INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and
community systems programme

Technical Note AIVC 32

Reporting Guidelines for the Measurement of Airflows and Related Factors in Buildings

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Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-one IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of forty-two Implementing Agreements, containing a total of over eighty separate energy RD&D projects. This publication forms one element of this programme.

Energy Conservation in Buildings and Community Systems

The IEA 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, as well as air quality and studies of occupancy. Seventeen countries have elected to participate in this area and have designated contracting parties to the Implementing Agreement covering collaborative research in this area. The designation by governments of a number of private organisations, as well as universities and government laboratories, as contracting parties, has provided a broader range of expertise to tackle the projects in the different technology areas than would have been the case if participation was restricted to governments. The importance of associating industry with government sponsored energy research and development is recognized in the IEA, and every effort is made to encourage this trend.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures that all projects fit into a pre-determined strategy, without unnecessary overlap or duplication but with effective liaison and communication. The Executive Committee has initiated the following projects to date (completed projects are identified by *):

I Load Energy Determination of Buildings*
II Ekistics and Advanced Community Energy Systems*
III Energy Conservation in Residential Buildings*

IV Glasgow Commercial Building Monitoring*
V Air Infiltration and Ventilation Centre
VI Energy Systems and Design of Communities*
VII Local Government Energy Planning*
VIII Inhabitant Behaviour with Regard to Ventilation*
IX Minimum Ventilation Rates*
X Building HVAC Systems Simulation*
XI Energy Auditing*
XII Windows and Fenestration*
XIII Energy Management in Hospitals*
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XVI BEMS - 1: Energy Management Procedures
XVII BEMS - 2: Evaluation and Emulation Techniques
XVIII Demand Controlled Ventilating Systems
XIX Low Slope Roof Systems
XX Air Flow Patterns within Buildings
XXI Thermal Modelling
XXII Energy Efficient Communities
XXIII Multizone Air Flow Modelling

Annex V Air Infiltration and Ventilation Centre

The IEA Executive Committee (Building and Community Systems) has highlighted areas where the level of knowledge is unsatisfactory and there was unanimous aggreement 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 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 groundwork the experts group recommended to their executive the formation of an Air Infiltration and Ventilation 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 firm basis for future research in the Participating Countries.

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

INTRODUCTION

One of the aims of the Air Infiltration and Ventilation Centre is to encourage the collection and dissemination of air infiltration and airflow data as well as energy use 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.

These reporting guidelines have been produced to provide a common reference for research workers, wishing to plan experimental work or catalogue their experimental data. Thus making complete information available for entry into a numerical database (Ref.1) for subsequent analysis or mathematical model development. The guidelines have been designed to provide the necessary parameters for the calculation of airflow and airflow models, including those that emphasize pollutant factors, and for the validation of thermal models of building energy use. These parameters vary with the application and this has been taken into account in the guidelines. The basic reference for these guidelines is AIVC-TN 6, Ref.2, aided by work in Annex XX.

The guidelines structure is purposely rather loose, to cater to 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. Some parameters are more important than others, and this has been highlighted using the Applicability Coding which is described next.

The Applicability Code is stated in the parenthesis following each item, as follows:

R = Required, I = Important, U = Useful.

If these codes are listed alone they are assumed to apply to all applications. Individual applications are:

- -1 = Parameters for airflow measurements and models; e.g. model validation, stock characterisation or design studies.
- -2 = Additional parameters for air flow models that include pollutant factors; e.g. indoor air quality work.
- -3 = Additional parameters for thermal measurement and models, e.g. model validation, energy use calculations. If the requirement is for cooling models only it will be noted as -3C;

- 4 = Additional parameters for comfort-related questions that involve: temperature stratification, room airflow, ventilation effectiveness, radiation, etc.

Thus an important parameter that would be applied to an airflow model involving pollutants would be listed as (I-2).

These guidelines may be used directly for entering results and should also serve as a useful checklist to aid those who are initiating projects. Recognising that experimental data today relies heavily upon the computer for both collection and storage, the guidelines have taken this into account. Using a compiled dBase IV application developed by the Centre, text data may be entered in the structure of the guidelines, stored on disk in dBASE IV format and a report produced. This application is available from the centre on 3" or 5" disk so that data entry can be further streamlined and made more uniform. Any numerical data supplied to the Centre should be backed up by a report produced according to these guidelines, preferably on disk.

Sections of this Technical Note cover:

- General Information, emphasising the purpose and approach used and how to contact the project leaders.
- Test Site Description, including geographic and climatic information.
- Building Description, including leakage paths, heating and ventilation systems, etc.
- Operation/Function of Building, including occupancy and pollutant sources.
- Measurements, procedures, equipment characteristics and accuracy.
- Economic Factors, especially energy savings evaluations.
- Numerical/Computer Models, plus comparison to measurements.
- Disk Data Files, describing data files, formats, and contents.
- General Remarks, and the opportunity to supply conclusions.
- Examples of Reporting Guidelines Application.

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 measurement methods are raised in the notes. Also included are details of minimum standards of measurement where these have been indicated by past experience or are predicted to be future requirements.

The AIVC will be pleased to receive copies of the completed Guidelines along with associated numerical data 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 will be available through the nominated organisations in the participating countries.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions from participants in Annex XX, the AIVC Steering Group and the attendees of the AIVC Numerical Database Workshop held March, 1990. Comments on the guidelines content have proven invaluable. We also gratefully acknowledge examples supplied by Switzerland, and the very recent LESO Building example from J-M Furbringer and C-A Roulet, (references 11 and 12).

READ THESE NOTES FIRST

Important Points

- 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.
- For all sections involving measurements, the instrument used and the accuracy of the measurement should be stated: 1) with the data listing, 2) referenced to the Measurements Section V, or 3) referenced to the AIVC Measurements Techniques Guide (Reference 4). Date and time of measurements should be included in Julian format. Attach relevant photographs, diagrams, tables, graphs and give details of any disk data files.
- 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.
- Where blocks of information are common to several buildings, these need only be cited once in the appropriate position and referred to as necessary.
- If information is on disk it should be in MS-DOS compatible format on 3" or 5" disk. Please indicate file names, contents and format (with short example if possible) and include a disk with the report.
- Any information supplied to the AIVC will be regarded as freely available to any bona fide enquirer with the under standing that the origin of the dataset will be acknowledged.

I. GENERAL INFORMATION - NOTES

(2) State names, organisation, address, country, telephone, fax, telex and E-Mail, if available.

(3) See (2).

(5) Purpose should be stated and if more than one purpose is envisioned please state each one.

(6) This will assist in future planning of similar projects.

(7) See (6).

(8) There is great interest in how research groups choose to approach a particular objective, please state your research plan.

(9) Selection criteria for the building could be statistical, it could be because the building is malfunctioning or perhaps the building displays exceptional performance. Whatever the criteria please outline it.

(10) References to similar studies within the research group or other directly related studies would be most welcome.

(11) Comments at this point in the data guidelines should be viewed as an opportunity to state any special features of the study or how the study relates to past work.

I. GENERAL INFORMATION

(1) Report Date (R):

(2) Principal Researcher(s) (R):

(3) Other Participants (U):

(4) Project Title (R):

(5) Principal Objectives (I):

(6) Start Date/End Date (I):

(7) Number of Man Hours (I):

(8) Project Approach (U):

(9) Building Selection (U):

(10) References (I):

(11) Comments (U):

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 information.

(2) Height above mean sea level to the building main entrance.

(3) Terrain. Please state the terrain catagory, i.e. (a) open sea, ice, desert, tundra, (b) open country with low scrub and scattered trees, (c) suburban area of small towns and well-wooded areas, and (d) urban area with numerous tall buildings, city centres and/or well-developed industrial areas. (Also see V-B when wind tunnel methods are used. See Reference 3.)

Particular effort should be expended on defining the "immediate building surroundings", using a rough "rule of thumb" of 10 building heights radius from the building. Please append map showing the surrounding area indicating location and size of obstacles such as trees, fences and other buildings, also relief data, which can provide angle to the horizon, and information on surrounding ground albedo would be helpful.

If the roughness of the terrain varies strongly with direction, it would be helpful to specify catagory by 15 or 22 sectors (as for wind direction) and ground slope (gradient).

(4) Orientation of the test building should be clearly stated. Orientation should also be noted on Site Plan II-A(3), Building Plan and under item III-B(1). State based upon 0-North, 90-East, 180-South and 270-West.

II. TEST SITE DESCRIPTION

A. Geographic Information

(1) Location (including longitude and latitute) (R):

(2) Height above sea level (R):

(3) Terrain/Test Site Plan (R):

(4) Orientation (R):

(5) Comments (U):

II. TEST SITE DESCRIPTION - Notes

B. Climatic Information (General)

General climatic data for a region is usually provided over a period of about 10 years. The dates covered should be noted as there are local changes of climatic pattern which take place over the shorter time scale which may cast doubt on the usefulness of the more general information.

Where the aim of the work is to determine future energy consumption, climatic information is vital. For all studies, if available, it should be included for the sake of completeness of the data set.

(1) Location of the Meteorological Station may be indicated on the Site Plan II-A(3) if it is nearby; but distance from the test site should be stated here, as well as terrain conditions at the station.

(2) % frequency of wind speed with direction (by 22 sector or 15 sector where available) - this should be a sufficiently finely divided direction set for all practical purposes and data is 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 somewhat less easy to obtain. Hourly average wind speed and direction is a common way to express these parameters. Indicate reference height of wind readings and the averaging period. Airport, meteorological station and site data will differ. The important point is to convert available data to estimate conditions at the test site. Use of techniques as outlined in the AIVC Calculation Techniques Guide (Reference 5) are recommended for this purpose. State the method used.

(3) Air temperature recorded at the Station, and more important at the test site, is normally recorded on an hourly basis. For validation studies, pre test period data for at least 12 hours is desirable.

(5) Daylight/insolation data is important for thermal modelling, especially cooling, and should include radiant temperature and diffuse as well as solar intensity.

(6) Cloud factor data are useful for energy use modelling.

II. TEST SITE DESCRIPTION

B. Climate Information (General)

(1) Location of Meteorological Station (R):

(2) % frequency wind speed versus direction (I):

(3) Air temperature (R):

(4) Degree Day information (I-3):

(5) Daylight/insolation (R-3):

(6) Cloud factor (U-3):

II. TEST SITE DESCRIPTION - Notes

B. Climatic Information (General)

General climatic data for a region is usually provided over a period of about 10 years. The dates covered should be noted as there are local changes of climatic pattern which take place over the shorter time scale which may cast doubt on the usefulness of the more general information.

Where the aim of the work is to determine future energy consumption, climatic information is vital. For all studies, if available, it should be included for the sake of completeness of the data set.

(7) Precipitation, and relative humidity (RH) may usually be found from the meteorological station. RH has particular significance in cooling calculations, 50% or more of the energy may be used to reduce inside RH.

(9) Soil depth for temperature reading is typically 8 cm (3 inches). Note location(s) on Site Plan II-A(3).

(10) Here should be included man made environmental effects, e.g., local sources of industrial effluent, heat or water vapour (power stations). Proximity to local bodies of water (rivers, lakes and reservoirs) and 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 should be noted.

II. TEST SITE DESCRIPTION

B. Climate Information (General)

(7) Precipitation and relative humidity (U-1,R-3C):

(8) Barametric pressure (indicate the reference level)(U,R-3):

(9) Soil temperature (state depth) (U-3):

(10) Other factors (I-2,3):

(11) Comments (U):

III. BUILDING DESCRIPTION - Notes

A. General Description

(2) Building type and classification should also provide details such as single storey, split level, two-storey, etc.

State building classification, for example:

Residential			
Single Family	- Houses		- Prisons
Multi Family	- Flats, Apartments		- Boarding Schools
Communal	- Hotels	Intermittent	- Holiday Homes
	- Hostels	Other	- Houseboats
	- Communes		- Caravans
Institutional	- Hospitals		- Mobile Homes
	- Nursing Homes		- etc.

Commercial/Industrial			
Office	- Clerical		- Bus Stations
Storage	- Warehouse		- Public Houses
Factory/Plant	- Telephone Exchange		- Clubs, Theatres
	- Chemical Plant		- Restaurants
	- Computer Centre		- Museums
	- Auto Plant		- Art Galleries
	- Refinery		- Churches
	- Brewery		- Shops
Farm	- Greenhouses		- Schools
	- Milking Parlour	Other	- Laboratories
	- Abattoir		- Mortuaries
Public	- Airports		- Bank Vaults
	- Railway Stations		- etc.

(3) History. This section should contain the date of construction and any structural modifications, retrofits, etc. Some mention should be made of past usage (where relevant) as this may have affected the structure of the building and/or the distribution of ventilation and heating/cooling within the building.

