	2.5	836	1338	1171	1338
3	9.0	9.5	7.5	3.6	1673	1840	2007	2174
4	14.5	15.5	12.0	6.5	2342	2676	3011	3512
5	21.0	24.5	15.0	8.5	3011	3680	3680	4349
6	36.9	34.9	21.4	12.5	4248	4683	4683	5018
7	44.8	37.4	25.9	13.5	4783	4850	5185	5352
8	45.8	38.9	27.4	15.0	4850	5018	5352	5519
9	47.3	42.4	29.4	15.4	4850	5185	5519	5687
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A = 285.288$ $\beta_1 = 0.7524$ $r^2 = 0.9917$ $\alpha_1 = 1324.35$
2. $\alpha . (A + 0.02) = 311.171$ $\beta_2 = 0.7458$ $r^2 = 0.9972$ $\alpha_2 = 2701.19$
3. $\alpha . (A + 0.09) = 500.760$ $\beta_3 = 0.7177$ $r^2 = 0.9980$ $\alpha_3 = 1923.48$
4. $\alpha . (A + 0.27) = 846.486$ $\beta_4 = 0.7145$ $r^2 = 0.9970$ $\alpha_4 = 2078.51$

$\alpha_{av.} = 2006.88$

CONSIDER CONDITION 1 ONLY:

$Q_5 = 957.6$
$Q_{10} = 1613.2$
$Q_{20} = 2717.6$
$Q_{30} = 3666.9$
$Q_{40} = 4578.0$
$Q_{50} = 5414.9$

A = EQ. LEAKAGE AREA
= 0.1423 m^2

GEN. EQ.: $Q = 0.1423 \alpha_{av.} . \Delta P^{\beta}$

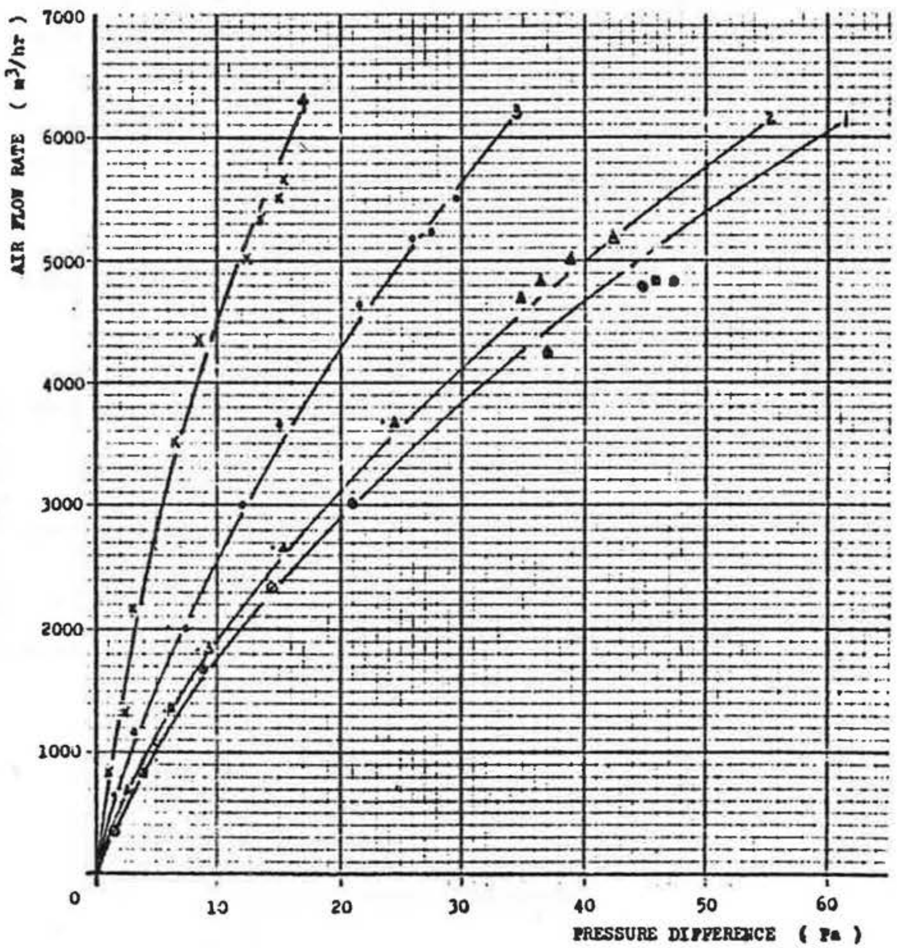
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 35

DEPRESSURIZATION



HOUSE NO. [illegible]

DATA OF TEST : 29.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/066~~, 05/062

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED~~, ~~END-DETACHED~~, TERRACE

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 79.65 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 14 °C, OUTDOOR : 10 °C, ΔT : 4 °C

WIND : SPEED : ____ Ft/min OR 4.57 m/s, DIRECTION : NW

RELATIVE HUMIDITY : INDOOR : 65 %, OUTDOOR : 70 %

WEATHERSTRIPPING OF OPENINGS : ~~YES~~ / NO

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS :
1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	1.5	1.0	1.0	1.5	380	335	502	1045
2	2.5	3.0	2.2	3.0	502	903	836	1673
3	5.0	7.8	7.5	4.2	1004	1673	2007	2041
4	13.0	11.5	13.0	6.3	2007	2342	3379	2676
5	17.4	17.4	19.9	10.0	2542	3044	4683	3746
6	32.5	29.9	22.4	14.2	4014	4683	4850	4683
7	37.0	33.4	23.9	16.0	4315	5084	5186	5018
8	46.5	36.9	25.9	16.5	5285	5452	5486	5185
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 279.128 β_1 = 0.7627 r^2 = 0.9974 α_1 = 3893.40
2. $\alpha . (A + 0.02)$ = 356.996 β_2 = 0.7587 r^2 = 0.9978 α_2 = 1812.99
3. $\alpha . (A + 0.09)$ = 483.905 β_3 = 0.7447 r^2 = 0.9984 α_3 = 1744.76
4. $\alpha . (A + 0.27)$ = 797.962 β_4 = 0.6656 r^2 = 0.9996 α_4 = 1921.61

