INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and
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Technical Note AIC 6

Reporting format for the measurement of air infiltration in buildings

December 1981

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

This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme

Annex V Air Infiltration Centre

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Participants in this task:

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

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Carolyn Allen

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PREFACE

International Energy Agency

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

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

Energy Conservation in Buildings and Community Systems

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

Annex V Air Infiltration Centre

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

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

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

INTRODUCTION

One of the aims of the Air Infiltration Centre is to encourage the collection and dissemination of air infiltration data arising from programmes of research and experimental investigation. This task can be made much easier and more effective if the relevant test information and results are presented in a comprehensive and uniform manner.

This standardised reporting format has been produced to provide a common method for research workers to set out their experimental data, so making the information easy to extract for subsequent analysis or mathematical model development.

The structure of the format is purposely rather loose, to cater for the differing interests of the various investigators who will be using it. It has been made as comprehensive as possible but should not be regarded as exclusive. Correspondingly, the user should not feel impelled to fill in all the sections; however, if the results are entered in the order given, it immediately becomes apparent which items of information are present and which absent.

The format may be used directly for entering results and should also serve as a useful checklist to aid those who are initiating projects.

Sections cover:

- general information
- test site description, including

  geographic information
  climatic data
  building description (leakage paths, heating and ventilation systems, etc.)

- building function, including occupancy, etc.
- measurement procedures and results, including

  pressure tests
  surface pressure measurements
  internal and external conditions, weather, etc.
  infiltration

- numerical models
- economic factors
- general remarks

The contents of each section are printed on the right-hand pages of the report and are accompanied by explanatory notes on the left-hand pages. Points relevant to the use of various methods are raised in the notes. Also included are details of minimum standards of measurement where these have been indicated by past experience or future requirements.

An example of the format is included as an appendix.

The AIC will be pleased to receive copies of the completed formats for inclusion in the Centre's numerical database. An up-to-date record of the contents of this database is maintained and copies of the data are available through the nominated organisations in the participating countries.

NOTES

General Points

(1) Units to aid comparison of results.

We ask that *all* data be supplied in *S.I. units.* The use of other sets of units for local convenience, in addition, is optional. Where a quantity is in common use, e.g. air changes/hour, it may be noted for cross comparison.

(2) Any entry for which the data supplied takes up much more space than has been allowed may be supplied as an appendix, which should be clearly labelled with the same letter and number code as the corresponding entry on the form, and should be supplied in the same order.

(3) Users are asked to supply as much of the general information as they can in addition to their own special interest — the more complete the data set, the more valuable it is.

(4) Where blocks of information are common to several buildings, these need only be cited once in the appropriate position and referred to as necessary.

(5) Any information supplied to the AIC will be regarded as freely available to any bona fide enquirer with the understanding that the origin of the data set will be acknowledged.

I. GENERAL INFORMATION

Country | **Principal Researcher** | **Date**

Address:

Telephone/Telex:

Title of Project:

Principal Objectives:

References:

Comments:

II. TEST SITE DESCRIPTION – Notes

A. Geographic Information

(1) Longitude, latitude, name of site (address where it would be helpful). Map coordinates if available e.g. Ordnance Survey (sheet number, six figure reference number). US Geological Survey (State, sheet number reference). Or equivalent.

(2) Height above mean sea level.

(3) Terrain. The terrain category would be useful here.

(a) Open sea, ice, tundra, desert.

(b) Open country, low scrub, scattered trees.

(c) Suburban area, small towns, well wooded areas.

(d) Numerous tall buildings, city centres – well developed industrial areas.

(Also see section IIIB. when wind tunnel methods are used. See reference 6.)

If the roughness of the terrain varies strongly with direction, it would be helpful to specify category by 22½° sector as for wind direction, also slope (gradient).

(4) Orientation and (5) Location of the Meteorological Station may be indicated on a map of the site as described but should also be quoted numerically.

B. Climatic Information

Climatic data is usually quoted over a period of about 10 years. The dates covered should be quoted as there are local changes of climatic pattern which take place on that time scale which may cast doubt on the usefulness of this information.

Where the aim of the work is to determine future energy consumption, this is of interest. If available it should be included for the sake of completeness of the data set.

(1) % frequency of wind speed with direction (by 22½° sector or 10° sector where available)– this should be a sufficiently finely divided direction set for all practical purposes and data are usually readily available from most national meteorological agencies. This is the case for ground level records. Upper level records may be useful from the point of view of calculating velocity profiles for correlation with wind tunnel work. These are rather less easy to obtain.

(2) % frequency wind speed v temperature. These too are normally readily available.

(3) Hours of daylight and (4) Cloudiness are useful for the purpose of assessing energy requirements.

(5) Precipitation, r.h. etc. may usually be found from the same source.

(6) Here should be included man made environmental effects, e.g. local sources of industrial effluent heat or water vapour e.g. power stations; proximity to local bodies of water e.g. rivers, lakes and reservoirs, permanent wet land should also be considered here. Large paved areas such as airports, motorways, etc. should also be mentioned. In short, any environmental factor which is likely to have a strong effect on the micro-climate at the test site.

II. TEST SITE DESCRIPTION

A. Geographic Information

(1) Location.

(2) Height above sea level.

(3) Terrain.

Please append map showing the surrounding area indicating location and size of obstacles such as trees, fences and other buildings, also relief.

(4) Orientation.

(5) Location of Meteorological Station.

B. Climatic Information (where available)

(1) % frequency wind speed v direction *(by 22½° sector – attach table).*

(2) % frequency wind speed v temperature *(attach table).*

(3) Hours of daylight/insolation *(attach table).*

(4) Cloudiness.

(5) Precipitation, humidity.

(6) Other – anthropogenic factors.

C. The Building – Notes

(1) History. This section should contain the date of construction and any structural modifications, retrofit, etc. Some mention should be made of past usage (where relevant) as this may have affected the fabric.

(2) Construction materials and technique. Here one should describe the structure of the envelope, paying attention to jointing methods and its effect on communicating spaces, e.g. wall cavities, crawlspace, etc., giving details of insulation, moisture barriers, etc.

(3) Dimensions, should cover *all* physical dimensions of the building, internal and external.

(a) and (b) should be supplied as drawings, showing the location of doors, windows, service shafts, etc. The numerical values should be tabulated separately. Measurement sites should be marked on these diagrams.

(c) and (d) both of these should be quoted as they are not necessarily the same for practical cases.

(k) Shape – here one should include irregularities in the form of the envelope, e.g. bay windows, garages, etc. The roof pitch should be given as this can have a profound effect on surface pressure distribution.

(l) As shown. Details can be given here or under section IIC. (4e), whichever seems to be more suitable for the task in hand.

C. The Building

(1) History.

(2) Construction material and technique.

(3) Dimensions *(Please append diagram to report for clarity.)*

(a) Plan: attach diagram (internal/external).

(b) Elevation.

(c) Total volume.

(d) Effective volume.

(e) Floor area.

(f) Ceiling area.

(g) Facade (wall) area.

(h) Total area of windows.

(i) Total area of external doors.

(j) Number, volume and layout of rooms (refer to (a)).

(k) Shape: roof pitch, etc.

(l) Attic, basement, crawlspace.

(i) Insulation.

(ii) Description.

(4) Gaps in the envelope.

(a) (iii) Include weatherstripping details.

(b) (i) E.g. sash window, casement window, double or single glazed etc. Fixed glazing — if cracks readily measured and regular, enter here. Otherwise (h).

(ii) Include frame — wall cracks.

(iii) Include such additional sites as roller blind boxes. Also details of weatherstripping.

(c) (i) E.g. foundation grilles, air bricks, purpose provided stacks etc.

(4) Gaps in the envelope.

(a) Doors (external).

(i) Type.

(ii) Cracklength.

(iii) Comments.

(b) Windows.

(i) Type.

(ii) Cracklength.

(iii) Comments.

(c) Ventilation openings.

(i) Type.

(ii) Cracklength.

(iii) Open area.

(iv) Degree of closure.

(v) Comments.

(d) Including flue dampers; give information on operating cycle.

(e) Floor and wall cavities and roof spaces may provide an easy path for airflow. The presence of impedences to this should be mentioned even if only by referring to another section.

(h) Other major sources. Here one should include any major source not covered by the above but arising from the design of the building, e.g. coal cellar doors, hatches, manholes, internal garages, etc.