(4) Construction materials and technique, e.g. timber frame, masonry, concrete, prefabricated. Here one should describe the structure of the envelope, paying attention to materials, jointing methods and the effect on communicating spaces, e.g., wall cavities, crawlspace, etc., giving details of insulation, moisture barriers, etc. Specify absorption transmission and emissivity properties of the materials. Such information may be directly related to background air leakage, to energy loss or gain, and to the generation of pollutants.

III. BUILDING DESCRIPTION

A. General Description

(1) Building Name (I):

(2) Building Type (R):

(3) History (I):

(4) Construction materials, properties and techniques. (I):

(5) Comments (U):

III. BUILDING DESCRIPTION - Notes

B. Dimensions

Dimensions should cover all physical dimensions of the building, internal and external. Since terminology may differ between countries, photographs of important features or building components are highly recommended

Items (5) - (17) represent data beyond that needed for simple tracer gas testing.

(1) 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.

(2) see (1)

(4) both effective and total volume should be stated if there is a noticeable difference, e.g., ceiling plenums, raised floor systems etc.

(6) Ceiling height has meaning for room air stratification. Ceiling area different from floor area would occur with pitched/cathedral ceilings influencing heat transfer modelling and room air circulation.

III. BUILDING DESCRIPTION

B. Dimensions (R*)

(1) Plan, attach diagram (internal/external). (Note: reference all succeeding items to this plan.):

(2) Elevation (Include elevation for each facade where applicable):

(3) Total volume:

(4) Effective volume (if available):

(5) Floor area (internal dimensions):

(6) Ceiling height (and area, if different from floor area) (I):

(7) Facade (wall) area (include insulation levels for energy use calculations):

(8) Total area of windows for each wall, describe window type:

(9) Total area of external doors or hatches for each wall or ceiling, describe door type:

* Exceptions to (R) rating noted after individual items.

III. BUILDING DESCRIPTION - Notes

B. Dimensions

Dimensions should cover all physical dimensions of the building, internal and external. Since terminology may differ between countries, photographs of important features or building components are highly recommended

Items (5) - (17) represent data beyond that needed for simple tracer gas testing.

(11) 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. Drawings or photographs would prove helpful.

(12) Details can be given here or under Section III(C5-C8), whichever seems to be more suitable for the task in hand.

(13) Interior walls influence thermal mass and surface treatments can influence pollutant generation. For offices, specify partitions in open office plan and specify gap under partition and height. These parameters directly influence airflows in the spaces.

(14) Interior openings control inter-room airflows and the condition of such openings should be specified in Section III (C1-C4), (i.e. open, closed, partly open, etc.). Specified airflows are listed under Section IV-C(4).

(15) Stairshafts may be part of the interior construction or be separated by fire doors. If these doors are open the stairshaft becomes an interior building component. Stairshafts may be vented passively or mechanically to assure a low smoke environment in case of fire. Such venting should be noted under III-C(8).

(16) Elevator shafts, like stair shafts, can offer a direct link between floors and/or the outside. To vent a shaft when the elevator is moving, the top of the shaft is normally vented. Loose fitting doors may contribute to a major vertical airflow. List under III-C(8).

(17) Rubbish chutes link the inside to the outside and can be a major source of infiltration and/or exfiltration, list under III-C(8).

III. BUILDING DESCRIPTION

B. Dimensions R*

(10) Number, volume and layout of rooms: Name rooms and function where applicable:

(11) Shape roof pitch, etc:

(12) Attic, basement, crawlspace, description, insulation levels and degree of interaction with conditioned space should be specified:

(13) Interior wall, specify size, thickness and materials used (including moveable partitions) (U,R-3):

(14) Interior doors and devices, e.g., openings above the door (U,R-2,4):

(15) Number and sizes of stairshafts and venting arrangement:

(16) Number and size of elevator shafts, including size of opening at top of shaft:

(17) Rubbish chutes:

(18) Comments (U):

* Exceptions to (R) rating noted after individual items.

III. BUILDING DESCRIPTION - Notes

C. Air Leakage

Gaps in the building envelope and associated parameters such as background leakage and neutral pressure level are covered in this section. State type, location and crack length for each component.

(1) Include any weatherstripping details. State materials, reinforcements, hinge and locking mechanisms and closing systems (automatic, electric, etc.).

(2) Examples are: sash window, casement window, double or single glazed etc. Fixed glazing - if cracks are readily measured and regular, enter information here, otherwise under (9).

Include frame-wall cracks and additional sites such as roller blind boxes. Also add details of weatherstripping. State materials, reinforcements, hinge and locking mechanisms and closing systems (automatic, electric, etc.).

(3) State open area and degree of closure. Openings include: foundation grilles, air bricks, purpose provided stacks, etc.

(4) Include flue dampers; give information on operating cycle.

(5) Floor and wall cavities and roof spaces may provide an easy path for airflow. The presence of such paths as well as impedences to airflow should be noted.

(8) 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., basement/cellar doors, hatches, manholes, internal garages, etc.

(9) 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 - depressurisation curve or refer to V-A(4).

(10) The neutral pressure level for the building should be measured or calculated so that leakage areas which represent infiltration and/or exfiltration may be determined.

III. BUILDING DESCRIPTION

C. Air Leakage (R-1,2,I-3)

Gaps in the building envelope:

(1) Doors

(2) Windows.

(3) Ventilation openings.

(4) Chimney, flues.

also estimates of air leakage for:

(5) Communicating spaces such as cavity walls.

(6) Structural joints: soleplate, ceilings, corners, skirting boards, vapour and air barrier treatments, etc.

(7) Service routes: plumbing outlets, drains, electrical outlets, etc.

(8) Other air leakage sources such as items III-B(15) to III-B(17).

from the above, building construction type and the measured leakage, estimate:

(9) Background leakage.

(10) Neutral pressure level (I-1):

(11) Comments.

III. BUILDING DESCRIPTION - Notes

D. HVAC Systems

HVAC system includes any heating, ventilating or air conditioning system for items that are applicable.

Note: Specify airflow rates into and out of rooms under Section IV-C(4).

(1) This item should include:

- HVAC systems.
- AC systems.
- Ventilation systems such as dryer vents, bathroom and kitchen exhaust systems , etc.
- 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 III-C(4) chimneys, flues.)

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

(4) The daily and seasonal variations in the operation of the system should be included, e.g. midwinter unit on 50% of the time. Weekdays use one schedule, weekends another.

(5) Similar to (4).

(6) Indicate location of air inlets and outlets, especially height above floor level and the direction of airflow.

(7) Conditioning sources may directly influence room air flow and heat exchange to the exterior.

(8) Balance of airflow systems is vital. Lack of balance means encouraging air exfiltration in some zones and air infiltration in others. Pollutant movement can be directly involved, e.g., radon movement.

(9) Many HVAC systems directly involve the addition of outside air which may only take place when system is on.

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

III. BUILDING DESCRIPTION

D. HVAC Systems (R)

(1) Type of system:

(2) Blower fan capacity (where available):

(3) Duct tightness, size, insulation, type and location:

(4) Frequency of operation, duration of operating cycle:

(5) Operating temperature:

(6) Location of air inlets and outlets:

(7) Location of conditioning sources (grilles, radiators, etc.):

(8) Include balance report for systems that move air:

(9) Ventilation rate (outdoor airflow supplied by system):

(10) Note any recirculation between rooms due to HVAC system:

(11) Comments:

III. BUILDING DESCRIPTION - Notes

E. Pollutant Sources

Materials within the building can be a source of pollution. This often includes the building construction itself, as well as surface treatments (paints, stains, etc.). The actual pollutants include such substances as: radon, formaldehyde, sulphates, organics, mercury, etc. Radon may be a direct result of the building materials but more likely is a result of the building site, i.e., the soil gas entering the lower part of the building.

There is also pollution indoors that is a direct result of other outside sources, such as: pollutants in the ambient air, motor vehicle exhaust, stack exhaust from factories, etc.

Pollution arising from occupancy is dealt with under Section IV-A(6).

Indoor or outdoor pollutants may account for possible sources of interference in tracer gas studies.

III. BUILDING DESCRIPTION

E. Pollutant Sources (R-2)

(1) Interior sources:

(2) Exterior sources:

III. BUILDING DESCRIPTION - Notes

F. Pressure Coefficients

Pressure coefficients are used to calculate the leakage rates anticipated in the building. See the AIVC Calculation Techniques Guide (Reference 5) for explanation and examples. Section V-B should be used for listing detailed information.

Specify pressure coefficients for the building for representative weather conditions (measurements near leakage paths are preferred, lacking such building data one may make best use of AIVC datasets on similar buildings):

III. BUILDING DESCRIPTION

F. Pressure Coefficients (I)

III. BUILDING DESCRIPTION - Notes

G. Furniture, Interior Fittings

Large pieces of furniture can influence time lags in thermal models, moisture balance in cooling models and serve as pollutant sources.

Specify size, position and materials for large pieces of furniture.

III. BUILDING DESCRIPTION

G. Furniture, Interior Fittings (U)

IV. OPERATION/FUNCTION OF BUILDING - Notes

A. Occupant Related Data

This is basically qualitative data from questionnaires or other sources. If monitoring is taking place list under Section V. Dates and times of operation/function should be specified in Julian format. Descriptions can be algorithms, tables, graphs as a function of time or other parameter.

(1) Times occupied, number of users. These can be monitored where relevant, and should include individual rooms where this data is available.

(2) Enter Section V-H(4) when measured directly, Otherwise supply general information here.

(3) Internal doors should be included.

(4) Include extract fans in kitchens, toilets, bathrooms, etc.

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

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

(7) Sedentary, physically active, etc.

IV. OPERATION/FUNCTION OF BUILDING

A. Occupant Related Data (I)

(1) Times occupied and number of users :

(2) Window opening:

(3) Door opening:

(4) Other voluntary ventilation:

(5) Heating habits:

(6) Pollution (I-1,3,R-2):

(7) Level and type of occupant activity:

(8) Comments:

IV. OPERATION/FUNCTION OF BUILDING - Notes

B. Special Ventilation Requirements

This is basically qualitative data from questionnaires or other sources. If monitoring is taking place list under Section V. Dates and times of operation/function should be specified in Julian format. Descriptions can be algorithms, tables, graphs as a function of time or other parameter.

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 facilities, furniture stores, etc.

IV. OPERATION/FUNCTION OF BUILDING

B. Special Ventilation Requirements (I)

IV. OPERATION/FUNCTION OF BUILDING - Notes

C. Control Values (Refer to Section III-D where appropriate.)

This is basically qualitative data from questionnaires or other sources. If monitoring is taking place list under Section V. Dates and times of operation/function should be specified in Julian format. Descriptions can be algorithms, tables, graphs as a function of time or other parameter.

These settings provide an "expected operation" of the building and the measurements from Section V determine whether or not operation has been achieved.

(3) Comfort and air movement in the individual zones are often directly related to room air stratification. Observe conditions are noted here. Detailed measurements are listed under V-C(2).

(4) Airflow within a zone or between zones directly or indirectly affects comfort and indoor air quality. Multi-room modelling also requires this data.

(5) Relative humidity levels can have a direct effect on pollutant levels (e.g., formaldehyde concentration, etc.) and on comfort and cooling considerations.

IV. OPERATION/FUNCTION OF BUILDING

C. Control Values (R)

(1) Specified airflow rates to rooms:

(2) Specified supply/exhaust airflows to building:

(3) Specified thermostat settings:

(4) Specified inter-room or zonal airflows:

(5) Specified relative humidity levels (I,R-2,3,):

(6) Other:

(7) Comments:

IV. OPERATION/FUNCTION OF BUILDING - Notes

D. Pollutant Sources/Sinks

This is basically qualitative data from questionnaires or other sources. If monitoring is taking place list under Section V. Dates and times of operation/function should be specified in Julian format. Descriptions can be algorithms, tables, graphs as a function of time or other parameter.

Pollution source and sinks involve occupants and material in the space or those influencing the space.

Occupant related sources should be listed under IV-A(6). Material sources in III-E. Moisture sources not covered in these sections should be detailed here, (e.g. swimming pools, washing machines and dryers). Noise sources external/internal should be noted along with any preventative measures.

IV. OPERATION/FUNCTION OF BUILDING

D. Pollutant Sources/Sinks (R-2)

IV. OPERATION/FUNCTION OF BUILDING - Notes

E. Additional Heat Sources

This is basically qualitative data from questionnaires or other sources. If monitoring is taking place list under Section V. Dates and times of operation/function should be specified in Julian format. Descriptions can be algorithms, tables, graphs as a function of time or other parameter.

Heat sources other than the purpose provided heating systems should be detailed here, e.g. computers, lights (with schedules) - state if light fittings are used as extracts.

IV. OPERATION/FUNCTION OF BUILDING

E. Additional Heat Sources (U,R-3)

V. MEASUREMENTS - Notes

A. Pressurisation Measurements - Internal

Include any diagrams/photographs of the instrumentation/techniques used.

(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. See Ref.4.

Any components which are sealed during the test should be noted in the data.

Pressure tests on individual components should be described here.