$\alpha_{av.}$ = 2343.19

CONSIDER CONDITION 1 ONLY:

Q_5 = 952.6
Q_{10} = 1616.2
Q_{20} = 2742.2
Q_{30} = 3736.0
Q_{40} = 4658.6
Q_{50} = 5515.8

A = EQ. LEAKAGE AREA = 0.1190 m^2

GEN. EQ. : $Q = 0.1190 \alpha_{av.} \Delta P^{\beta_1}$

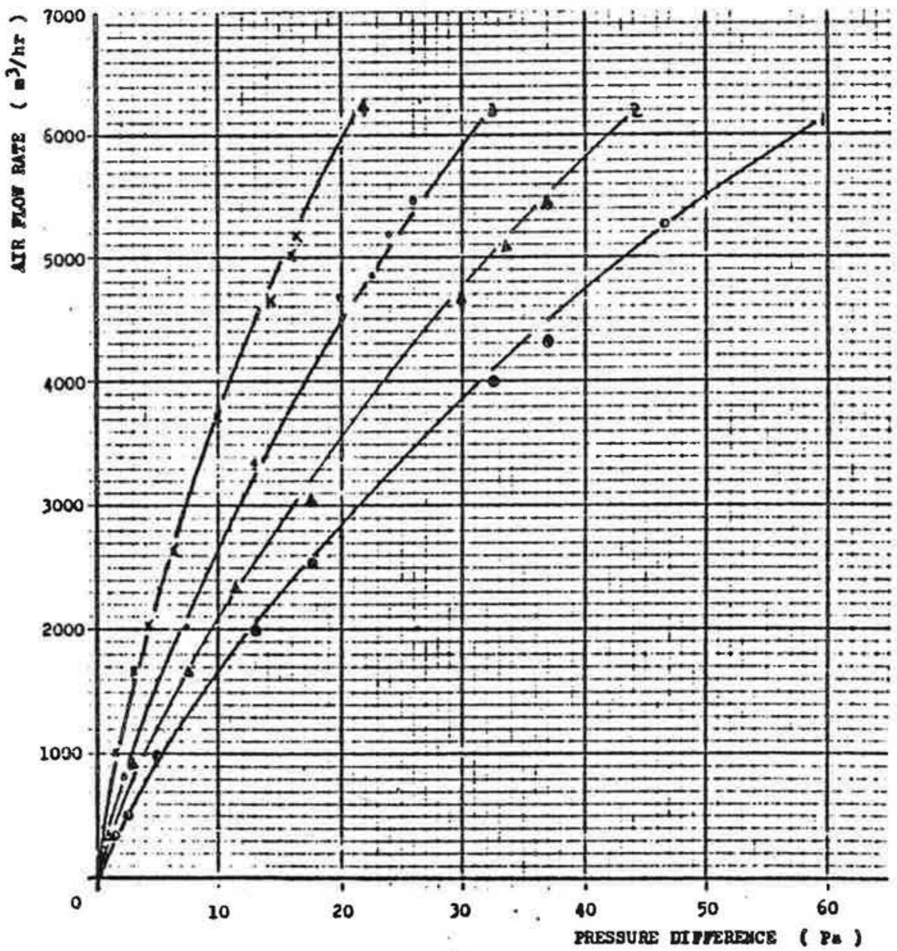
BETTER INSULATED HOUSE PROJECT

BO'NESS KINNEIL SITE PHASE 1C

AIR INFILTRATION GRAPH

HOUSE NO. 40

PRESSURIZATION



HOUSE NO. 41
DATE OF TEST : 29.1.82

AIR INFILTRATION - PRESSURIZATION TEST RESULT SHEET

HOUSE CODE : ~~03/065~~, ~~03/066~~, 05/062

HOUSE GROUP : CONTROL, ~~TEST~~

HOUSE TYPE : ~~DETACHED~~, ~~ENL DETACHED~~, TERRACE

HOUSE VOLUME : 230.85 m^3

HOUSE ENVOLOPE (EXPOSED SURFACE) WALL AREA : 79.65 m^2

NO. OF CRAWLSPACE VENTILATORS : 15

TEMPERATURE : INDOOR : 14 °C, OUTDOOR : 10 °C, ΔT : 4 °C

WIND : SPEED : ____ Ft/min OR 4.57 m/s, DIRECTION : NW

RELATIVE HUMIDITY : INDOOR : 60 %, OUTDOOR : 70 %

WEATHERSTRIPPING OF OPENINGS : YES / ~~NO~~

HEATING CONDITION DURING TEST : ON / ~~OFF~~

TEST CONDITIONS : 1. ALL WINDOWS TIGHTLY CLOSED
2. ONE WINDOW OPEN TO APPROX. 10mm GAP ($0.02m^2$)
3. ONE WINDOW OPEN TO APPROX. 45mm GAP ($0.09m^2$)
4. ONE WINDOW OPEN TO APPROX. 135mm GAP ($0.27m^2$)

TEST RESULTS (PRESSURIZATION / ~~DEPRESSURIZATION~~)

NO.	PRESSURE DIFFERENCE (Pa)				AIR FLOW RATE (m^3/hr)			
	1	2	3	4	1	2	3	4
1	1.5	2.0	1.0	1.0	397	609	502	1004
2	3.0	3.7	2.5	2.5	669	970	1004	1686
3	5.0	7.8	8.5	3.2	1004	1840	2342	2107
4	13.0	13.0	12.0	6.2	2107	2676	3011	3011
5	24.9	24.9	15.0	9.0	3178	4014	3345	3680
6	31.5	29.9	19.9	13.2	3680	4515	4014	4683
7	35.0	32.4	24.4	15.0	4014	4683	4683	5185
8	47.2	34.9	29.9	19.1	4683	4850	5319	5687
9								
10								

RESULT ANALYSIS ($Q = \alpha . A . \Delta P^{\beta}$)