(j) Background leakage. Practice has shown this to be a very important contribution to the total leakage of a building, as much as 50%. Some estimate should always be made of adventitious openings. Give pressure — depressurization curve or refer to IV.A (4a and b).

(d) Chimneys, flues.

(i) Size, type.

(ii) Location.

(iii) Condition of dampers.

also estimates of crack size for:

(e) Cavity walls and other communicating spaces, also electrical outlets.

(f) Soleplate, ceilings, corners, skirting boards.

(g) Plumbing outlets, drains, etc.

(h) Other major sources.

from the above and the measured leakage,

(j) Background leakage.

(k) Comments.

(5) HVAC system.

(a) Include:

HVAC systems.

AC systems.

Ventilation systems.

Heating systems with or without forced air movement.

Additional self-contained mobile heating units.

One should mention any special ventilation requirements for the system in question.

(cross reference IIC. (4d) chimneys, flues.)

(c) It should be stated whether ducts are in heated or non heated space.

(d) The seasonal variations in the operation of the system should be included, e.g. midwinter unit on 50% of the time.

Similarly for (e).

(f) Indicate location of inlets and outlets.

(g) Include remarks on air movement generated by heating plant operation.

(6) Pollution (non anthropogenic).

Should cover pollution due to building fabric.

– Radon, Formaldehyde, Sulphates, Organics, Mercury etc. and from outside sources, Ambient air, Motor vehicles etc.

Pollution arising from occupancy is dealt with under section IIIB. (2e). This is intended to account for possible sources of interference in tracer gas studies.

(5) HVAC system.

(a) Type of system.

(b) Blower fan capacity (where available).

(c) Duct tightness and location.

(d) Frequency of operation, duration of operating cycle.

(e) Operating temperature.

(f) Location of air inlets.

(g) Comments.

(6) Pollution (non anthropogenic).

(a) Interior.

(b) Exterior.

A. Type

State building classification, for example:

Residential

Single Family	–	Houses
Multi Family	–	Flats, Apartments
Communal	–	Hotels
	–	Hostels
	–	Communes
Institutional	–	Hospitals
	–	Prisons
	–	Boarding Schools
Intermittent	–	Holiday Homes
Other	–	Houseboats
	–	Caravans
	–	Mobile Homes
	–	Nuclear Bomb Shelters

Commercial/Industrial

Office	–	Clerical
Factory		
Storage	–	Warehouse
Plant	–	Telephone Exchange
	–	Chemical Plant
	–	Computer Suite (Machinery dominates requirements)
Farm	–	Battery Houses
	–	Greenhouses
	–	Milking Parlour
	–	Abattoir, etc.
Public	–	Airports
	–	Railway Stations
	–	Bus Stations
	–	Public Houses
	–	Clubs, Theatres
	–	Restaurants
	–	Museums
	–	Art Galleries
	–	Churches
	–	Shops
	–	Schools
Other	–	Laboratories
	–	Mortuaries
	–	Bank Vaults

B. Occupancy

Any other feature of the *function* of the building which affects the infiltration rates, e.g. necessary opening of doors.

(1) Times occupied, number of users. This can be monitored where relevant.

(2) Behaviour of occupants.

(a) Enter in Section IVF. (3) when measured directly. Otherwise as shown.

(b) Including internal doors.

(c) Extractor fans in kitchens, toilets, etc.

(d) This allows for variations in heating policy of the inhabitants, e.g. which rooms are heated all the time/sometime/never, in summer/winter, etc.

(e) Pollution (anthropogenic). Pollution sources arising from human activity should be described here. Cooking, aerosols and smoking are shown but there may be other – candles or oil or coal fired appliances, incense sticks, etc.

(f) Sedentary, physically active.

C. Special Requirements

There may be special ventilation needs in an environment to preserve safety or hygiene – hospitals, mortuaries, biological and chemical laboratories, factories handling toxic or irritant materials, or to create steady conditions to prevent deterioration, e.g. museums, art galleries, computer suites, furniture depositories, etc.

A. Type (including use)

B. Occupancy

(1) Times occupied and number of users.

(2) Behaviour of occupants.

(a) Window opening.

(b) Door opening.

(c) Other voluntary ventilation.

(d) Heating habits.

(e) Pollution (anthropogenic).

(i) Cooking.

(ii) Aerosols, solvents, etc.

(iii) Smoking.

(iv) Other

(f) Level of activity of occupants.

(g) Comments.

C. Special Requirements

D. Other

E. Comments

A. Pressurisation Measurements – internal

(1) Measurements at several pressures are recommended (both positive and negative) for steady state methods. If crack distribution varies strongly over the envelope we recommend that repeat observations be made for different wind directions.

Any components which are sealed during the test should be given.

Pressure tests on individual components should be described here.

IV. MEASUREMENTS

Date and time measurements taken.

A. Pressurisation Measurements – internal

(1) Technique employed.

(2) Equipment used.

(3) Description of procedures for calibrating equipment.

(4) Results (attach relevant tables, graphs etc.)

(a) Pressurisation.

(b) Depressurisation.

(c) Alternating pressurisation (infrasonic).

(5) Comments.

B. Pressure Measurements — external

(1) The conditions under which the pressure test is carried out should be specified.

Pressure Coefficients

In various combinations the following have been used in the past. Where possible these should be given:

Pressures — Mean pressure $\bar{p}$. Extreme pressures for a given time scale, e.g. 1/32s $\hat{p}$, mean internal pressure p_I. The standard deviation and skewness should also be given.

Velocities — Mean velocity $\bar{v}$. Extreme velocity for given time scale $\hat{v}$ as for $\hat{p}$. Velocities are related to specific heights 3m, 10m, roof ridge height, etc. Whichever height is chosen as reference, both mean and extreme values should be given where possible. When pressure coefficients are quoted the expression used to define them should be explicitly given at this point.

Scaling with reference to velocity at a height of 10m or to internal pressure would seem to be best from the viewpoint of matching with wind tunnel models and standard meteorological data.

(4) Some work by BRE, (Ref. 1) on exterior pressure measurements has indicated that large pressures are experienced near corners, therefore, we would recommend as wide a distribution of sensing points as possible. Raw pressure data is preferred where available, as this should simplify standardising values.

If wind tunnel studies are used:

- the scale of the model and the size of the wind tunnel should be described.
- the geographical area covered by the model should be indicated (possibly on the map IA.(4)).
- the method used to generate the turbulent profile in the wind tunnel should be described.
- the assumptions made regarding the velocity profile and turbulent spectrum should be stated.
- if available, it is desirable to mention the level of correspondence between modelled conditions and real conditions on site.

Such studies as performed by BRE (Ref. 1), British Gas (Ref. 2) and others have indicated that while a 1/50th scale model was probably satisfactory for mean pressures, for adequate representation of major pressure fluctuations a scale of 1/200 with accurate modelling of the surroundings for a radius of 200m proved necessary.

B. Pressure Measurements — external (including wind tunnel studies)

(1) Technique used (including conditions)

(2) Equipment used.

(3) Calibration procedure.

(4) Location of surface pressure taps (see II.C (3)).

(5) Measurement results (attach as table).

(6) Comments)

C. Interior Conditions — Notes

Where relevant, the time dependence of these quantities should be given here.

D. Exterior Conditions

(3) (e) and (f). Where these are given, the range of frequencies covered should be given. Presentation as a spectrum would be acceptable.

(g) This is considered useful since many studies assume neutral stability — an assumption which is not always justified, especially in connection with wind tunnel studies, as the wind speeds modelled mostly correspond to stable conditions. Stable conditions are known to reduce the scale of turbulence and unstable conditions to increase it; buoyancy being less important as wind speed increases. The degree to which this is effective is somewhat uncertain. Experimental evidence which would help to clarify this would be of great value.

C. Interior Conditions

(1) Temperature (dry bulb).

(2) Relative humidity.

(3) Air flow.

(4) Other.

(5) Comments.

D. Exterior Conditions

(1) Description of equipment used.

(2) Weather — off-site.

- (a) Wind speed.
- (b) Wind direction.
- (c) Dry bulb temperature.
- (d) Stability conditions.
- (e) Other (see A5. for location).
- (f) Comments.

(3) Weather on-site.

- (a) Wind speed.
- (b) Wind direction.
- (c) Dry bulb temperature.
- (d) Relative humidity.
- (e) Turbulence scale.
- (f) Turbulent intensity.
- (g) Stability conditions (where available).
- (h) Other.
- (i) Comments.