(2) Include type, location and calibration of sensors. General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

A. Pressurisation Measurements - Internal (R)

(1) Technique employed:

(2) Equipment used:

(3) Calibration procedures/results:

(4) Results:

(5) Comments:

V. MEASUREMENTS - Notes

B. Pressure Measurements - External (including wind tunnel (Pressure Coefficients (use Ref.3 as background) studies)

Include any diagrams/photographs of the instrumentation/techniques used. Where possible these values should be provided: Pressures - List mean exterior, , extreme or peak values can be noted, and mean internal pressure. The standard deviation and skewness should also be noted. Velocities - List mean velocity, v, and extreme velocity for given time scale. Velocities are related to specific heights 3m, 10m, roof ridge height, etc. When pressure coefficients are quoted the expression used to define them should be explicitly given. 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.

(1) The conditions under which the pressure test is carried out should be specified. If wind tunnel studies are used, describe:
- the scale of the model and the size of the wind tunnel.
- the geographical area covered by the model (possibly on the map II-A(3) (Geographic information).
- the method used to generate the turbulent profile in the wind tunnel.
- the assumptions made regarding the velocity profile and turbulent spectrum.
- the level of correspondence between modelled conditions and real conditions on site.

Such studies as performed by BRE (Ref.6), British Gas (Ref.7) 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.

(2) General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Some work by BRE (Ref.6) 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 are preferred where available, as this should simplify standardising values.

(5) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

B. Pressure Measurements - External (I)

(1) Technique employed:

(2) Equipment used:

(3) Calibration procedures/results:

(4) Location of surface pressure taps (refer to IIIB(1):

(5) Results:

(6) Comments:

V. MEASUREMENTS - Notes

C. Interior Conditions

Include any diagrams/photographs of the instrumentation/techniques used.

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

This item includes detailed surveys of room temperature stratification.

(1) Include type, location and calibration of sensors. General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(2) - (7)

Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

C. Interior Conditions

(1) Instrumentation used (R):

(2) Temperature (dry bulb) (R):

(3) Relative humidity (I,R-4):

(4) Airflow within room (U,R-4):

(5) Airflow between rooms (U,R-2):

(6) Pollutant concentrations (U,R-2):

(7) Other:

(8) Comments:

V. MEASUREMENTS - Notes

D. Weather On-Site

Include any diagrams/photographs of the instrumentation/techniques used.

Detail monitored on-site weather information resulting from the project.

(1) Include type, location and calibration of sensors used. General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(2) - (14)

Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

(6) - (7)

Where these are given, the range of frequencies covered should be stated. Presentation as a spectrum would be acceptable.

(8) 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.

V. MEASUREMENTS

D. Weather On-Site

(1) Instumentation used (R):

(2) Wind speed (R):

(3) Wind direction (R):

(4) Dry bulb temperature (R):

(5) Relative humidity (U,R-3):

(6) Turbulence scale (U):

(7) Turbulent intensity (U):

(8) Stability conditions (where available) (U):

(9) Atmospheric pressure (U,R-3):

(10) Solar radiation (U,R-3):

(11) Cloud factor (U,R-3):

(12) Precipitation (U-3):

(13) Soil Temperature (U-3):

(14) Other:

(15) Comments:

V. MEASUREMENTS - Notes

E. Weather Off-Site

Include any diagrams/photographs of the instrumentation/techniques used.

Detail monitored off-site weather data resulting from the project, (weather data from weather services should be listed under II). This data is only required if on-site data is incomplete or unavailable. Properly instrumented on-site data is always more valuable than off-site data.

(1) Include type, location and calibration of sensors used. General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(2) - (10)

Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

E. Weather Off-Site

(1) Instrumentation used (R):

(2) Wind speed (I):

(3) Wind direction (I):

(4) Dry bulb temperature (I):

(5) Stability conditions (See Note V-D(8)(U):

(6) Atmospheric pressure (U,R-3):

(7) Solar radiation (U,R-3):

(8) Cloud factor (U,R-3):

(9) Precipitation (U-3):

(10) Other

(11) Comments:

V. MEASUREMENT - Notes

F. Infiltration - Tracer Gas Methods

Include any diagrams/photographs of the instrumentation/techniques used.

(1) Use of Ref.4 (especially chapter 6) for guidance. Examples include:

- Tracer gas decay method (on-site analysis)
- Tracer gas decay method (grab sampling - bottles, bags, etc.)
- Tracer gas decay method (grab sampling - detector tubes)
- Tracer gas constant emission rate (passive sampling)
- Tracer gas constant concentration
- Multiple tracer gas decay rate

(2) General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

F. Infiltration - Tracer Gas Methods (I,R-1,2)

(1) Technique employed:

(2) Equipment used:.

(3) Calibration procedures/results:

(4) Results:

(5) Comments:

V. MEASUREMENT - Notes

G. Inter-room Airflow Rates

Include any diagrams/photographs of the instrumentation/techniques used.

The data for inter-room airflow rates will normally come from multi-tracer gas studies employing measurement equipment on site, or passive samplers evaluated in the laboratory. Details on these methods are found in Reference 4.

(2) General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

G. Inter-Room Airflow Rates (R-2)

(1) Technique employed:

(2) Equipment used:

(3) Calibration procedures/results:

(4) Results:

(5) Comments:

V. MEASUREMENT - Notes

H. Pollutant Concentrations

Include any diagrams/photographs of the instrumentation/techniques used.

Pollutant concentrations can vary with time of day, RH level that is present, occupant related factors, materials being used or brought inside, etc., therefore single measurements may be insufficient and continuous monitoring will be necessary.

2) General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

H. Pollutant Concentrations (U,R-2)

(1) Technique employed:

(2) Equipment used:

(3) Calibration procedures/results:

(4) Results:

(5) Comments:

V. MEASUREMENT - Notes

I. Duct Flow Rates & Temperatures

Include any diagrams/photographs of the instrumentation/techniques used.

Flow rates must be specified for airflow work, temperatures for energy usage and thermal modelling.

(2) General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

I. Duct Flow Rates & Temperatures (I,R-3)

(1) Technique employed:

(2) Equipment used:

(3) Calibration procedures/results:

(4) Results:

(5) Comments:

V. MEASUREMENT - Notes

J. Other

Include any diagrams/photographs of the instrumentation/techniques used.

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

For example:

I.R. Thermography (I-3)

Energy Consumption: For use in such expressions as Energy Signature (Ref.8) (match with Degree Day data, or outside temperature, where possible).
See also Section VI.

Qualitative Air Leakage (see Ref:4, Chapter 3) i.e., smoke sticks and/or acoustic techniques, etc..

Behaviour Related Measurements

(2) General instrumentation information and instrument accuracy should be listed here and referenced in the succeeding sections.

(4) Date and time of measurements should be included in Julian format. Attach relevant tables, graphs and name any disk data files (give full details in VIII-DISK DATA FILES).

V. MEASUREMENTS

J. Other (I)

(1) Technique employed:

(2) Equipment used:

(3) Calibration procedures/results:

(4) Results:

(5) Comments:

VI. ECONOMIC FACTORS - Notes

A. Retrofitting Measures

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

Energy Signatures (Ref.8) and similar ways of preparing energy consumption should be used. NAC, normalized annual consumption, is one method of making such comparisons (see Ref.9).

VI. ECONOMIC FACTORS (U,R-2,3)

A. Retrofitting Measures.

(1) Procedures:

(2) Energy consumption before and after retrofit:

VI. ECONOMIC FACTORS - Notes

B. Ventilation, Energy and Health

Effects on energy consumption and health due to controlling ventilation rates:

VI. ECONOMIC FACTORS (U,R-2,3)

B. Ventilation, Energy and Health

VI. ECONOMIC FACTORS - Notes

C. Other Factors

Energy Signatures (Ref.8) and similar ways of preparing energy consumption should be used. NAC, normalized annual consumption, is one method of making comparisons (see Ref.9).

VI. ECONOMIC FACTORS (U,R-2,3)

C. Other Factors

VII. NUMERICAL/COMPUTER MODELS - Notes

A. Type of Model/Correlations
(See Reference 10)

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

(2) Some examples are: regression, finite difference, etc.:

(4) Please include:

- Type of equipment.
- Storage required for program.
- Time to run program.
- Average cost of simulations.

(7) This comparison is considered very important:

VII. NUMERICAL/COMPUTER MODELS

A. Type of Model/Correlations (R)

(1) Name of Model:

(2) Description of Model:

(3) Assumptions in Model:

(4) Computer equipment, run time and data storage required:

(5) Input data required:

(6) Output:

(7) Agreement with observations:

(8) Problems encountered:

(9) Comments:

VII. NUMERICAL/COMPUTER MODELS - Notes

B. Other Theoretical Work of Interest

This section should be used to describe any new algorithms etc., developed or resulting from the measurement work described in V. and/or the modeling work described in VII-A.

VII. NUMERICAL/COMPUTER MODELS

B. Other Theoretical Work of Interest

VIII. DISK DATA FILES - Notes

A. Measurements

(1) Explain the structure of your disk filenames ie. names & extentions according to contents.

Name and describe the measurment variables/channels/types as recorded on disk.

(2) Give a brief description of the contents of each disk file.

(3) Describe in detail the disk file format used with examples.

If a common database/spreadsheet format such as .DBF (dBASE IV) or .WK1 (Lotus 123) has been used please just give field headings, types and sizes.

VIII. DISK DATA FILES

A. Measurements

(1) Nomenclature

(2) File names/contents

(3) File Formats

(4) Comments

VIII. DISK DATA FILES-Notes

B. Numerical/Computer Models

(2) Describe all file names and types with extensions. Give a breif description of file contents.

i.e. Program,data, input file, output file etc.

(3) Give details of input/output file formats.

VIII. DISK DATA FILES

B. Numerical/Computer Models

(1) Name of Model

(2) File names/contents

(3) File Formats

(4) Comments

IX. GENERAL REMARKS - Notes

This section should be used to raise any points not covered by the prior suggested data guidelines. 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.

IX. GENERAL REMARKS

X. EXAMPLES OF GUIDELINES APPLICATION

This section provides examples of the guidelines applied to two kinds of buildings:

A) The Canadian HUDAC upgraded house which was originally outlined in Reference 13.

B) The LESO Laboratory building of the Ecole Polytechnique

Clearly these two examples represent a wide range of building complexity. It is the goal of the reporting guidelines to accomodate the full range of building complexity, deleting those topic areas that don't apply to the particular building or the particular experiment or testing goal. Further information on the LESO laboratory, referred to in this section, can be found in References 11 and 12, as well as references listed in the example.

Since both the descriptions of the test buildings used in this section were originally designed for the format outlined in Reference 2, listings have been changed wherever possible to fit the updated guidelines described in this technical note. Both examples have been truncated from their original form but should give a good indication of the depth of data required by the guidelines for proper reporting.

Example A has been generated using the AIVC Reporting Guidelines dBASE IV applications package. This application is available from the centre on 3" or 5" disk so that data entry can be further streamlined and made more uniform. Any numerical data suplied to the Centre should be backed up by a report produced according to these guidelines, preferably on disk.

X. EXAMPLES OF GUIDELINES APPLICATION

A. The Canadian HUDAC House

GENERAL INFORMATION

Report date

1980

Principal Researcher

C.Y. Shaw

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National Research Council
Ottawa
Ontario
K1A 0R6
Canada

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Other Researchers

G.T. Tamura

Project Title

The Mark XI Energy Reserch Project.

Air tightness and air infiltration measurements.

Project Purpose

To measure energy cosumption and factors which affect it, including infiltration.

Project start/end dates

1978/9

Building Selection

The Division of Building Research of the National Research Council of Canada and the Housing and Urban Developement Association were participating in a joint programme to study energy conservation in four detached two-sorey houses. One of the

GENERAL INFORMATION

Building Selection

houses H1 was built to a construction standard similar to houses in the same area. The other three were built with added insulation and a specially applied polyethylene vapour barrier to improve the air tightness of the house envelope.

References

1. Quiroutte, R.L.
   The Mark XI Energy Research Project:
   Design and Construction
   Building Res. Note No. 131

2. Shaw, C.Y. and Tamura, G.T.
   Mark XI Energy Research Project:
   Airtightness and Air Infiltration Measurements.
   Building Res. Note No. 162, June 1980.

Comments

Tests to measure the air tightness were carried out on four houses. Air infiltration was measured for the standard house (H1) and the upgraded house with heat pump (H4). Because the building envelope of the standard and upgraded houses differs primarily in degree of airtightness, a comparison of simultaneously obtained infiltration data should show whether or not there is a correlation between infiltration and air tightness.

TEST SITE DESCRIPTION

Geographic Information

Location

Fortune Drive
Orleans
Ontario
Canada
(5km east of Ottawa)
See Fig. 1

Terrain/Site Plan

Flat with low buildings (houses)
See Fig. 1 for site plan.
Shielding is moderate.
Buildings within 2 house heights + 2.5m earth berm.