1. $\alpha . A$ = 294.832 β_1 = 0.7352 r^2 = 0.9973 α_1 = 3466.50
2. $\alpha . (A + 0.02)$ = 364.162 β_2 = 0.7450 r^2 = 0.9949 α_2 = 2223.87
3. $\alpha . (A + 0.09)$ = 519.578 β_3 = 0.6910 r^2 = 0.9992 α_3 = 2761.76
4. $\alpha . (A + 0.27)$ = 953.655 β_4 = 0.6220 r^2 = 0.9975 α_4 = 2674.45

$\alpha_{av.}$ = 2781.65

CONSIDER CONDITION 1 ONLY:

Q_5 = 962.6
Q_{10} = 1602.4
Q_{20} = 2667.4
Q_{30} = 3593.8
Q_{40} = 4440.3
Q_{50} = 5231.9

A = EQ. LEAKAGE AREA
= 0.1060 m^2

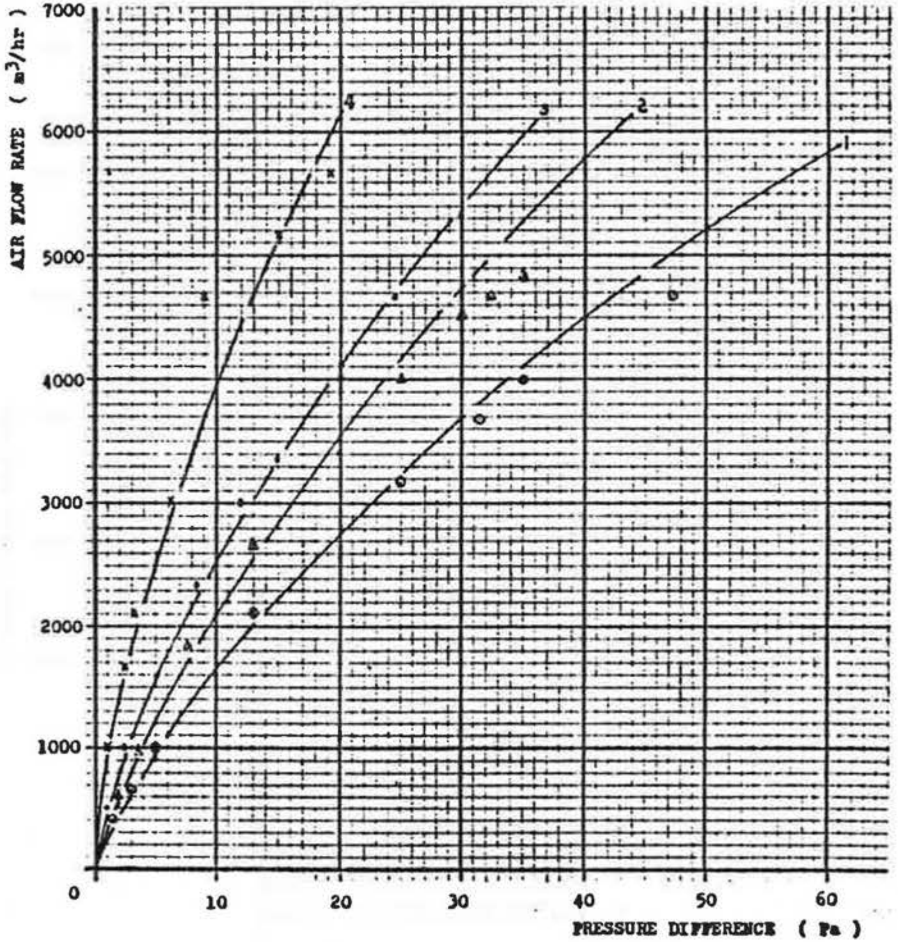
GEN. EQ.: $Q = 0.1060 \alpha_{av.} \Delta P^{\beta_1}$