E. Infiltration — Notes

(1) (a) Rate of decay. Several successive measurements recommended, also repeat measurements for different weather conditions. Bias error a problem.

(b) Transfer index method. Ref. 4 (pp. 62, 65, 66).

(c) Equilibrium concentration rate. Probably of limited usefulness for tight houses.

(d) Steady concentration method. Good for long term monitoring. Ref. 3.

— for information on limitations, see Ref. 4.

E. Infiltration

(1) Measurement technique.

(2) Equipment used (include photographs).

(3) Calibration procedures.

(4) Measurement results (attach relevant table, graphs, etc).

(5) Comments

F. Other – Notes

Any measurements which may be of interest, not covered by A to E.

(2) For use in such expressions as Harrje's Energy Signature (Ref. 5). See also Section VI.

F. Other

(1) Qualitative.

(a) Smoke sticks.

(b) Acoustic techniques.

(c) IR. Thermography.

(2) Energy consumption.

(3) Other.

(4) Comments.

V. NUMERICAL/COMPUTER MODELS – Notes

A. Type of Model

E.g. regression, finite difference etc.

We would like to encourage the use of physically dimensionally correct equations where practical.

C. Computer Models

Please include:

– Type of machine.

– Storage required for program. Time to run program.

– Average cost of simulations.

(4) This is considered important!

V. NUMERICAL/COMPUTER MODELS

A. Type of Model

B. Correlations

(1) Variables used.

(2) Sign and goodness of fit.

(3) Problems encountered in attempting to find a correlation.

(4) Comments.

C. Computer Models

(1) Name and description of model, including assumptions.

(2) Input.

(3) Output.

(4) Agreement with observation.

(5) Comments.

D. Any Other Theoretical Work of Interest

VI. ECONOMIC FACTORS – Notes

This section should cover the economic effectiveness of retrofitting, construction methods etc. where available.

Energy Signature etc.

VI. ECONOMIC FACTORS

(1) Retrofitting measures.

(a) Procedures.

(b) Energy consumption before and after retrofit.

(2) Effects on energy consumption and health of controlling ventilation rates.

(3) Other.

VII. GENERAL REMARKS – Notes

This section should be used to raise any points not covered by the above. Remarks relating to general principles would be welcome.

A discussion of practical limits on the usefulness of experimental techniques, suitable time scales, turbulent frequency ranges, etc. would be of value. This would help to lay a foundation for future standard practices.

Any conclusions arising from the study should be given here.

VII. GENERAL REMARKS

VIII. REFERENCES

1 Eaton K. J. and Mayne J. R.
'The measurement of pressures on two storey houses at Aylesbury.'
Building Research Establishment current paper.
CP 70/74, July 1974.

2 Alexander D. K. and Etheridge D. W.
'The British Gas multi-cell model for calculating ventilation.'
ASHRAE Trans. Vol 86, part 2, pp 808–821. 1980

3 Gale R.
'Ventilation heat loss, outside in.'
Gas Engng and Management, 19, No. 11, pp. 563–572, 1979.

4 Hitchin E. R. and Wilson C. B.
'A review of experimental techniques for the investigation of natural ventilation in buildings.'
Building Science Vol 2 pp 59–82. 1967

5 Harrje D. T., Dutt G. S. and Beyea J. E.
'Locating and eliminating obscure but major energy losses in residential housing.'
ASHRAE Trans. Vol. 85, part 2, pp. 521–534, 1979 .

6 Cook N. J.
'On simulating the atmospheric boundary layer in wind tunnels.'
Building Research Establishment current paper.
CP 71/78 (December 1978), also
Journal of Industrial Aerodynamics 1978 ,Vol. 3, No. 2/3, pp. 157–176 and Vol. 2, No. 4, pp. 311–321.

APPENDIX

Use of Reporting Format – example

I. GENERAL INFORMATION

Country	Principal Researcher	Date
Switzerland	H. Muehlebach P. Hartmann	June, 1981

Address:

EMPA
Section 151
Ueberlandstrasse
8600 Duebendorf
Switzerland

Telephone/Telex:

Telephone: 01/823 4251
Telex: 53817

Title of Project:

Messgebäude Maugwil (Maugwil Test Building)

Principal Objectives:

Measurement of air infiltration data as a function of climatological data in an unoccupied, closed building and measurement of energy consumption for computer model verification.

References:

1. EMPA Report No. 39400/c
   Langzeit-Untersuchung betreffend Luftdurchlässigkeit und Luftwechsel eines Einfamilienhauses. April 1981
2. Hartmann, P., Muehlebach, H.
   Automatic measurements of air change rates (decay method) in a small residential building without any forced-air-heating system.
   1st AIC Conference, Windsor, UK, 6-8 October 1980.
3. Air Infiltration in Switzerland
   AIR, Volume 1 No.4, 1980.

Comments:

II. TEST SITE DESCRIPTION

A. Geographic Information

(1) Location. Approximately 4 Km to the north of Wil SG in Maugwil.
47.5°N, 9.1°E
Site plan : (see Ref.1)

(2) Height above sea level.

(3) Terrain.

Please append map showing the surrounding area indicating location and size of obstacles such as trees, fences and other buildings, also relief.

The house is located on the upper part of a south-facing slope (see Plate 1).

The slope provides some shelter from the wind on the north side, otherwise the situation is exposed with few nearby structures or trees (see Fig 1).

(4) Orientation. The facades of the house face approximately N65°E (East facade) N155°E (South facade) N245°E (West facade) N335°E (North facade) (see Fig.2).

(5) Location of Meteorological Station.

Meteorological measurements were made on site.

B. Climatic Information (where available)

Climatic data is supplied for Zurich (see Table 1)

(1) % frequency wind speed v direction *(by 22½° sector – attach table).*

(2) % frequency wind speed v temperature *(attach table).*

(3) Hours of daylight/insolation *(attach table).*

(4) Cloudiness.

(5) Precipitation, humidity.

(6) Other – anthropogenic factors.

C. The Building

(1) History.

The test building was erected in the early part of 1979. The measuring equipment was installed in July of the same year

(2) Construction material and technique.

The building has a solidly-constructed basement floor and 2 upper floors of wood construction

External walls and ceilings:

The outside wall and ceiling of the cellar were constructed of concrete cast in situ. Such of the cellar walls as lie below ground level are of concrete slabs on the outside. Outside walls not covered by earth in the heating space in the entrance hall and the ceiling over the tank room are insulated with a 5cm thick slab of wood-wool-polystyrene compound and plastered.

Both of the upper floors were built using a lightweight wood construction.

(continued overleaf)

(3) Dimensions *(Please append diagram to report for clarity.)*

(a) Plan: attach diagram (internal/external). (see Fig. 2 and Ref. 1)

(b) Elevation. Building height is 10m

(c) Total volume.

(d) Effective volume. *Heated volume is given as 500m³

(e) Floor area. 74.9m²

(f) Ceiling area.

(g) Facade (wall) area. 160 m²

(h) Total area of windows. 27 m²

(i) Total area of external doors.

(j) Number, volume and layout of rooms (refer to (a)). (see Table 2)

(k) Shape: roof pitch, etc.

(l) Attic, basement, crawlspace.

(i) Insulation.

(ii) Description.

* *see overleaf*

(2) *(continued)*

The thermal insulation (5cm thick) is found between the wooden uprights.

The ground floor external walls have an additional 2cm thick layer of insulation on the outside.

The ceiling joists of the ground floor ceiling penetrate the external walls at the eaves and form the supports for the rafters.

The steep roof and top floor ceiling are insulated with a total of 8cm of polystyrene slabs.

Windows and doors:

Except for the stairwell window, the wood framed windows are fitted with laminated glass and sealed using soft PVC section in the grooves. The stairwell window is double glazed and has no caulking strip. For internal doors there is an air gap of approximately 5mm between the door leaf and the floor (no sill).

(3) (d) * *Excluding the bomb shelter, the tank room and the volume between the roof and the top floor ceiling (see Table 2 for room volumes).*

C. The Building

(4) Gaps in the envelope.

(a) Doors (external). (see Table 3 and Ref. 1 for measured and estimated leakage values, type, etc.)

(i) Type.

(ii) Cracklength.

(iii) Comments.

(b) Windows. (see Table 3 and Ref. 1 for measured and estimated leakage values, type, etc.)

(i) Type.

(ii) Cracklength.

(iii) Comments.

(c) Ventilation openings.

(i) Type. The only major ventilation opening is one in the chimney supplying air directly to the fire.
(continued overleaf)

(ii) Cracklength.