Building Orientation

Front facade points 24°W of North

Climatic Information

Meteorological Station

On site

Comments

Detailed measurements taken on site.

BUILDING DESCRIPTION

General Description

Building type

Single detached houses.
2 storey, 3 bedroom, 1½ bathroom and basement, attached garage.
See Fig. 2.

History

Built to Ontario Building Code 1975 by Talback Construction of Ottawa. Construction began on 6th July 1977, essentially completed by end of December 1977.

Construction

Standard House (see Fig. 2)

Wood frame construction. 2 x 4 stud walls, 2 x 8 wood joists, wood trusses 24" oc.
Cast-in-place concrete foundations, 8" walls.
Wall insulation: Glass fibre, paper backed, R12.
Ceiling insulation: Glass fibre, paper backed, R20
Basement insulation,glass fibre, paper bached,R7, inside, extending 2ft below grade.
Windows: Double glazed, wood frame (sliding and double hung).
Exterior doors: Metal insulated, ~R6, no storm door.
Sliding Horizontal: Alum. 8" ivory white.
Roof: Asphalt shingles 210 lbs.
Brick on front of house only, one storey garage.
Soffits continually vented, A6.
Facia: Aluminium.

Upgraded house.(See Figs. 3 & 4)

As Standard, except:

6" walls, 2x4 studs + 2x2 horizontal strapping inside.
Wall insulation: Glass fibre, friction fit, R12+R7, 4mil polyethylene vapour barrier throughout.
Ceiling insulation: Glass fibre friction fit, R20 + R12
Exterior sheathing: 1" fibreboard, thermal value, R3
Basement insulation: Closed cell polystyrene 1½", R7.5, outside extending to footing.
Windows: triple glazed, wood frame, casement, awning,

Exterior doors, metal insulated, with storm door, ~R7.5.

Comments

Estimated annual heating consumption:

BUILDING DESCRIPTION

General Description

Comments

Standard - 20212 kW.h
Upgraded - 15125 kW.h (conventional heating)
Upgraded 7560 kW.h (with solar heating)
Upgraded - 9980 kW.h (with heat pump)

Dimensions

Plan

See Figs. 2 & 4.

Elevation

See Figs. 2 & 4.

Total volume

Including basement 386 cubic metres.

Internal floor area

Gross: 1249 $ft^2/118m^2$

Ceiling height

Ceiling area: 673 $ft^2/63.7m^2$

Facade (wall) area

Above grade: 1525 $ft^2/144.4m^2$

Foundation wall: 891 $ft^2/84.4m^2$

Windows

Area: 164 $ft^2/15.5m^2$

External Doors/Hatches

Area: 44 ft^2/4.2m^2

Rooms

See Figs. 2 & 4.

Attic/Cellar/Crawlspace

Gross basement enclosure area: 1437ft^2/136m^2

Internal Walls/Partitions

See Figs. 2 & 4.

Comments

See reference 1 for more details.

Air Leakage

Windows

Length of sash crack Standard - 42.85m
Upgraded - 67.59m

Frame/wall leakage - Negligible
Window leakage see figure 8.

Chimneys, flues

No chimney.

Comments

Wood frame enclosure area: 227.7m^2.
Gross basement enclosure area: 136m^2

The area of the building envelope is defined as the area of the exterior walls above grade lus that of the ceiling of the upper floor.

HVAC Systems

Type of system

Standard House.

Heating system:	Forced air electric furnace 15 kW.
Design heating load:	46400 Btu/h - 13.6 kW

Upgraded House.

Heating system:	Forced air electric furnace 10 kW.
Design heating load:	13 755 Btu/h - 10.186 kW

Solar House.

Heating system:	Solar, air to air, with forced air distribution.
Suplementary heating:	Forced air electric furnace 10 kW.
Design heating load:	13 755 Btu/h - 10.186 kW

Heat Pump House.

Heating system:	Heat pump, air to air, with forced air distribution.
Suplementary heating:	Forced air electric furnace 10 kW.
Design heating load:	13 755 Btu/h - 10.186 kW

Balance report

Air flows measured in forced airducts by orifice plate - results not given.

Comments

See reference 1 for more details.

OPERATION/FUNCTION OF BUILDING

Occupant Related Data

Occupation times/numbers

Unoccupied during tests, but furnished. Will be let to families in future and monitoring will continue.

Window Opening

Windows instrumented to detect opening, but not used in this experiment.

Door opening

To be instrumented, but no results given.

Additional Heat Sources

Electrical energy to each room, also to appliances - monitored, results not given.

MEASUREMENTS

Internal pressurisation

Technique employed

See Fig. 5.
A centrifugal fan with a capacity of 380 l/s was placed in the living room of each house. The discharge side of the fan was connected by a 10 cm diameter duct to an outside window, which was replaced by a plywood panel. The flow rate of the fan was adjusted manually with a damper and was measured with a liminar flow element.
The air leakage rates through windows and doors of the heat pump house were also obtained by comparing the overall air leakage rates taken before and after the particular components were sealed with plastic sheets.

Equipment used

MERIAM LFE Element: accuracy of 5% of measured value.

Results

See Figs. 6,7 & 8.

Using Q=CA(P)^n
Q in l/s, C in l/(s.m².(Pa)^n), P(Pa)
(A = 227.8 for both)

Standard - C=0.11 n=0.71)
) whole house

Upgraded - C=0.075 n=0.71)

Comments

See reference 2 for full results and discussion.

Wind pressure & Wind Tunnels

Technique employed

The exterior walls and ceilings were fitted with pressure taps, but no measurements were made in this series.
Presure differences have been measured at four different levels in calm weather, wind speed < 1m/s, to find the neutral plane - results not given.

Interior Conditions

Temperature (dry bulb)

Measured by thermocouple (See tables 1 & 2)

Relative humidity

Monitored - results not given.

Other

Moisture in the building fabric was also monitored - no results given.

Weather - on site

Instrumentation

Measured at 10m to rear of house at 18m above ground.

Wind speed

See tables 1 & 2.

Wind direction

By octant - see tables 1 & 2.

Dry bulb temperature

See tables 1 & 2.

Infiltration

Measurement technique

Used tracer gas decay method. Tracer gas was CO_2 produced by placing pieces of dry ice on a hot plate in the living room. After a pre-determined amount of CO_2 gas was generated, the remaining dry ice was taken out of the house. After allowing sufficient time for the tracer gas to mix with the air inside the house, using the forced-air circulation system, the CO_2 concentration was measured periodically by sampling from the return air duct of the forced-air system. during the tests, a sample of air was drawn alternately from the return air duct of each test house using 0.63cm polyethylene tubing, and was

MEASUREMENTS

Infiltration

Measurement technique

analysed using an infrared gas analyser. An automatic system was used to take air samples and measure the CO_2 concentrations to avoid introducing additional CO_2 into the houses by the presence of research personnel.

Equipment used

Infrared analyser - accuracy 1% of full scale.

Results

See Figs. 9,10,11 & 12.
See tables 1 & 2.

Autumn, Winter and Spring measurements were made simultaneously on both houses. In Summer the standard house was occupied so only the results from the upgraded house were available.

Comments

See reference 2 for full results and discussion.

ECONOMIC FACTORS

Ventilation rate effects

See Fig. 13.

See reference 2 for full results and discussion.

Other factors

Heat Loss Analysis indicates ventilation heat loss of 4.415kW (32.1%) for the standard house.

See reference 2 for full results and discussion.

NUMERICAL/COMPUTER MODELS

Other Theoretical Work

See Fig. 14.

See reference 2 for full details and discussion.

GENERAL REMARKS

Air leakage rates were measured in the four energy-conservation research houses using the fan-pressurisation method. It was found that the air leakage of the standard house was about 50 per cent higher than that of the upgraded houses. The high leakage of the solar house could probably be attributed to the additional air leakage through the ductwork and solar collector of the aor to air solar heating system. There was no detectable air leakage through joints around windows and doors. The air leakage through the windows of the heat-pump house, which were tested as installed was about 50% lower than the maximum value permitted by ASHRAE 90-75 for new building design.

Air infiltration rates were measured simultaneously in the standard and heat-pump houses using the tracer gas method with CO2 as a tracer gas. It was found that for wind speeds lower than 3.5m/s, the air-infiltration rate can be expressed in terms of inside-outside temperature difference by an equation similar to the air flow equation with the same exponent. The ratio of the infiltration rates of the two houses is approximately equal to the ratio of the flow coefficients, which indicates that there is a correlation between infiltration and air leakage as measured by fan pressurisation tests. The significance of inside-outside temperature is reduced as wind speed increases.

Air infiltration, on average, accounted for about 20% of the total energy purchased for the standard and heat pump houses in the 1978-1979 heating season.