BETTER INSULATED HOUSE PROJECT
BO'NESS KILNGIL SITE PHASE 1C

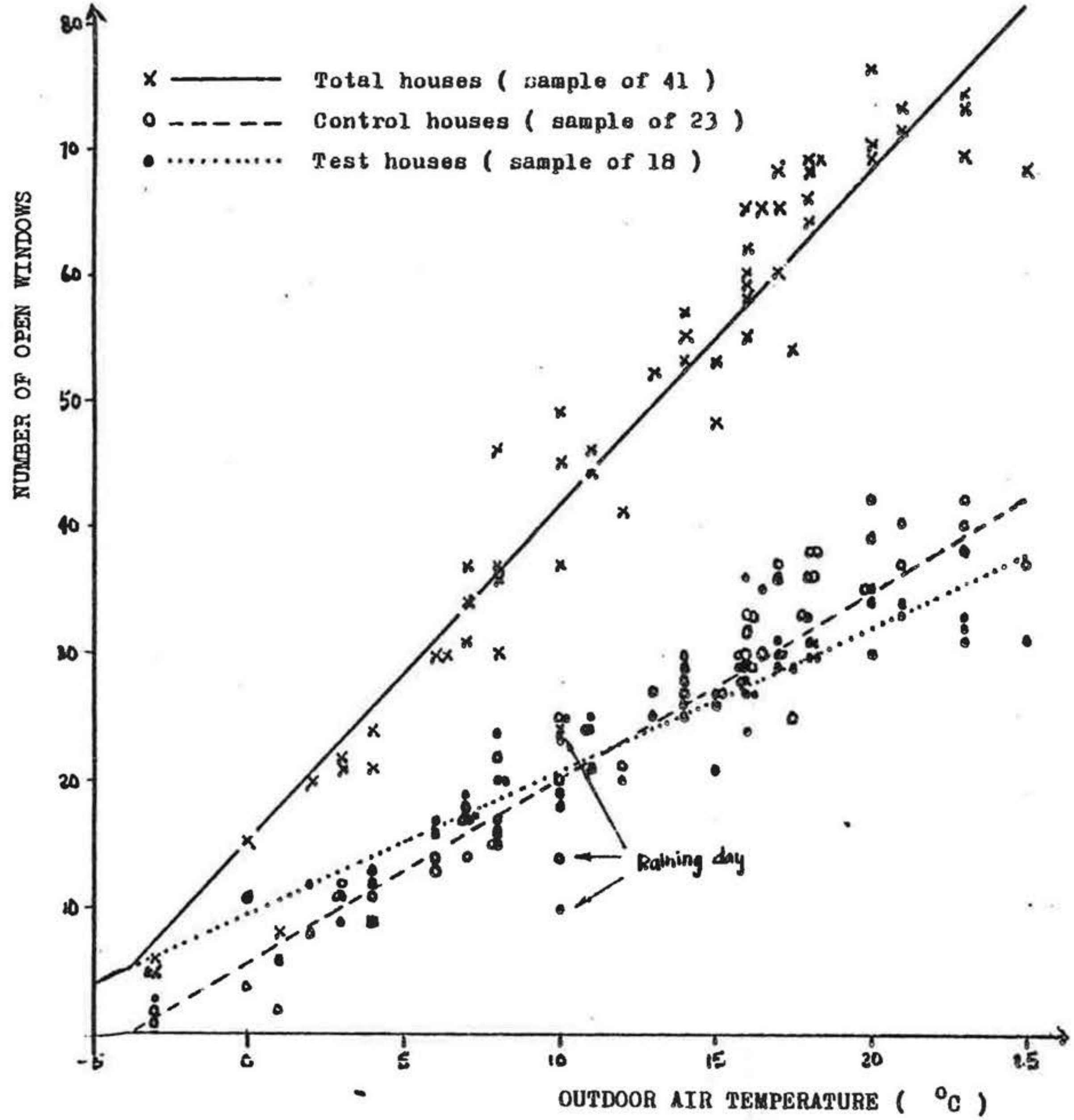
AIR INFILTRATION GRAPH

HOUSE NO. 41

PRESSURIZATION



APPENDIX B



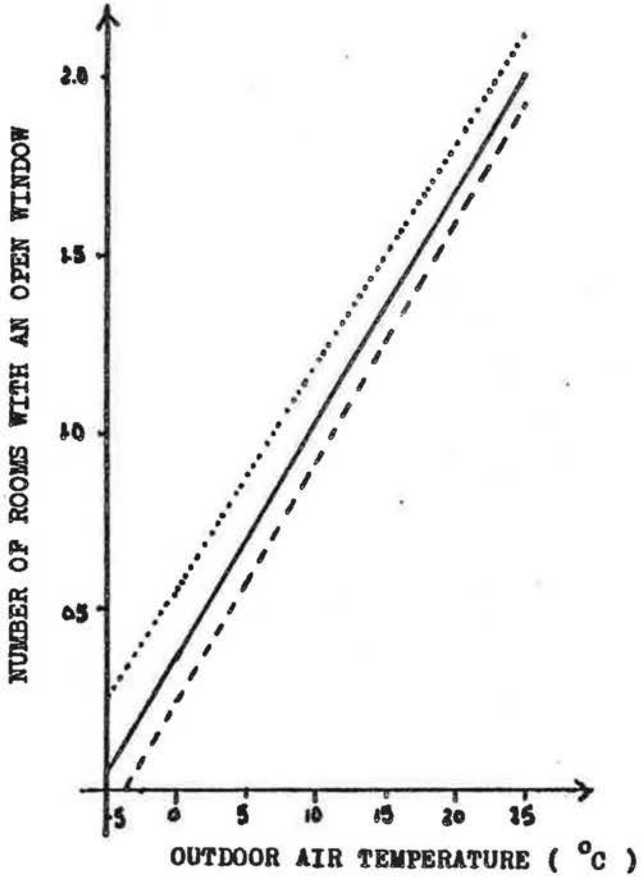
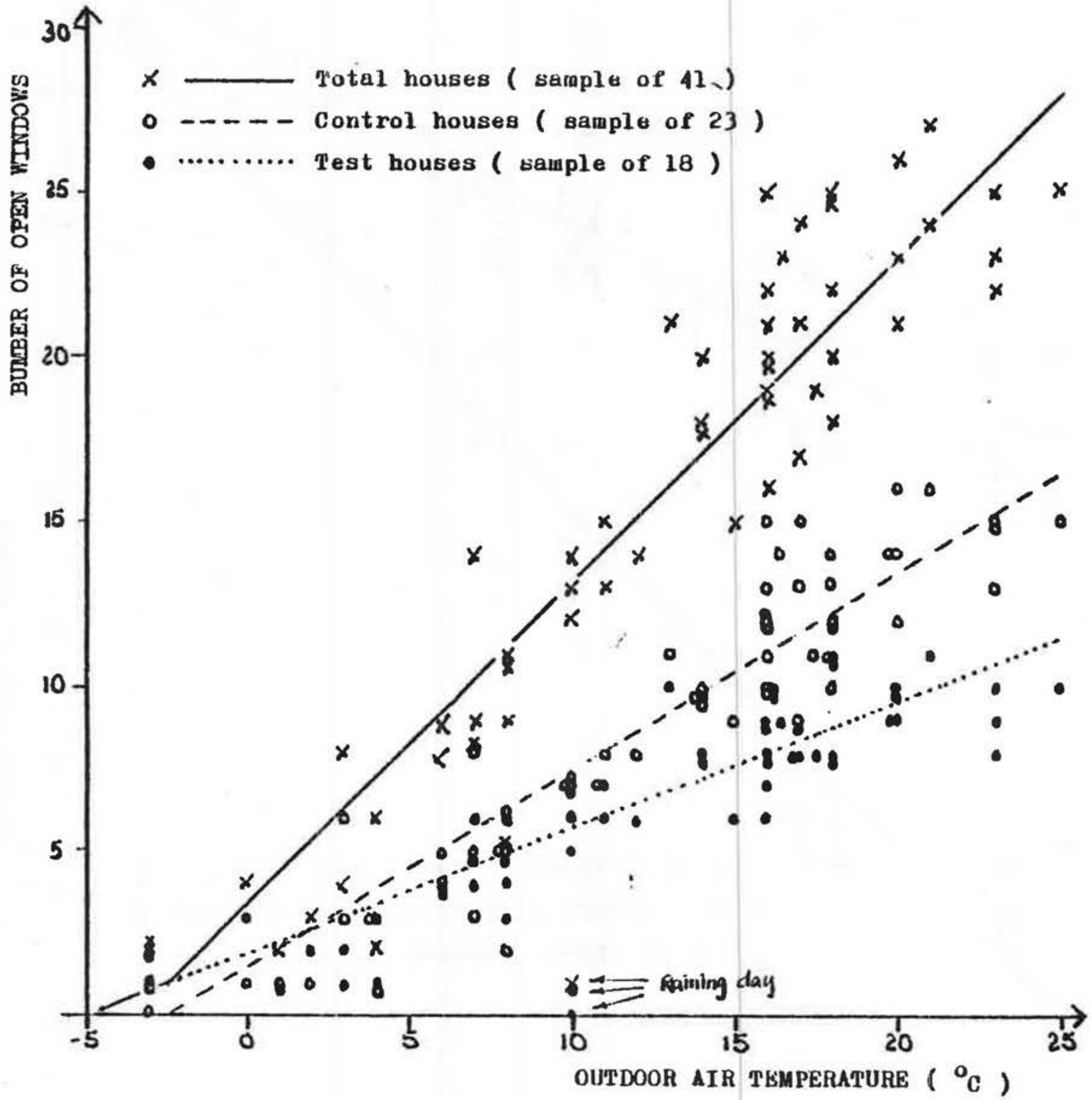