(iii) Open area.

(iv) Degree of closure.

(v) Comments.

(4) (c) (i) *(continued)*

The chimney has a square cross-section 20cm x 20cm and is 6m in height. It is located in the living room (No. 6). (See Fig.2 for room numbers).

C. The Building (continued)

(d) Chimneys, flues.

(i) Size, type.

(ii) Location.

(iii) Condition of dampers. The damper supplying air to the fire is leaky when closed leaving a circular gap of area approximately 30 - 40cm^2. This supply air is also directed to the furnace room (see Ref. 1 for details).

also estimates of crack size for:

(e) Cavity walls and other communicating spaces, also electrical outlets.

(f) Soleplate, ceilings, corners, skirting boards.

(g) Plumbing outlets, drains, etc.

(h) Other major sources.

from the above and the measured leakage,

(j) Background leakage.

(k) Comments.

No numerical estimates are given for other sources of leakage, although leakage was detected where the joists supporting the floor penetrate the outside wall at the junction of the outside and the roof, the internal wall/roof junction on the upper floor, the hatchway on the attic staircase and the penetration of the connecting rods through the window frames. These were located using thermography with an underpressure of 20 Pa (see Ref. 1).

C. The Building (continued)

(5) HVAC system.

(a) Type of system.

The house is heated by an oil fired burner feeding hot water radiators and the domestic hot water supply. The storage tank for the latter is fed by a charge pump. This pump was disconnected and the boiler emptied for the duration of the tests.

Heating in the rooms is by panel radiators and convectors. The convectors are in the living room (6) and the studio (5). (See Fig.2 for room numbers)

(b) Blower fan capacity (where available).

(c) Duct tightness and location.

(d) Frequency of operation, duration of operating cycle.

(e) Operating temperature. *(see overleaf)*

(f) Location of air inlets. (see page 9, (c)(i))

(g) Comments.

(6) Pollution (non anthropogenic).

(a) Interior.

(b) Exterior.

(5) (e) *(continued)*

The flow temperature of the system has a maximum of 90°C with a return temperature of 70°C. The flow temperature is regulated by an outside air thermostat and the heat output to the rooms by radiator thermostats.

During the tests, the room temperatures were held constant as far as possible to 20°C throughout the tests, day and night.

III. FUNCTION OF BUILDING

A. Type (including use)

The house is designed as a single family house but was unoccupied at the time of tests.

B. Occupancy

(1) Times occupied and number of users.

(2) Behaviour of occupants.

(a) Window opening.

(b) Door opening.

(c) Other voluntary ventilation.

(d) Heating habits.

(e) Pollution (anthropogenic).

(i) Cooking.

(ii) Aerosols, solvents, etc.

(iii) Smoking.

(iv) Other

(f) Level of activity of occupants.

(g) Comments.

C. Special Requirements

D. Other

E. Comments

IV. MEASUREMENTS

Date and time measurements taken. October 1979-June 1980 (see Fig.5 Ref.1 Page 10 for details)

A. Pressurisation Measurements — internal

(1) Technique employed.

Pressurization method:

The determination of the air leakage of the building envelope was carried out by raising a pressure difference across the facade with an efficient fan. The volumetric flow rate was measured for the ranges of pressures ± 10 Pa to ± 50 Pa. From these the characteristic curve was found.

(continued overleaf)

(2) Equipment used.

(see Fig. 3). Further details not given.

(3) Description of procedures for calibrating equipment.

(4) Results (attach relevant tables, graphs etc.)

(a) Pressurisation.

The leakage curves are shown in Fig. 4 and Table 4 for unsealed and sealed condition and for two different dates.

(b) Depressurisation.

(c) Alternating pressurisation (infrasonic).

(5) Comments.

(1) Pressurization method: *(continued)*

The volumetric flow rate for 50 Pa was found and reduced to an air change number by

$$n_{L50} = \frac{\dot{V}_{L50}}{V} \quad [h^{-1}]$$

n_{L50} = air change number for a differential pressure of 50 Pa $[h^{-1}]$

$\dot{V}_{L50}$ = volume air flow for a differential pressure of 50 Pa $[m^3/h]$

V = air volume of the house $[m^3]$

B. Pressure Measurements — external (including wind tunnel studies)

(1) Technique used (including conditions)

(2) Equipment used.

Not described

(3) Calibration procedure.

(4) Location of surface pressure taps (see II.C (3)).

(see Fig. 1)

(5) Measurement results (attach as table).

The results are displayed in columns 14 to 17 of Table 7.

(6) Comments)

C. Interior Conditions

(1) Temperature (dry bulb).

(2) Relative humidity.

(3) Air flow.

(4) Other.

(5) Comments.

(See Tables 5 and 6 for measurement details and location of sensors. See Tables 7 and 8 for data).

D. Exterior Conditions

(1) Description of equipment used.

(2) Weather — off-site.

(a) Wind speed.

(b) Wind direction.

(c) Dry bulb temperature.

(d) Stability conditions.

(e) Other (see A5. for location).

(f) Comments.

(3) Weather on-site.

(a) Wind speed.

(b) Wind direction.

(c) Dry bulb temperature.

(d) Relative humidity.

(e) Turbulence scale.

(f) Turbulent intensity.

(g) Stability conditions (where available).

(h) Other.

(i) Comments.

(See Tables 5 and 6 for measurement details and location of sensors. See Tables 7 and 8 for data)

E. Infiltration

(1) Measurement technique.

A schematic of the experimental arrangement is given in Fig. 5 and the apparatus is illustrated in Fig. 6. The tracer gas is nitrous oxide injected into the rooms when the gas concentration decays to a preset threshold. The six rooms are then sampled in turn, each for 10 minutes, such that each room is visited once per hour (Table 7). The tracer gas is mixed by two fans for 10 minutes after injection. The data is recorded continuously on a paper strip for monitoring purposes and on magnetic tape near the end of each 10 minute sampling period, together with all other data.

(1) *(continued)*

The number of air changes is calculated for each room and the mean value determined. This is given in the final column of Table 8.

(2) Equipment used (include photographs).

(3) Calibration procedures.

(4) Measurement results (attach relevant table, graphs, etc).

(See Tables 7 and 8 for summary of results) Further details are available from AIC.

(5) Comments

F. Other

(1) Qualitative.

(a) Smoke sticks.

(b) Acoustic techniques.

(c) IR. Thermography. Details given in Ref. 1

(2) Energy consumption.

(3) Other.

(4) Comments.

V. NUMERICAL/COMPUTER MODELS

A. Type of Model

B. Correlations

(1) Variables used.
Effect on air change rate of wind speed, temperature difference, sealing of chimney

(2) Sign and goodness of fit.

(3) Problems encountered in attempting to find a correlation.

(4) Comments.
(See Figs. 7(a) and (b))

C. Computer Models

Details of the Fortran program used for processing the raw data can be supplied by the AIC if required.

(1) Name and description of model, including assumptions.

(2) Input.

(3) Output.

(4) Agreement with observation.

(5) Comments.