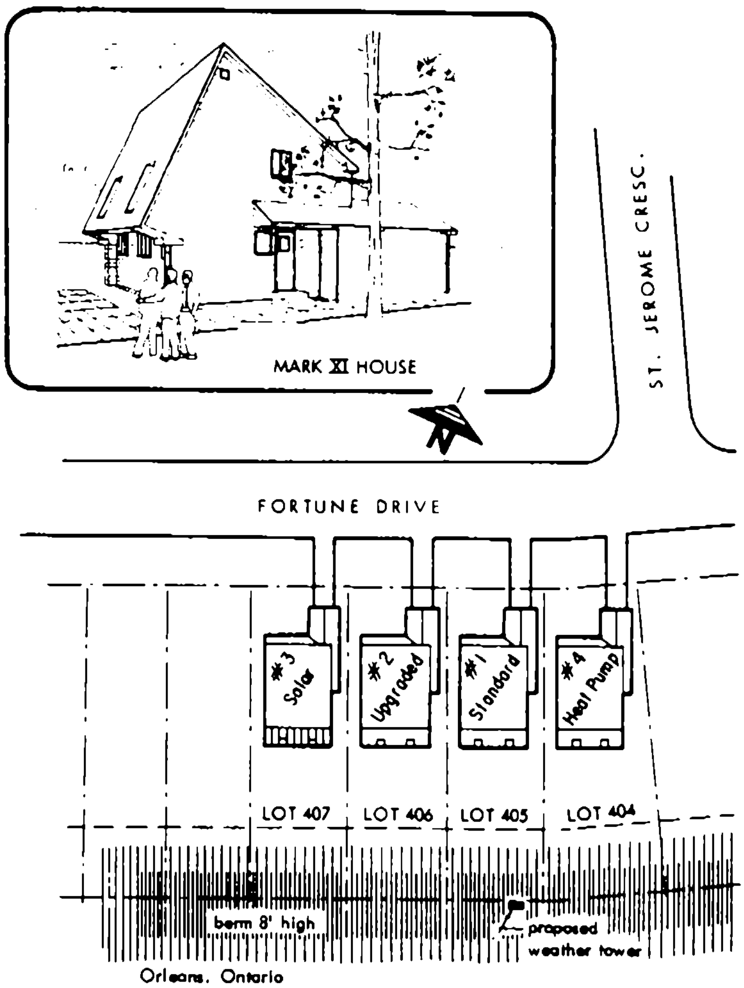


FIGURE 1

SITE PLAN - MARK XI PROJECT

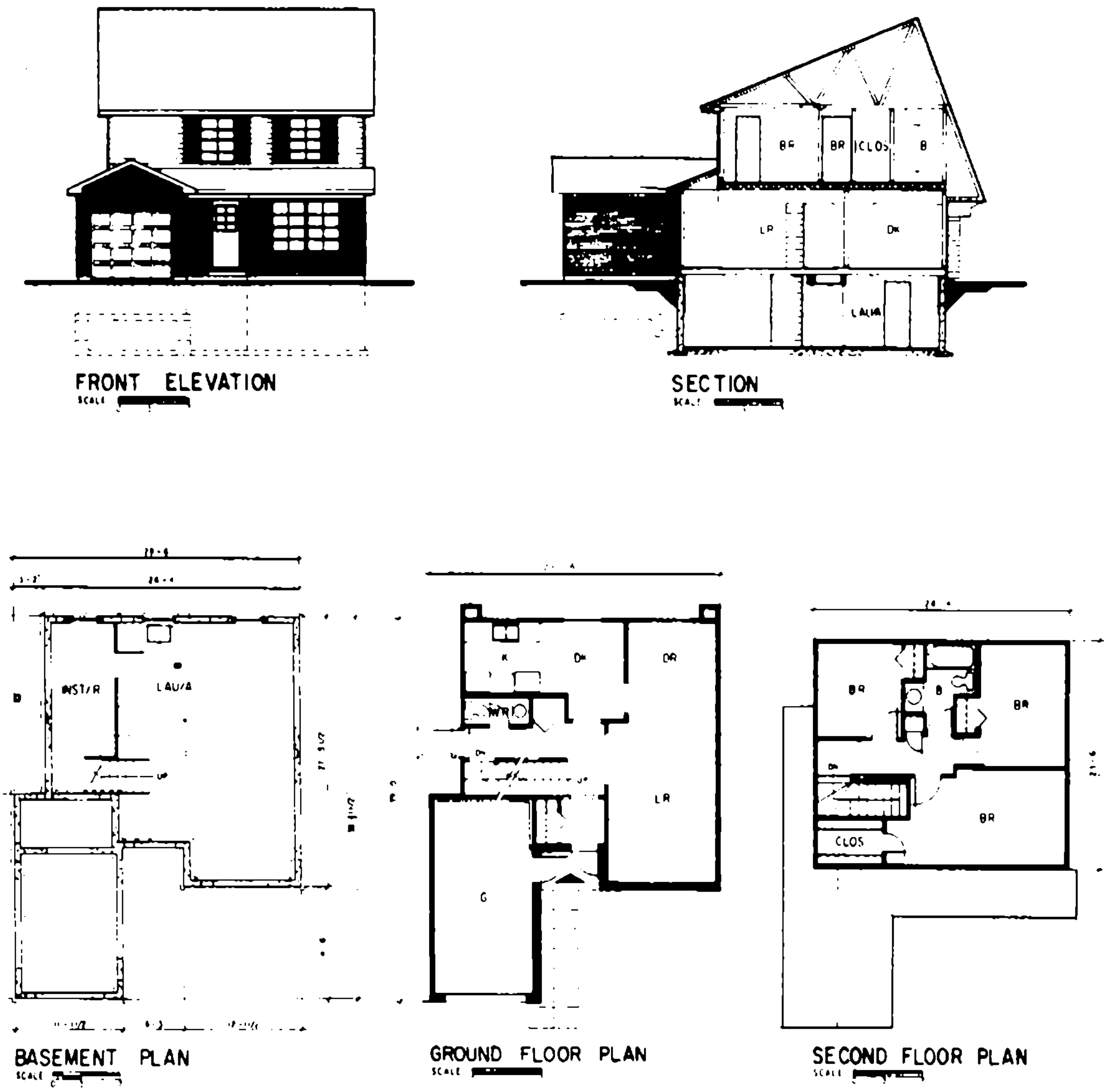


FIGURE 2

HOUSE NO. 1 - STANDARD CONSTRUCTION
(TYPICAL ARCHITECTURAL DESIGN OF ALL 4 HOUSES)

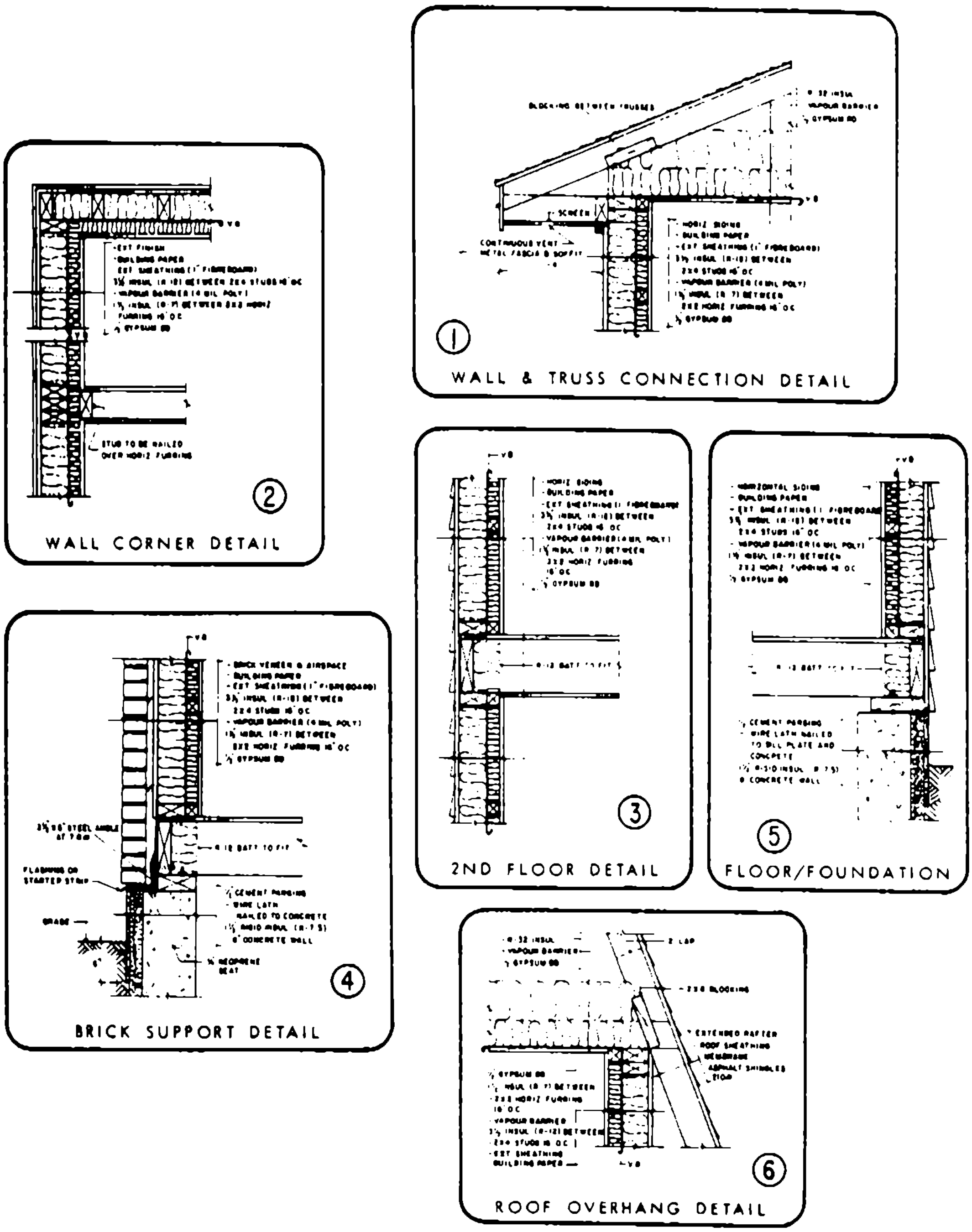
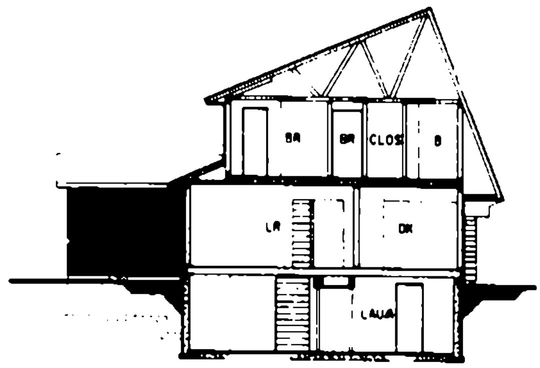


FIGURE 3

HOUSE NO. 2 - UPGRADED CONSTRUCTION

(CONSTRUCTION DETAILS FOR HOUSES 2, 3 & 4)