FIG.D.1 : RELATIONSHIP BETWEEN OPEN WINDOW AND TEMPERATURE : BEDROOMS



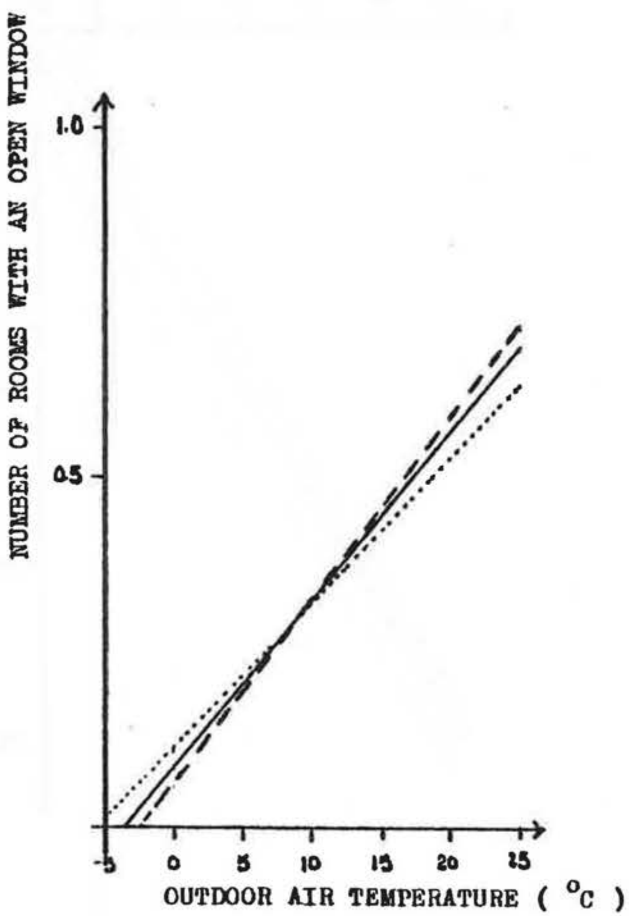


FIG. D.2 : RELATIONSHIP BETWEEN OPEN WINDOW AND TEMPERATURE : W.C.