D. Any Other Theoretical Work of Interest

Plate 1: View of test building from the West

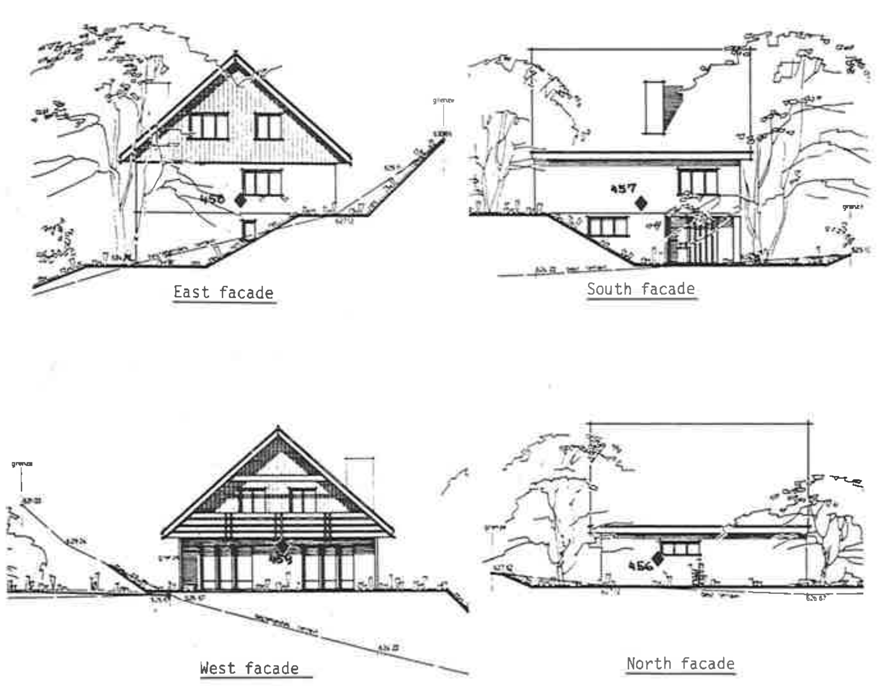

Fig. 1: Elevations of the test building

◆ *Pressure measurement point* 457 *Measurement number*

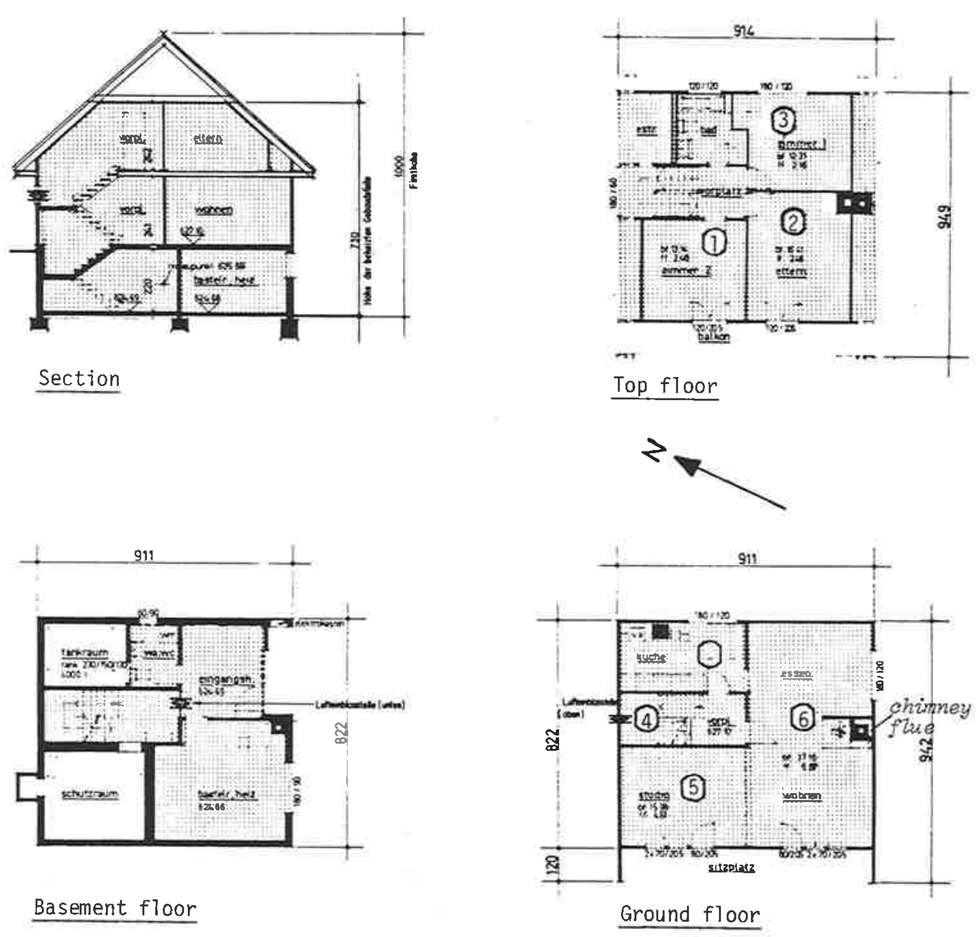

Fig. 2: Floor plans and building section

Sites of fans for pressurization and depressurization for the measurement of the leakage of the building envelope.

Heated part of the building.

(2) *Room number*

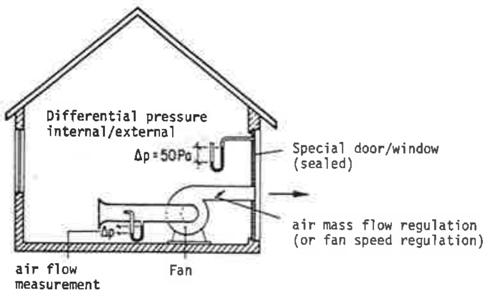

Fig. 3 . Measurement arrangement for the determination of the air leakage of the building envelope.

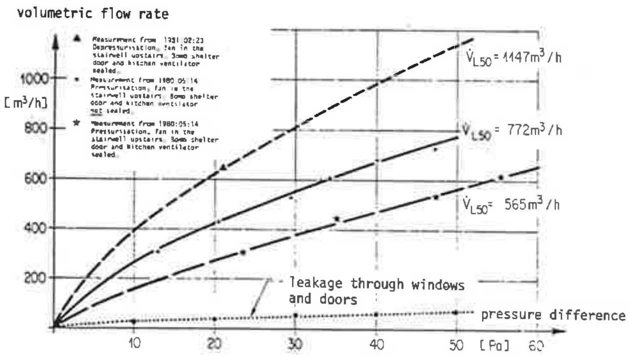

Fig. 4 . Air leakage characteristic curves for the building envelope

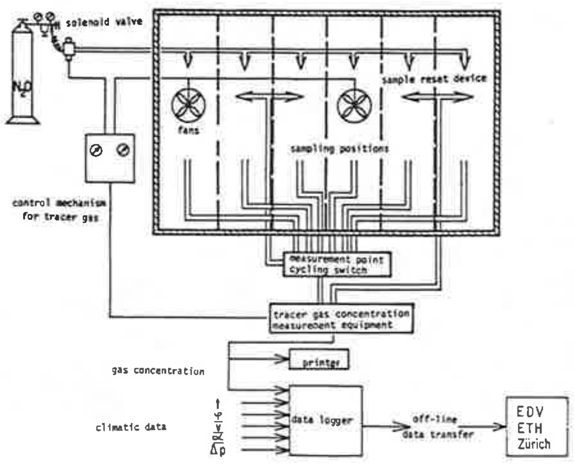

Fig. 5 . Schematic diagram for the experimental arrangements for the determination of the air change rate.

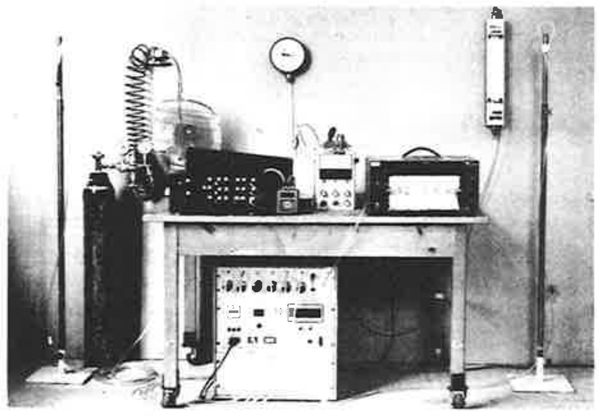

Fig. 6: Illustration of the equipment required for the measurement of air infiltration.

From left to right:

Tracer gas cylinder (N_2O) with pressure resulator valve, solenoid valve (above), fan for mixing the air, control equipment for the tracer gas supply (left foreground), air transfer pump, gas analyser, manometer for controlling the pressure in the gas analyser (above), chart-recorder and a flow meter for the determination of the volumetric flow rate of the sample.

A tracer gas injection point, with the closed end, is illustrated on the extreme left and a sampling point on the extreme right.

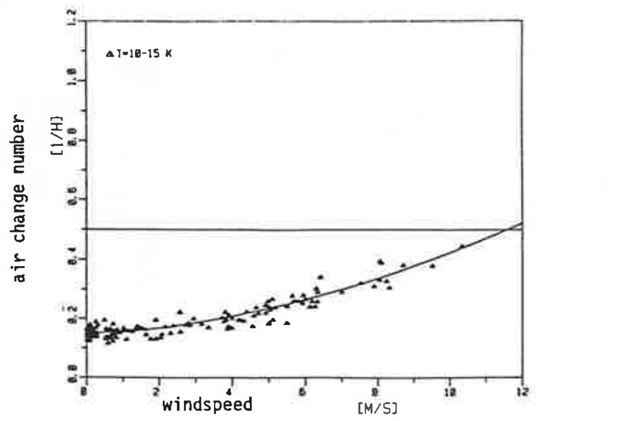

Fig. 7 (a) Air change measurement values depending on the windspeed for the temperature difference in the range 10 to 15°K with the chimney sealed.