FRONT ELEVATION



SECTION

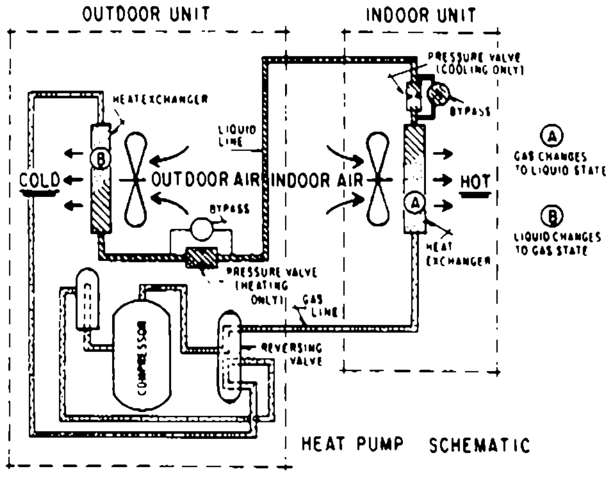


FIGURE 4

HOUSE NO. 4 - UPGRADED + HEAT PUMP

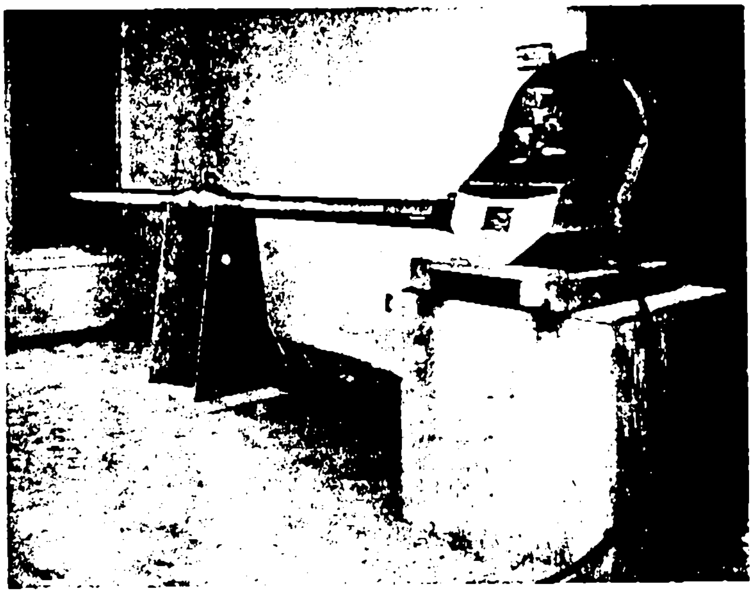


FIGURE 5 Equipment for fan-pressurization test

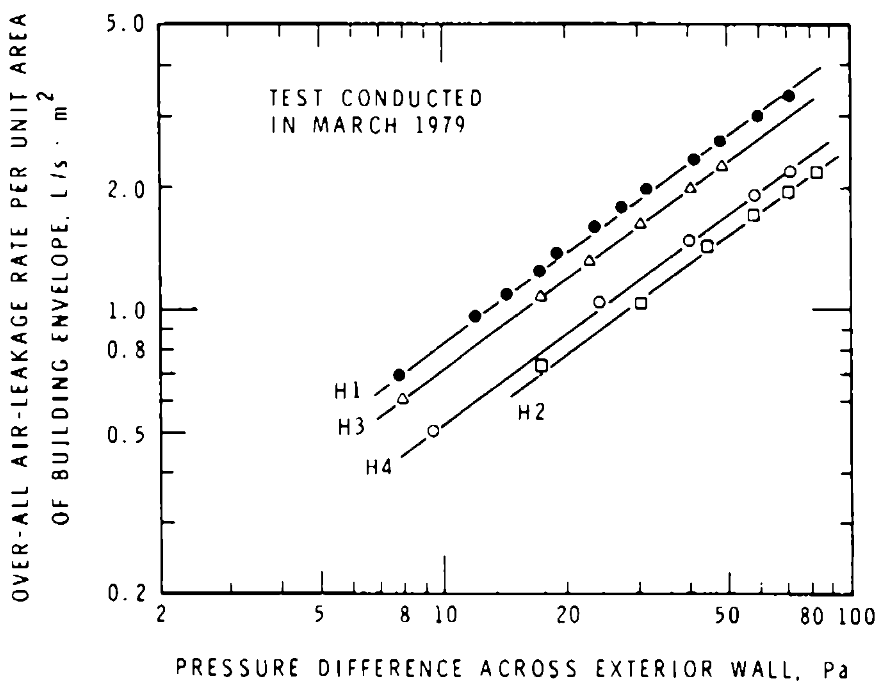


FIGURE 6

OVER-ALL AIR-LEAKAGE RATE FOR THE FOUR ENERGY-CONSERVATION RESEARCH HOUSES

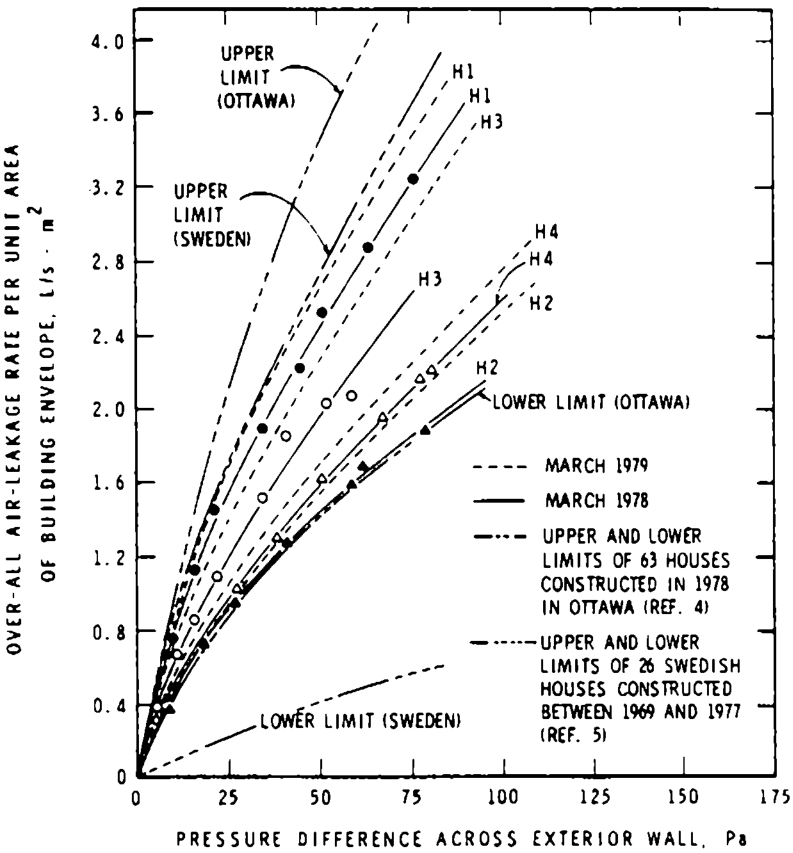


FIGURE 7

COMPARISON OF AIR-LEAKAGE RATE OF THE FOUR HOUSES AND OTHERS

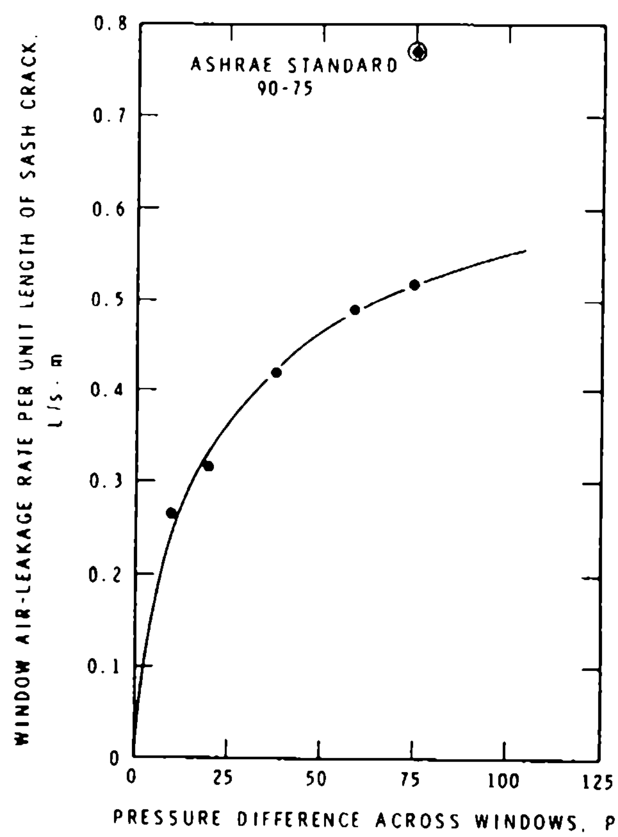


FIGURE 8

WINDOW AIR-LEAKAGE RATE OF THE UPGRADED HEAT-PUMP HOUSE

Report prepared according to: INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and
community systems programme

Air Infiltration and Ventilation Centre's

REPORTING GUIDELINES FOR THE MEASUREMENT OF AIRFLOWS IN BUILDINGS

(David T. Harrje & James M. Piggins)

Using the AIVC dBASE IV Reporting Guidelines Application

AIVC-AP-RG1-1990

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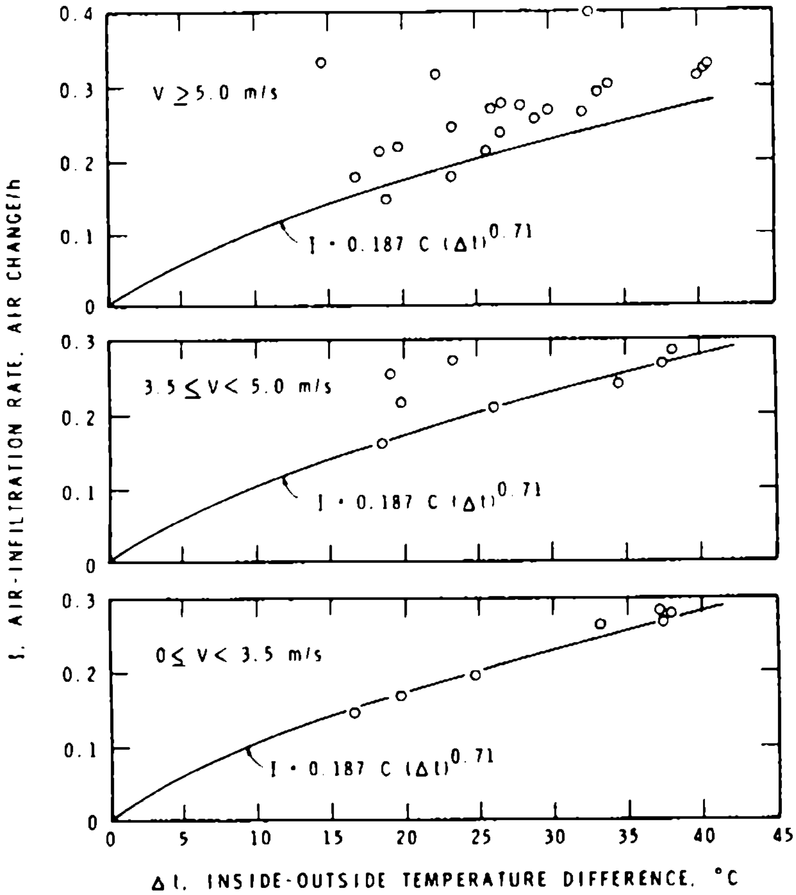