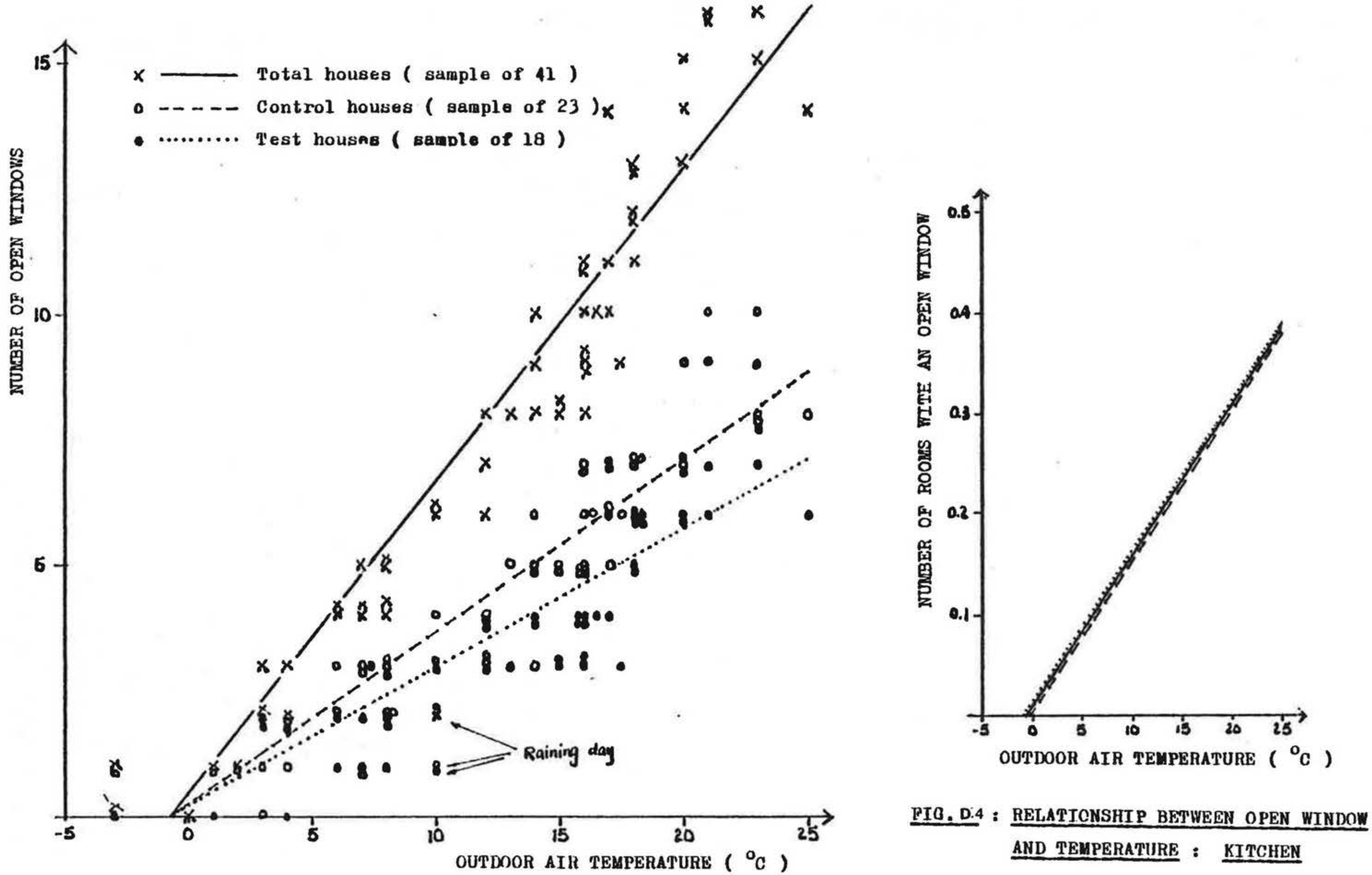
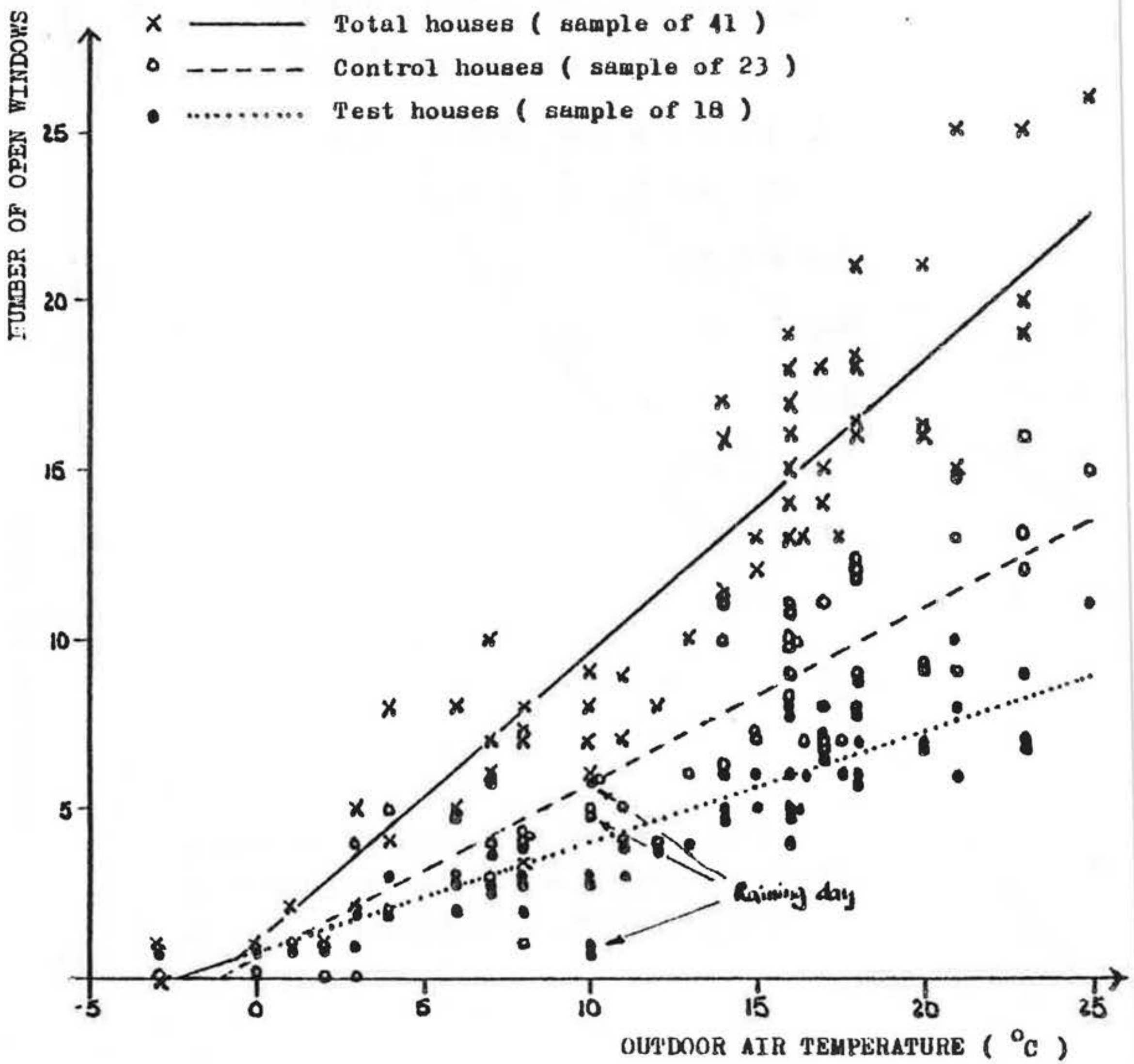