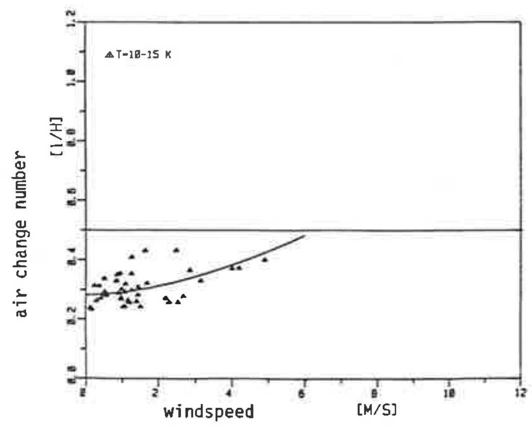

Fig. 7 (b) As above, but with the chimney unsealed.

TABLE 1 Climatic Information

Average monthly values (Period - 1901-60)

Zurich h = 563m, latitude = 47.2°N, longitude = 8.3°E

Ref: Swiss Meteorological Institute, Zurich

			Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temperature	daily mean	°C	-1.0	0.2	4.2	8.0	12.5	15.5	17.2	16.6	13.5	8.4	3.3	-0.2	8.2
	mean monthly max.	°C	10.5	13.1	19.1	23.6	28.3	30.4	32.3	31.4	27.6	21.7	15.2	11.6	33.1
	mean monthly min.	°C	-9.8	-9.4	-5.2	-1.5	1.9	6.7	8.7	8.1	4.5	-0.2	-3.9	-8.0	-12.5
Wind*	average speed	m/s	2.7	3.0	2.9	3.0	2.8	2.7	2.6	2.4	2.2	2.2	2.6	2.9	3.0
	directions > 15%		SW, W	SW,W, NE	W,SW, NE	SW,W, NE	NE,SW, NW,W	W,NW NE,SW	NW,W, SW,NE	W,MW, SW	W,SW, NE,NW	W,SW, NE,NW	SW,W NE,NW	SW,NE, W.	
Solar	mean sunshine duration Σ	h	45.6	79.2	142.6	166.8	203.1	219.6	240.3	216.4	166.8	111.0	53.4	35.3	1680
	max possible sun duration Σ	h	249	265	345	385	435	444	447	416	355	314	253	237	4145
	mean horizontal global radiation Σ	MJ/m²	101.1	177.8	321.2	425.1	572.0	616.2	635.2	537.9	375.6	225.1	105.9	173.2	4166
	cloudiness	1/10	8.3	7.3	6.2	6.3	6.3	6.3	5.9	5.8	6.1	7.1	8.2	8.6	6.9
	humidity	%	83	77	71	63	69	69	68	72	77	82	84	84	75
Precipitation	mean monthly Σ	mm	68	61	69	88	107	138	139	132	101	80	72	73	1128
	max. daily sum	mm	51	44	47	48	90	81	62	4	57	45	45	44	90
	mean no. of days with precipitation >0.3mm		14.2	12.8	11.7	13.3	14.3	14.7	14.3	14.1	12.4	11.9	12.0	13.0	158.7
	number of days with snowcover		16.7	12.3	6.4	2.3	0.1	-	-	-	-	0.2	4.1	12.1	54.2
	mean monthly max snow height	cm	17.0	13.6	8.8	6.0	-	-	-	-	-	0.4	6.4	9.1	24.4

* Zurich Airport

Table 2 Room Volumes

Room No.	Volume (m³)	Room Name
1	25	(Children's bedroom - West)
2	38	(Master bedroom)
3	26	(Children's bedroom - East)
4	67	(Staircase)
5	33	Studio
6	117	(Living room)
Total	306	

Table 3 Measured leakage values for doors and windows

Window/door	Weatherstrip	Cracklength (m)	Crack leakage a - value ($m^3_n/mh\Delta p^{2/3}$)	Air leakage of the windows ($m^3_n/h\Delta p^{2/3}$)
Standard window measured in the laboratory	Yes	6.60	0.029	0.191
Staircase	No	4.82	0.496	2.4
Kitchen	Yes	8.10	0.0435	0.352
Dining room	Yes	8.10	0.0194	0.157
Living room	Yes	5.53	0.0539	0.296
Studio	Yes	5.53	0.0985	0.542
Bathroom	Yes	5.78	0.0516	0.298
Child's bedroom I	Yes	8.10	0.0369	0.299
Master bedroom	Yes	7.53	0.0327	0.246
Child's bedroom II	Yes	7.53	0.0331	0.249
W.C. (basement)	Yes	2.82	0.0314	0.089
Front door	At the side and above	-	>0.900	>5.500

TABLE 4 Pressure Test

Measurement Building - Maugwil
Date of Measurement - 14.5.80

1. $Q = C.\Delta p^n$ Power curve Q [m³/s], Δp [Pa]

2. $A_{50} = \frac{Q_{50}}{V_H}$

3. Q_{50}

4. $L_4 = \frac{Q_4}{\sqrt{\frac{2}{\delta}\Delta p_4} \cdot A_H}$

Q_{50} = Flow rate at 50 Pa
A_{50} = Air change rate at 50 Pa
V_H = Volume of conditioned space
A_H = Floor area of conditioned space
δ = Density of air 1.2 kg/m³
L_4 = Spec. leakage area at 4 Pa

Notes:	V_H m³	A_H m²	C	n	A_{50} [h⁻¹]	Q_{50} [m³/s]	L [$\frac{cm^2}{m^2}$]
Chimney sealed	435	190	0.0157	0.67	1.77	0.214	0.81
All vents and stack sealed	413	180	0.00663	0.81	1.37	0.157	0.438

Notes by default

a) Volume of conditioned space (and area)

b) Structure in normal condition (unsealed)

Table 5. Measurement details for climatic data

Variable		Sampling Interval	Number of sample points	Locations of sample points
Air temperature	θL	10 min		
inside-			17	In the middle of the room at approx. 1.5m in height
outside-			2	On the north side of the building & 20m from it,3m above ground
Relative humidity	χL	10 min		
inside-			1	Staircase - ground floor
outside-			1	North facade
Solar radiation				Situated
global radiation- (horizontal)	I_g	30 sec	1	On south side of the building, approximately
diffuse radiation- (horizontal)	I_d	30 sec	1	5m from it.
Wind velocity	V_w	continuous	2	4m above the roof ridge (10m above garden seat)
Wind direction	γ	30 sec	2	Also 40m from building and 10m high

TABLE 6 Measurement List - Maugwil (EMPA)

Key to computer printout of measurements (Table 8)

Measurement Number	Measurement Type	Unit	Room No.		Comments
7	Temp	°C	4	staircase - ground floor	
8	Temp	°C		kitchen	
9	Temp	°C	6(E)	dining room	
10	Temp	°C	6(W)	living room	
11	Temp	°C	5	studio	
12	Temp	°C	4	staircase	
15	Temp	°C	3	child's bedroom - East	
16	Temp	°C	2	master bedroom	
17	Temp	°C	1	child's bedroom - West	
19	Temp	°C	Outside Temperature		180° N
61	Wind velocity	m/s	4m above top of roof		270° West, 90° East
62	Wind velocity	m/s	- 40m beside the house - 10m above ground level		
63	Wind direction		Average of No. 61 and 62 directions		0/360° South
456	Pressure	Pa	on North facade		10 Min. average
457	Pressure	Pa	on South facade		10 Min. average
458	Pressure	Pa	on East facade		10 Min. average
459	Pressure	Pa	on West facade		10 Min. average
460	N_2O Concentration	PPM	Measurement Time Hrs., Min	Room No.	
			10	1	
			20	2	
			30	3	
			40	4	
			50	5	
			0	6	

Table 7 Temperature, Wind , Pressure and Infiltration Data

(see Table 6 for key to measurement numbers)