FIGURE 9

AIR-INFILTRATION RATE VS INSIDE-OUTSIDE TEMPERATURE DIFFERENCE FOR HOUSE H1

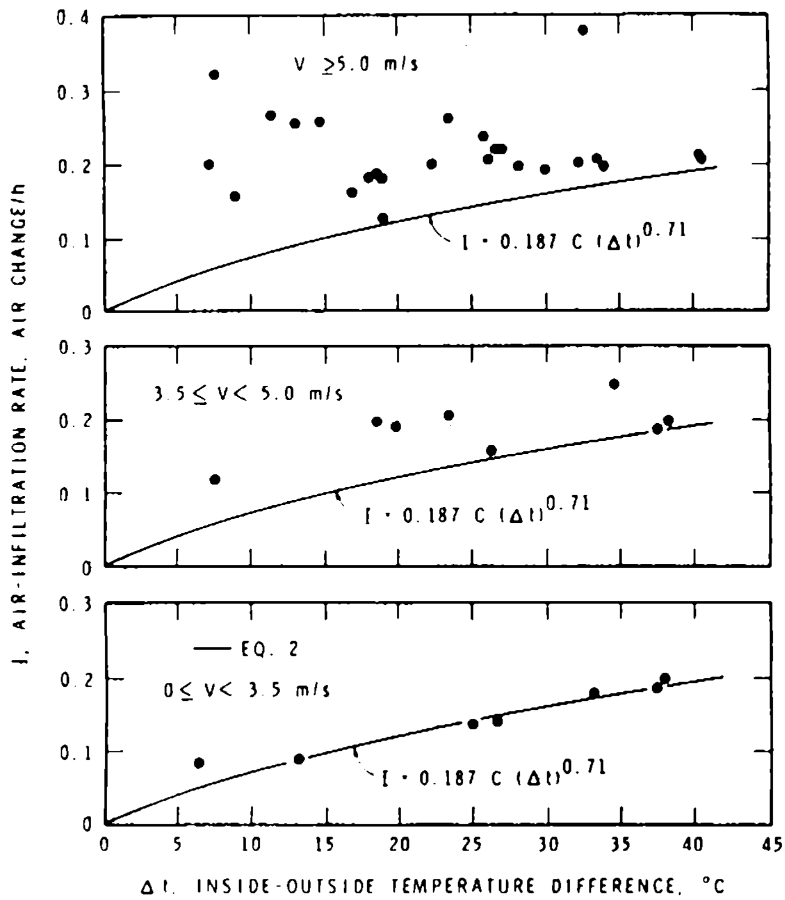

FIGURE 10

AIR-INFILTRATION RATE VS INSIDE-OUTSIDE TEMPERATURE DIFFERENCE FOR HOUSE H4

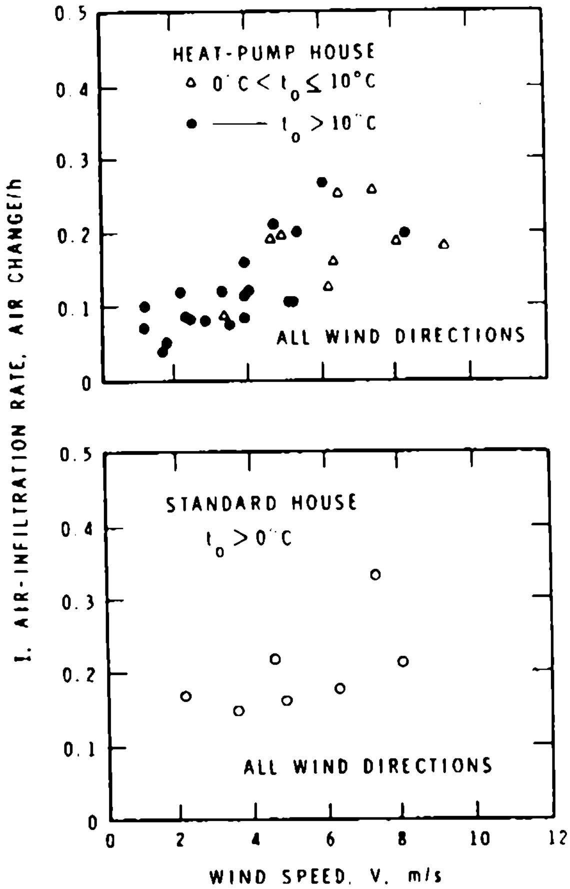

FIGURE 11
AIR-INFILTRATION RATE VS WIND SPEED

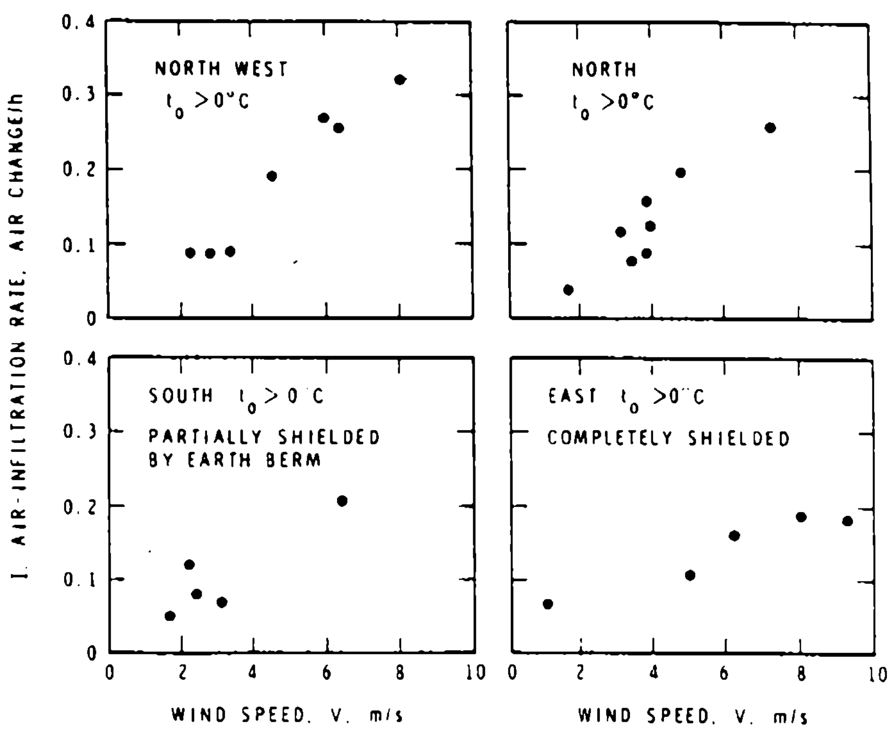

FIGURE 12
AIR-INFILTRATION RATE AT VARIOUS WIND SPEEDS AND WIND DIRECTIONS FOR HEAT-PUMP HOUSE

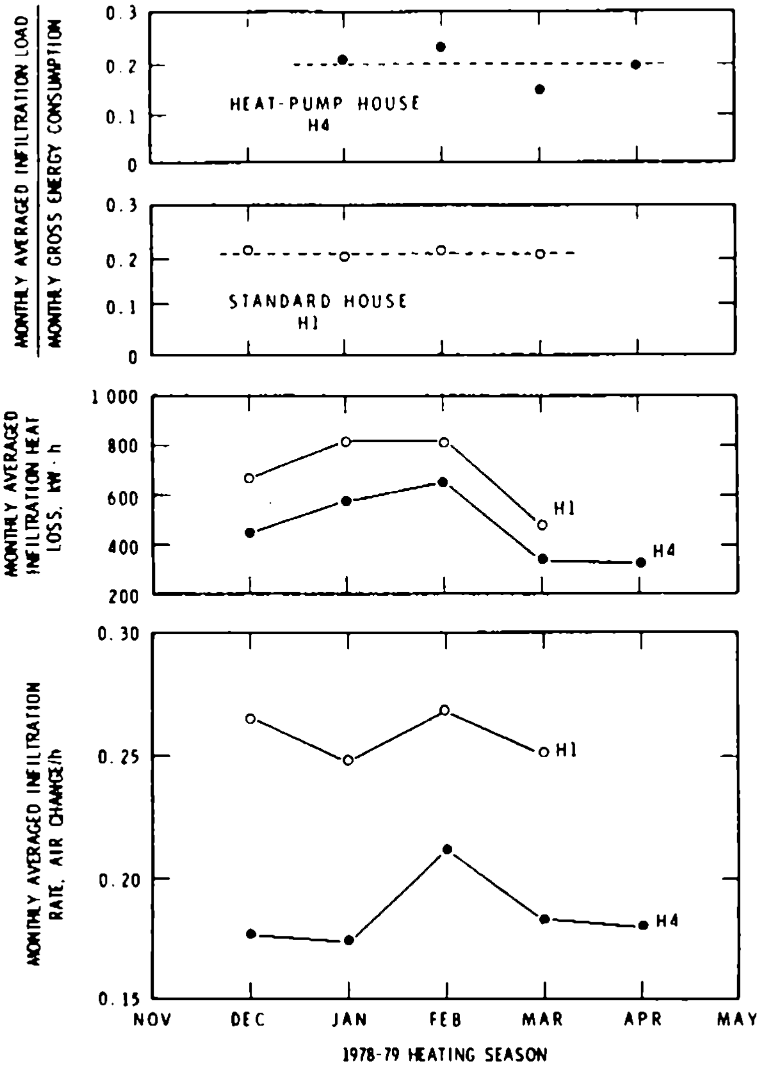

FIGURE 13

MONTHLY AVERAGED INFILTRATION LOAD AND ITS CONTRIBUTION TO TOTAL ENERGY CONSUMPTION

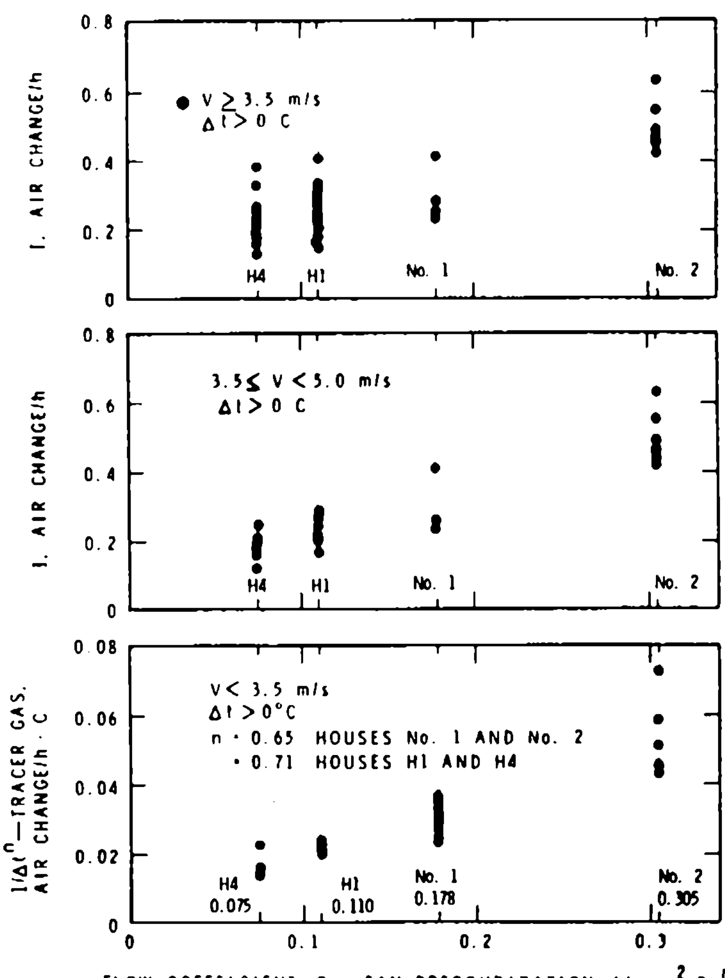

FIGURE 14

PROPOSED CORRELATION BETWEEN INFILTRATION AND AIR-LEAKAGE

TABLE 1
Air Infiltration rates - Spring, Autumn and Winter Results
(Tracer Gas Decay)

DATE 1978-1979	Wind Speed (m/s)	Wind Direction	Air Temperature Inside (°C)	Outside	Standard House Air changes/hr	Upgraded House Air changes/hr
Jan. 26	4.83	N	22.4	4.0	0.219	0.181
Dec. 20	1.65	N	20.4	-12.7	0.264	0.176
Feb. 12	0.98	N	21.8	-15.6	0.269	0.178
Apr. 10	7.33	N	22.0	7.5	0.334	0.258
Feb. 26	5.14	NE	20.6	-2.6	0.178	
Feb. 21	1.61	NE	22.8	-2.0	0.195	0.135
Apr. 9	9.34	E	22.5	4.6		0.182
Aug. 10	5.01	E	21.1	12.5		0.107
Apr. 2	8.05	E	22.2	3.8	0.214	0.149
Jan. 23	1.43	E	21.0	-5.6	0.236	0.148
Jan. 24	8.00	E	22.0	-4.7	0.260	0.195
Feb. 19	1.16	E	22.0	-15.9	0.279	0.196
Feb. 23	7.64	E	22.4	-1.0	0.281	0.247
Jan. 17	7.78	E	20.5	-19.5	0.314	
Feb. 20	6.48	S	22.4	-3.7	0.270	0.206
Apr. 6	7.38	S	22.0	-0.2	0.316	0.200
Jan. 5	5.95	SW	20.0	-9.0	0.256	
Apr. 20	3.84	W	22.5	15.0		0.114
Apr. 12	3.35	W	22.5	9.5		0.087
Feb. 28	1.07	W	21.4	3.9	0.155	0.103
Feb. 27	2.19	W	20.2	0.5	0.168	
Mar. 16	4.43	W	21.8	-4.4	0.210	0.156
Jan. 22	9.61	W	21.0	-4.7	0.222	0.201
Jan. 4	5.68	W	19.8	-9.3	0.255	0.181
Feb. 1	5.23	W	22.6	-9.6	0.265	0.201
Jan. 31	4.69	W	22.5	-7.4	0.267	0.108
Feb. 15	3.84	W	22.1	15.4	0.270	0.188
Jan. 30	5.63	W	22.6	-5.5	0.271	0.196
Jan. 19	2.32	W	19.0	-18.2	0.284	
Mar. 15	6.30	W	21.3	-12.2	0.292	0.206
Jan. 29	6.12	W	23.4	-3.4	0.301	0.201
Feb. 2	5.99	W	23.1	-10.8	0.303	0.197
Feb. 9	5.23	W	21.8	-18.7	0.326	0.212
Feb. 14	5.86	W	20.7	-19.9	0.331	0.208
Apr. 20	2.82	NW	22.5	16.2		0.082
Aug. 15	5.27	NW	22.5	15.5		0.201
Apr. 18	6.39	NW	22.2	9.3		0.255
Apr. 14	5.99	NW	22.5	0.3		0.268
Aug. 15	8.05	NW	22.5	15.0		0.322
Feb. 13	3.93	NW	20.7	-2.6	0.274	0.205
Feb. 16	4.11	NW	22.1	-16.1	0.288	0.199
Feb. 5	10.55	NW	22.0	-10.6	0.415	0.352

TABLE 2
Air Infiltration rates - Summer Results
(Tracer Gas Decay)

DATE 1978-1979	Wind Speed (m/s)	Wind Direction	Air Temperature Inside (°C)	Outside	Upgraded House Air changes/hr
Jul. 17	3.49	N	22.2	25.1	0.075
Jul. 17	3.13	N	22.2	25.4	0.116
Aug. 21	3.84	N	22.2	24.6	0.122
Jul. 17	3.93	N	22.2	25.1	0.123
Aug. 20	1.12	NE	21.7	21.5	0.073
Aug. 20	1.74	S	22.8	24.4	0.050
Aug. 13	2.41	S	22.5	23.6	0.080
Jul. 31	7.09	S	22.2	26.8	0.118
Jul. 31	6.39	S	21.9	24.5	0.120
Jul. 18	2.28	W	22.2	26.5	0.087
Jul. 19	5.14	W	21.1	29.0	0.105
Aug. 16	4.60	W	21.7	19.0	0.212

X. EXAMPLES OF GUIDELINES APPLICATION

B. The Swiss LESO Laboratory

GENERAL INFORMATION

Report Date March 1990

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Title of the project ERL - Task B 3.2

"Programmes de calcul détaillés et simplifiés des échanges d'air dans le bâtiment : Validation à l'aide de mesures expérimentales" [1, 2, 3].

Start/end dates 1987-1990

Principal objectives

Constitution of a data-set for purpose of validation.

References

1. Status Seminar "Forschungsprogramm : Energierelevante Luftströmungen in Gebäuden", *Winterthur, Switzerland, 1987 (French and German).*

2. Status Seminar "Forschungsprogramm : Energierelevante Luftströmungen in Gebäuden", *Lausanne, Switzerland, 1988 (French and German).*

3. Status Seminar "Forschungs programm : Energierelevante Luftströmungen in Gebäuden", *Zurich, Switzerland, 1989 (French and German).*

J.-L. Scartezzini, J.-M. Fürbringer, C.-A. Roulet
"Data needs for purpose of air infiltration computer code validation"
8th AIVC Conference proceedings, Ueberlingen, RFA, 1987.

J.-M. Fürbringer, C. Roecker, C.-A. Roulet
"The use of a guarded zone pressurization technique to measure air flow permeabilities of a multi-zone building"
9th AIVC Conference proceedings, Gent, Belgium, 1988.

J.-M. Fürbringer, R. Compagnon, C.-A. Roulet, A. Gadilhe
"Wind and pressure requirements of the validation of a multi-zone air infiltration program"
10th AIVC Conference proceedings, Espoo, Finland, 1989.

J.-M. Fürbringer, C.-A. Roulet
"Study of the errors occurring in measurement of leakage distribution in buildings by multifan pressurisation"
Submitted to "Building and Environment", Feb. 1990.

J.-M. Fürbringer, R. Compagnon
"Weather and aeraulic data-set for validation : the LESO building"
Part I : "Content of the data-set" - *LESO Internal report (1989).*

A. Faist et al. - Projet NEFF 110 "Rapport de Synthèse"
LESO report, Lausanne, Switzerland, 1985.

Institut Suisse de Météorologie "Valeurs journalières des précipitations enregistrées aux stations météorologiques et pluviométriques suisses"
ISM, Zurich (4ème trimestre 1988).

TEST SITE DESCRIPTION

Geographic information

Location

The LESO building is a laboratory building of the Ecole Polytechnique Fédérale, which is in Ecublens near Lausanne, a suburban area, at 500 [m] of the lake shore.