FIG. D.4 : RELATIONSHIP BETWEEN OPEN WINDOW AND TEMPERATURE : KITCHEN



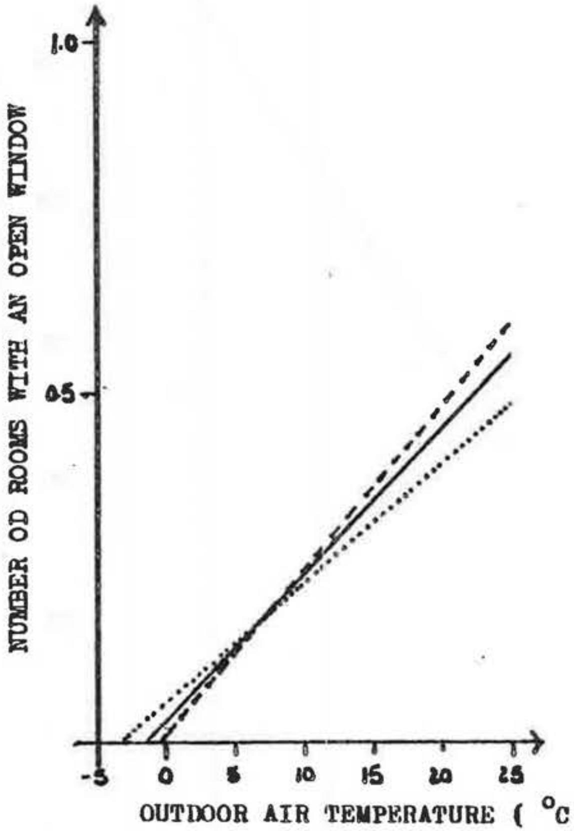
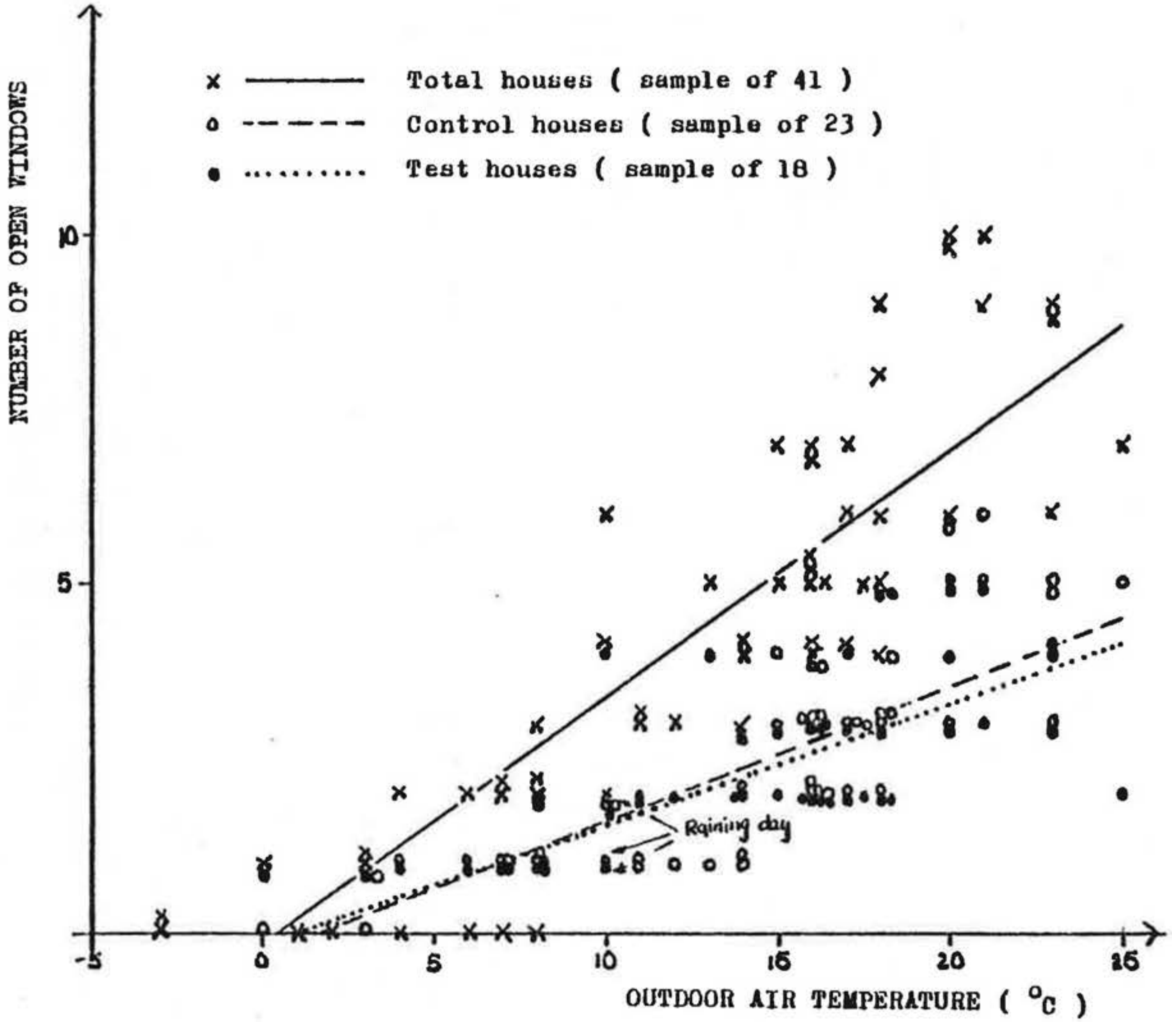