Measurement Number		7	8	9	10	11	12	15	16	17	19	61	62	63	456	457	458	459	460
MESSTELLNAME		007	008	009	010	011	012	015	016	017	019	C1	C2	29+33/2	456	457	458	459	460
EINHEIT		GRD C	GRD C	GRD C	GRD C	GRD C	GRD C	GRD C	GRD C	GRD C	GRD C	M/S	M/S	WINKEL	PA	PA	PA	PA	PPM
Date	hr. Min																		
10/12/79	18.00	20.2	21.1	21.7	21.5	20.8	20.0	21.0	20.2	20.3	10.0	8.4	7.8	283.5	.7	-2.6	6.1	16.5	7.8
10/12/79	18.10	20.1	21.1	21.7	21.7	20.7	20.0	20.9	20.2	20.3	10.3	9.1	8.5	286.4	.7	-1.7	7.9	19.1	9.8
10/12/79	18.20	20.1	21.0	21.7	21.5	20.8	20.0	21.0	20.1	20.2	10.0	8.5	7.8	283.4	.0	-1.6	5.4	17.5	8.6
10/12/79	18.30	19.8	21.1	21.7	21.5	20.7	20.0	21.0	20.1	20.5	9.9	8.6	8.1	288.1	-.0	-1.6	4.6	16.6	9.6
10/12/79	18.40	19.9	21.1	21.4	21.5	20.8	20.0	21.1	20.2	20.2	9.9	7.7	7.0	287.2	-.0	-1.5	6.2	15.7	36.1
10/12/79	18.50	19.8	21.1	21.7	21.6	20.7	20.0	21.0	20.2	20.4	9.9	7.0	6.8	282.4	-.0	-2.3	3.7	12.9	24.4
10/12/79	19.00	19.5	21.1	21.7	21.6	20.7	20.2	21.0	20.2	20.4	9.9	8.1	7.5	287.6	.0	-2.3	4.6	13.9	23.6
10/12/79	19.10	19.8	21.2	21.6	21.6	20.8	20.1	21.0	20.2	20.4	9.5	8.0	7.3	284.3	.8	-1.5	5.4	12.9	28.5
10/12/79	19.20	19.8	21.1	21.6	21.6	20.8	20.0	21.0	20.2	20.4	9.2	7.7	7.0	286.3	.0	-2.4	4.6	13.9	24.5
10/12/79	19.30	19.8	21.1	21.7	21.6	20.8	20.0	21.0	20.2	20.4	9.1	6.7	6.1	288.7	.0	-1.5	4.6	11.4	21.4
10/12/79	19.40	19.7	21.1	21.6	21.6	20.9	20.0	21.0	20.2	20.4	9.0	7.5	6.7	288.1	.0	-1.5	3.7	12.9	21.2
10/12/79	19.50	19.9	21.1	21.7	21.6	20.9	20.2	21.2	20.2	20.4	8.6	6.1	5.7	287.3	.0	-1.5	3.7	10.5	19.9
10/12/79	20.00	19.8	21.0	21.7	21.6	20.8	20.0	21.1	20.2	20.4	8.8	6.0	5.7	282.3	.0	-1.5	2.9	7.8	17.9
10/12/79	20.10	19.7	21.1	21.7	21.6	20.8	20.1	21.1	20.2	20.5	9.0	6.3	5.9	284.7	-.0	-1.4	2.9	8.7	22.1
10/12/79	20.20	19.7	21.1	21.7	21.6	20.8	20.1	21.1	20.2	20.4	8.9	6.5	6.1	272.0	.0	-1.5	2.9	10.5	19.4
10/12/79	20.30	19.8	21.1	21.7	21.6	20.9	20.0	21.1	20.3	20.4	9.2	6.0	5.8	277.6	.0	-1.4	2.9	7.8	18.2
10/12/79	20.40	19.8	21.2	21.7	21.7	20.9	20.0	21.1	20.2	20.4	9.0	7.0	6.7	280.6	.0	-2.3	2.9	13.5	16.3
10/12/79	20.50	19.7	21.2	21.8	21.6	20.8	20.1	21.1	20.3	20.5	8.9	6.3	5.9	278.3	.0	-2.3	1.9	11.4	15.3
10/12/79	21.00	19.7	21.1	21.8	21.6	20.9	20.1	21.1	20.3	20.4	8.7	6.4	5.9	278.6	.8	-2.2	2.9	9.6	13.3
10/12/79	21.10	19.8	21.1	21.8	21.6	20.7	20.1	21.1	20.4	20.4	8.7	5.8	5.4	279.9	.0	-1.3	2.9	8.8	17.0
10/12/79	21.20	19.7	21.2	21.8	21.6	20.9	20.1	21.1	20.3	20.5	8.9	6.2	5.7	278.9	.0	-1.5	1.8	8.7	15.0
10/12/79	21.30	19.8	21.2	21.8	21.6	20.9	20.1	21.2	20.3	20.5	9.1	6.2	5.9	277.8	.0	-2.4	1.9	8.7	14.8
10/12/79	21.40	19.7	21.2	21.8	21.7	20.9	20.1	21.1	20.3	20.5	9.1	6.7	6.6	276.0	.8	-3.3	2.8	10.5	12.4
10/12/79	21.50	19.9	21.2	21.9	21.6	20.7	20.2	21.1	20.3	20.5	8.8	6.8	6.8	274.6	-.8	-3.2	1.0	10.5	11.5
10/12/79	22.00	19.7	21.2	22.0	21.7	20.8	20.1	21.1	20.3	20.4	9.2	6.7	6.2	279.5	.0	-1.5	2.8	8.7	10.4
10/12/79	22.10	19.3	21.2	21.8	21.7	20.9	20.2	21.3	20.3	20.5	9.1	7.5	7.0	277.7	-.0	-3.4	3.7	12.1	13.0
10/12/79	22.20	19.8	21.2	21.8	21.7	20.8	20.0	21.1	20.4	20.5	9.2	8.0	7.5	285.7	.0	-1.6	5.4	14.7	11.5
10/12/79	22.30	19.8	21.2	21.8	21.7	20.9	20.1	21.1	20.3	20.5	9.1	7.3	6.7	278.3	.0	-2.5	3.7	12.9	11.8
10/12/79	22.40	19.8	21.0	21.5	21.6	20.8	20.1	21.0	20.3	20.3	9.5	7.1	6.9	284.3	.0	-.6	2.9	9.6	9.1
10/12/79	22.50	19.8	21.0	21.7	21.3	20.6	20.0	20.9	20.2	20.3	9.3	7.5	6.9	282.6	.0	-.5	3.6	14.7	8.3
10/12/79	23.00	19.9	20.8	21.2	21.4	20.6	19.9	20.7	20.0	20.2	9.6	7.4	6.7	284.7	.0	-1.5	5.4	11.3	29.1
10/12/79	23.10	19.9	20.7	21.2	21.5	20.4	19.8	20.5	20.0	20.2	9.2	5.9	5.5	278.4	.0	-2.4	2.9	9.6	32.2
10/12/79	23.20	19.7	20.6	21.2	21.2	20.3	19.8	20.4	19.9	20.0	9.3	5.7	5.7	273.8	.0	-2.3	1.9	8.7	28.3
10/12/79	23.30	19.7	20.5	21.2	21.2	20.2	19.7	20.3	19.8	19.9	9.2	5.1	4.7	274.2	.0	-1.4	1.0	6.0	24.5
10/12/79	23.40	19.7	20.4	21.1	21.1	20.1	19.7	20.1	19.7	19.8	9.5	4.8	4.5	282.3	.0	-1.4	1.0	5.2	25.6
10/12/79	23.50	19.6	20.3	21.0	21.0	19.9	19.6	20.0	19.6	19.7	10.2	6.3	5.8	284.2	.0	-.5	1.8	7.8	23.8
11/12/79	0.00	19.6	20.3	20.9	21.0	19.8	19.5	19.9	19.5	19.6	10.6	7.0	6.5	286.6	-.8	.3	3.6	12.1	22.0
11/12/79	0.10	19.6	20.2	20.8	20.9	19.8	19.5	19.8	19.5	19.5	10.4	5.8	5.5	282.2	.0	-2.4	2.9	10.5	27.3
11/12/79	0.20	19.5	20.2	20.8	20.9	19.7	19.4	19.7	19.4	19.4	10.7	5.9	5.5	279.0	.0	-2.3	1.9	8.7	22.4
11/12/79	0.30	19.5	20.1	20.7	20.9	19.6	19.4	19.6	19.3	19.3	10.7	5.0	4.7	277.4	-.0	-1.4	1.8	6.9	21.3
11/12/79	0.40	19.5	20.1	20.7	20.8	19.6	19.4	19.5	19.2	19.3	10.0	3.6	3.2	274.8	.0	-1.4	.1	3.6	20.6
11/12/79	0.50	19.4	20.0	20.6	20.8	19.5	19.3	19.5	19.2	19.2	10.3	5.1	4.7	279.6	.0	-1.4	1.0	5.2	19.3
11/12/79	1.00	19.4	20.0	20.6	20.8	19.5	19.3	19.4	19.1	19.2	10.8	6.9	6.4	284.0	.0	-.4	2.9	8.7	18.1
11/12/79	1.10	19.3	19.9	20.6	20.7	19.5	19.2	19.4	19.1	19.1	10.7	5.9	5.5	277.5	.0	-2.2	2.9	8.8	21.3
11/12/79	1.20	19.3	19.7	20.5	20.8	19.5	19.2	19.3	19.1	19.1	11.0	4.9	4.7	274.3	.0	-1.3	1.0	6.0	18.6
11/12/79	1.30	19.3	19.9	20.5	20.7	19.4	19.1	19.2	19.0	19.0	10.5	4.5	5.0	257.0	.0	-2.2	-2.3	5.2	18.3
11/12/79	1.40	19.3	19.9	20.4	20.7	19.4	19.1	19.2	18.9	18.9	9.7	4.3	4.6	265.2	.0	-2.4	-1.5	4.5	16.6
11/12/79	1.50	19.3	19.5	20.4	20.6	19.3	19.0	19.1	18.9	18.9	9.6	4.7	4.2	284.0	.0	-.4	1.0	5.2	15.7
11/12/79	2.00	19.3	19.8	20.4	20.6	19.3	19.0	19.1	18.8	18.9	9.3	4.0	3.7	285.0	.0	.4	.1	5.2	15.0
11/12/79	2.10	19.2	19.8	20.4	20.6	19.3	19.0	19.1	18.8	18.8	9.2	4.5	4.3	250.6	.0	-2.4	-2.3	5.2	16.8

Table 8 Summary of Results

		Injection Cycle		Temperature		Wind		Pressure Differences					
		Start Time	Duration	Inside TI	Inside/Outside TI - TA	Velocity V	Direction R	North (456)	South (458)	East (457)	West (459)		Air Change Rate
			H	C	K	M/S		Pa	Pa	Pa	Pa		1/H
DATE	TIME												
10/12/79	19.30		1.0	20.9	12.0	5.96	W	.09	2.83	-1.67	9.75	12.67	.266
10/12/79	19.30		2.0	20.9	11.9	6.33	W	.08	2.72	-2.27	10.39	13.19	.258
10/12/79	23.40		1.0	19.9	9.3	5.21	W	-.06	1.61	-1.39	7.60	9.20	.200
10/12/79	23.40		2.0	19.6	9.8	4.48	W	.16	-.89	-1.47	5.15	5.31	.200
10/12/79	23.40		3.0	19.4	10.8	3.71	W	.16	-1.78	-1.27	3.65	3.81	.201
10/12/79	23.40		4.0	19.3	10.2	5.92	W	-.13	2.24	-.94	10.01	12.25	.250
11/12/79	5.40		1.0	19.2	7.2	9.54	W	.25	5.37	-6.46	24.92	30.54	.351
11/12/79	5.40		2.0	19.6	8.3	10.23	W	1.12	.91	-10.25	28.17	30.19	.405
11/12/79	9.20		1.0	20.2	11.5	8.06	W	.58	2.01	-7.16	16.73	19.31	.392
11/12/79	12.30		1.0	20.4	13.2	8.24	W	-.28	5.00	-2.02	17.54	22.55	.326
11/12/79	12.30		2.0	20.5	13.8	7.52	W	-.11	4.79	-.69	11.77	16.57	.319
11/12/79	16.20		1.0	20.5	15.4	7.29	W	.44	2.80	-3.13	7.21	10.45	.413
11/12/79	19.20		1.0	20.5	16.0	7.41	W	.48	1.94	-3.52	-.11	2.42	.399
11/12/79	22.20		1.0	19.9	15.5	7.32	NW	.75	1.40	-3.98	16.20	18.35	.395
12/12/79	1.20		1.0	18.9	15.4	6.13	W	.73	1.27	-2.64	11.77	13.76	.315
12/12/79	1.20		2.0	18.8	15.3	5.72	W	.43	1.66	-1.91	10.03	12.13	.353
12/12/79	5.20		1.0	18.6	15.3	5.50	W	.30	2.81	-1.60	8.53	11.64	.274
12/12/79	5.20		2.0	19.0	16.0	5.75	NW	.55	2.73	-2.14	9.72	13.00	.324
14/12/79	11.40		1.0	20.2	14.8	3.99	NW	.24	1.69	.32	5.08	7.34	.167
14/12/79	11.40		2.0	20.3	15.2	5.76	NW	.36	2.27	-1.79	10.07	12.70	.270
14/12/79	11.40		3.0	20.3	15.6	6.64	NW	.23	3.31	-2.29	12.83	16.36	.271
14/12/79	11.40		4.0	20.4	15.7	6.74	NW	.31	4.01	-1.64	13.03	17.36	.271
14/12/79	17.40		1.0	20.4	17.5	3.31	NW	.46	2.37	.37	4.76	7.95	.207
14/12/79	17.40		2.0	20.4	18.3	1.34	NW	.51	2.24	1.56	2.07	6.37	.182
14/12/79	17.40		3.0	20.4	17.7	1.59	W	.31	2.18	2.24	1.46	6.19	.168
14/12/79	17.40		4.0	20.4	16.6	2.70	NW	-.12	.76	2.10	2.48	5.34	.196
14/12/79	17.40		5.0	20.2	15.6	4.12	NW	-.03	1.53	.42	6.11	8.06	.264
15/12/79	0.40		1.0	19.0	17.2	2.29	NW	.58	2.52	1.04	2.96	7.10	.197
15/12/79	0.40		2.0	18.8	16.2	2.50	NW	.45	1.86	1.14	3.25	6.71	.195
15/12/79	0.40		3.0	18.6	14.7	3.16	NW	.39	1.29	.95	3.74	6.37	.181
15/12/79	0.40		4.0	18.4	13.5	4.32	NW	.46	1.93	.05	5.58	8.02	.190
15/12/79	0.40		5.0	18.3	13.3	4.22	NW	.35	2.05	-.14	5.47	7.87	.193
15/12/79	0.40		6.0	18.6	13.9	2.59	NW	.43	1.51	.62	3.03	5.59	.154
15/12/79	8.40		1.0	19.6	14.3	3.35	N	.61	1.25	.43	1.45	3.74	.169
15/12/79	8.40		2.0	19.7	14.1	4.56	N	.29	1.61	.79	4.31	7.00	.172
15/12/79	8.40		3.0	19.9	13.6	5.12	N	.25	2.77	.35	7.68	11.04	.194
15/12/79	8.40		4.0	20.2	12.9	6.12	N	.52	2.86	-1.27	10.57	13.96	.239
15/12/79	8.40		5.0	20.3	13.9	8.32	N	.31	-.43	-3.93	20.12	20.43	.304
15/12/79	15.20		1.0	20.2	15.0	8.43	NW	.31	5.35	-2.35	19.50	25.17	.340
15/12/79	15.20		2.0	20.1	15.5	9.17	NW	.30	5.33	-2.36	23.51	29.14	.341
15/12/79	19.40		1.0	20.0	16.5	10.24	NW	.31	6.02	-3.46	28.64	34.98	.367
15/12/79	19.40		2.0	20.0	18.4	8.69	NW	.59	6.35	-2.48	22.81	29.75	.371
15/12/79	23.40		1.0	18.9	18.2	4.18	NW	.58	3.55	.19	7.41	11.74	.223
15/12/79	23.40		2.0	18.7	17.7	5.70	NW	.52	3.40	-1.31	11.35	15.27	.266
15/12/79	23.40		3.0	18.4	17.5	6.33	N	.65	2.69	-2.65	13.19	16.53	.324
15/12/79	23.40		4.0	18.2	17.3	6.47	N	.65	2.02	-3.05	13.73	16.41	.326
16/12/79	5.20		1.0	18.1	17.4	6.06	NW	.63	2.83	-2.35	12.51	15.98	.287
16/12/79	5.20		2.0	18.6	17.7	6.44	NW	.64	3.02	-2.67	13.61	17.26	.328
16/12/79	5.20		3.0	18.8	17.7	6.37	NW	.61	3.85	-1.95	12.97	17.43	.323
16/12/79	10.20		1.0	19.7	18.2	6.42	NW	.59	4.92	-1.14	12.29	17.80	.298

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