FIG. D.3 : RELATIONSHIP BETWEEN OPEN WINDOW AND TEMPERATURE : BATH



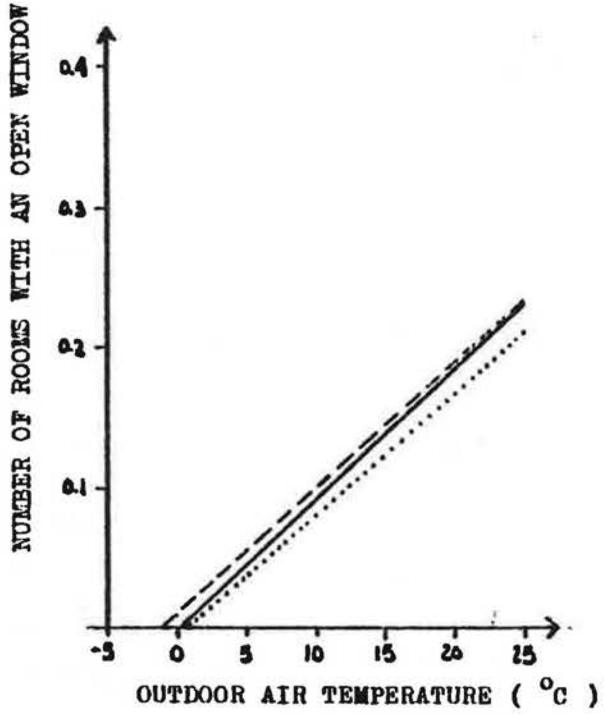
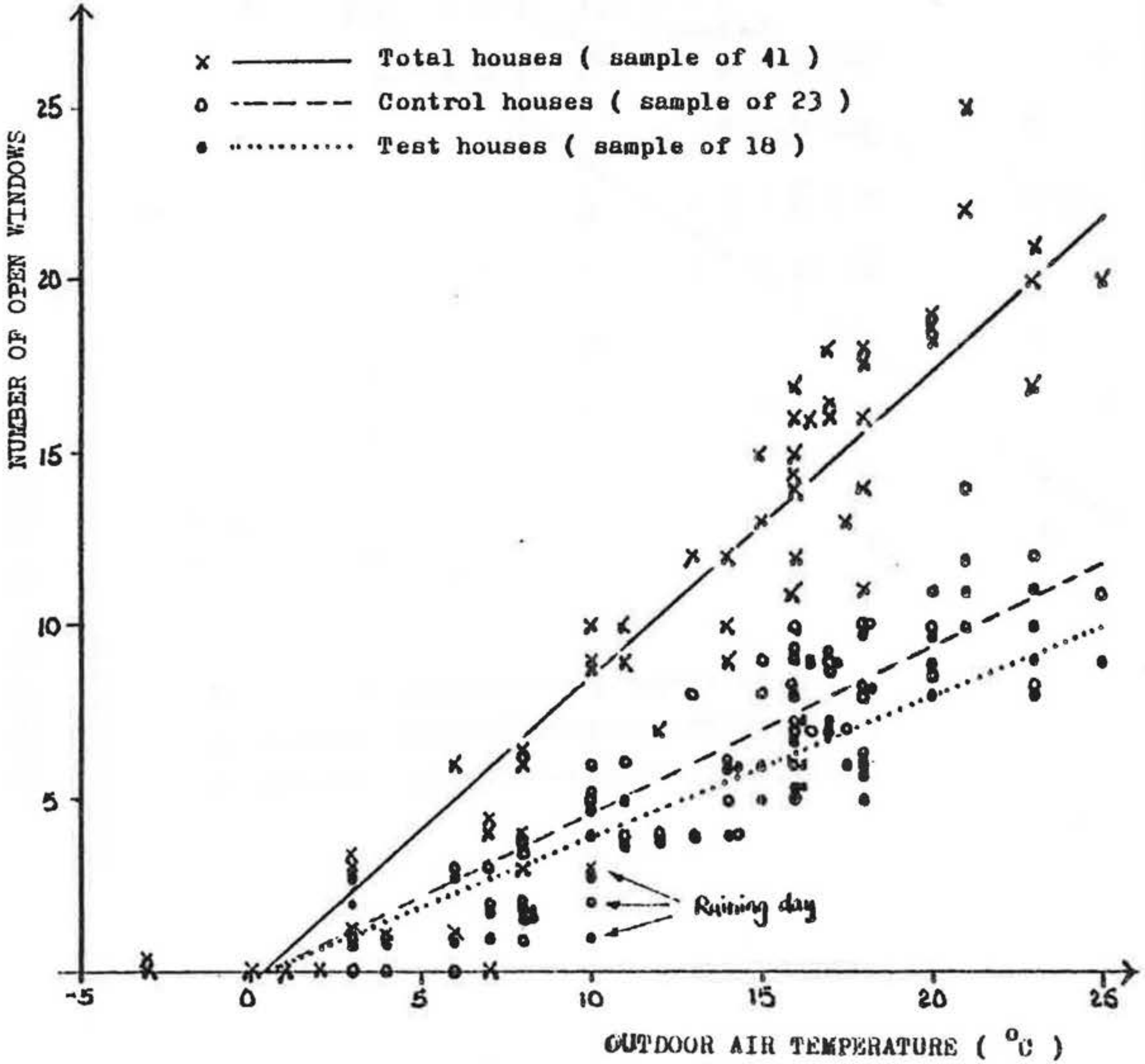


FIG. D6 : RELATIONSHIP BETWEEN OPEN WINDOW AND TEMPERATURE : DINING ROOM



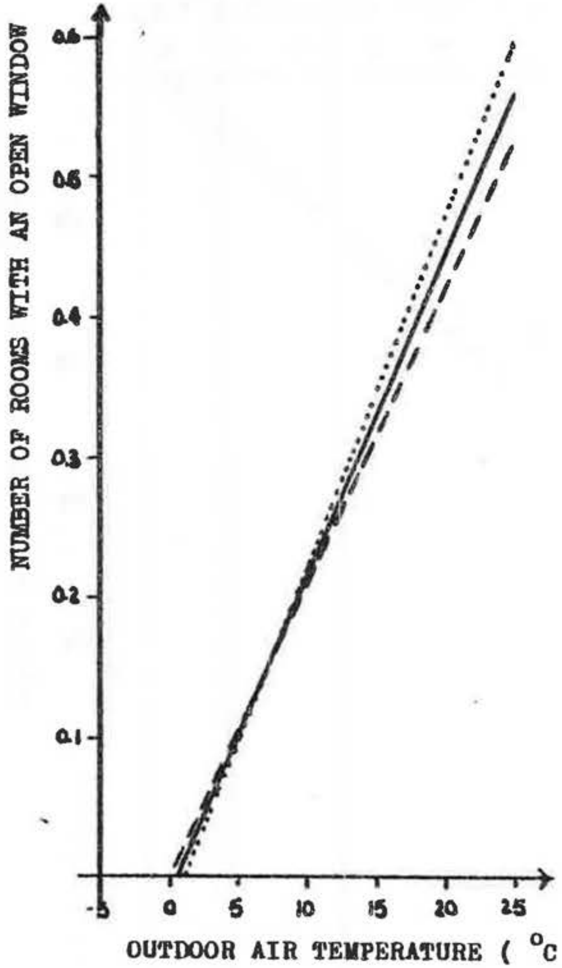


FIG. D.5 : RELATIONSHIP BETWEEN OPEN WINDOW AND TEMPERATURE : LIVING ROOM