Longitude :	(E)	6.58
Latitude :	(N)	46.53

Height above the sea level

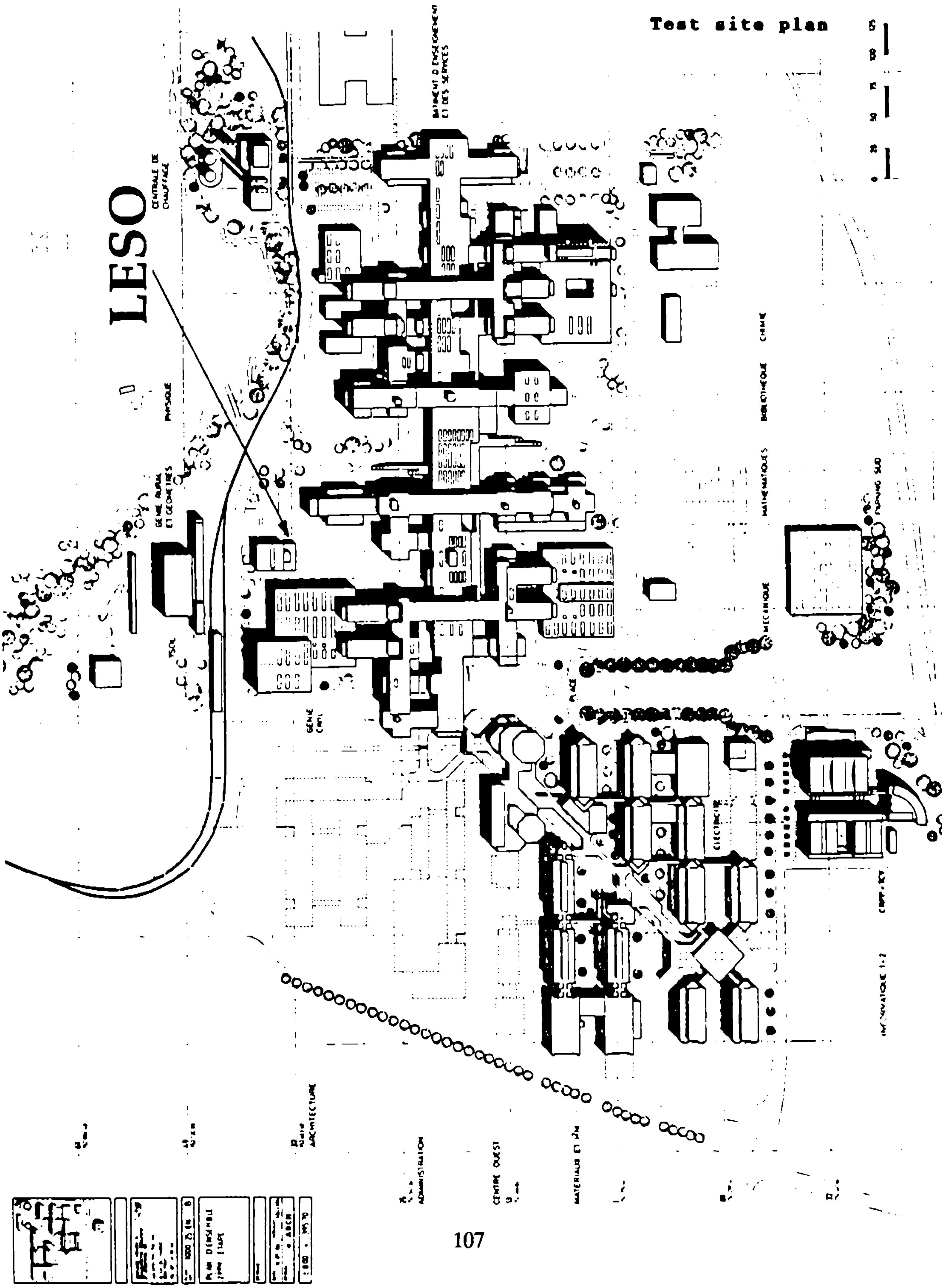
The front door is at ≈ 400 m above the sea level.

Terrain

Suburban area. The building is surrounded by slightly higher buildings
See following page for Test site plan.

Orientation

The building has its main axis East-West, the main façade, mostly glazed, is south oriented.


Test site plan
LESO

Climatic information

Location of meteorological station

The building has its own meteorological station. Temperatures, reference pressure, air moisture, solar radiation are measured on the roof of the building.

The wind speed and direction are measured at 18.2 [m] from ground level, on a mast 5.5 [m] over the roof. Figure 2.2 presents the location of the probes on the building.

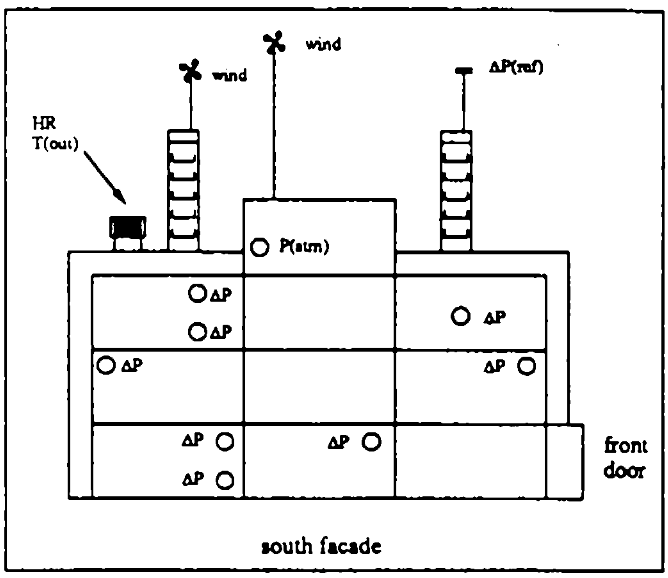


Figure 2.2 : South façade of the LESO Building with meteorological parameters probes position.

Distribution of wind speed versus direction

Two kinds of distributions are presented to evaluate the wind speed versus direction distribution from quarterly wind speed and direction measurements :

- The wind occurrence percentage in a given sector which indicates the orientation distribution without intensity information.

- The average wind integral (relative or not) in a given sector which indicates the distribution of the wind intensity.

The statistics and the graphics are extracted from 1989 all year measurements and from the two tracer gas measurement periods included in the data-set.

Figure 2.3 presents the distribution of the wind direction in 1989 in 36 sectors of 10° (south = 0°, West = 90°, North = 180°). The dominant winds come from North and South. This corresponds to the main winds in the area (north and south-west), the effect being enhanced by the surrounding buildings.

The average wind speed, calculated for every month in 1989 is presented in figure 2.4. The mean value is between 2 and 3 [m/s]. These winds are however feeble when compared to coastal areas or flat countries.

To have a statistical signification, this data should concern a longer time (≈ 10 years).

Figure 2.5 presents the relative wind integral for a 10 days period in December 1987 which corresponds with the tracer gas measurements. During this period the average wind speed has been west (m/s) with a dominant direction. The relative occurrences distribution presented in figure 2.6 confirms this results.

The same statistics for the year 1988 measurement period (figures 2.7 and 2.8) have given a dominant north wind.

Table 2.1 presents daily averages of wind speed, external temperature and moisture, insolation for the periods which correspond with the tracer gas measurement campaigns.

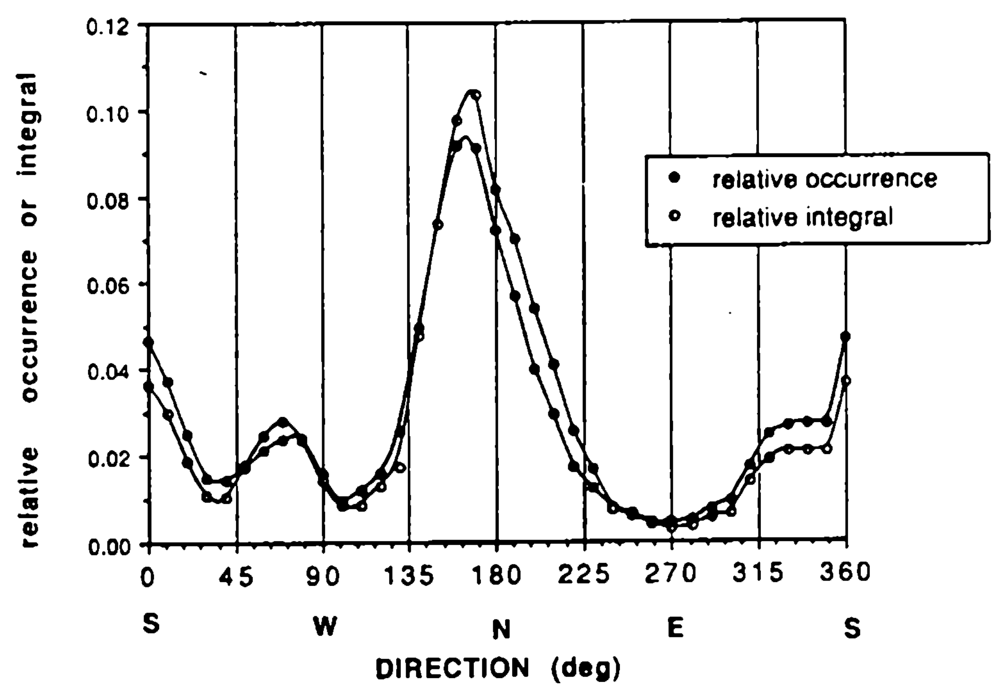


Figure 2.3 : Wind relative distribution (occurrences and integral) in 1989 from quartely wind measurement on the LESO-building.

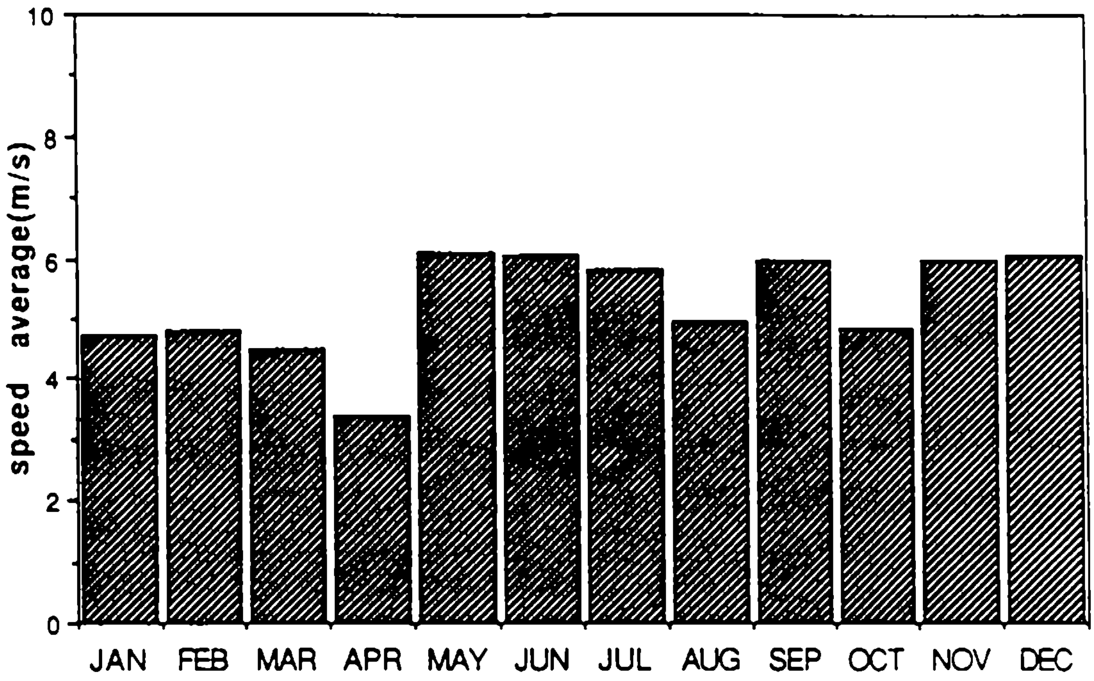


Figure 2.4 : Monthly average wind speed in 1989 from quartely wind measurement on the LESO-building.

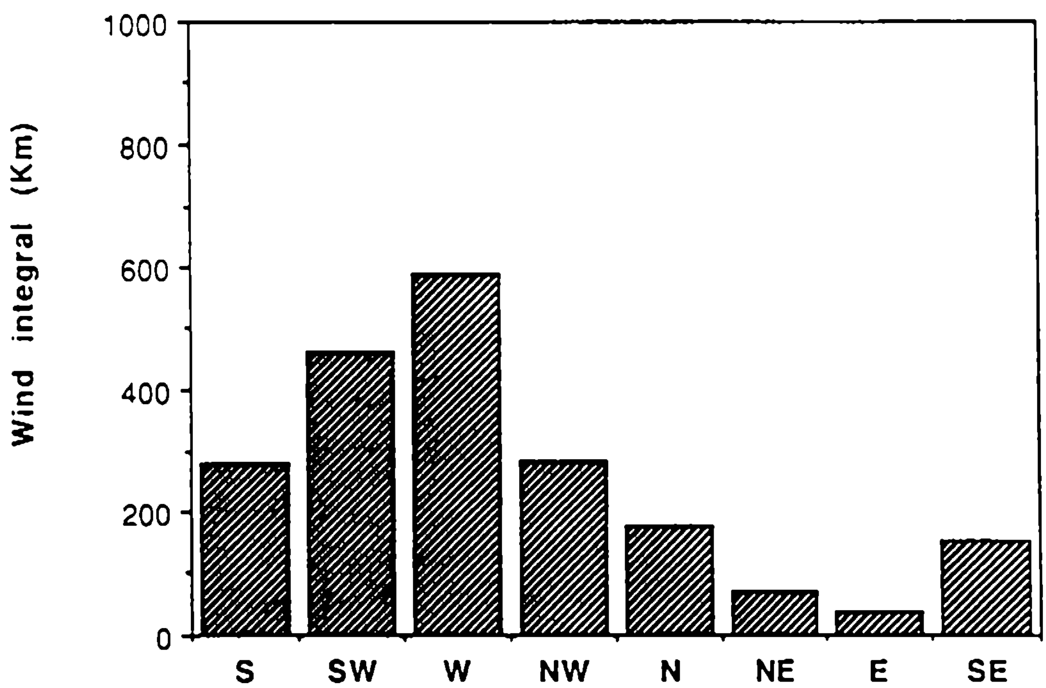


Figure 2.5 : Wind integral distribution for the 10 days measurement period in 1987.

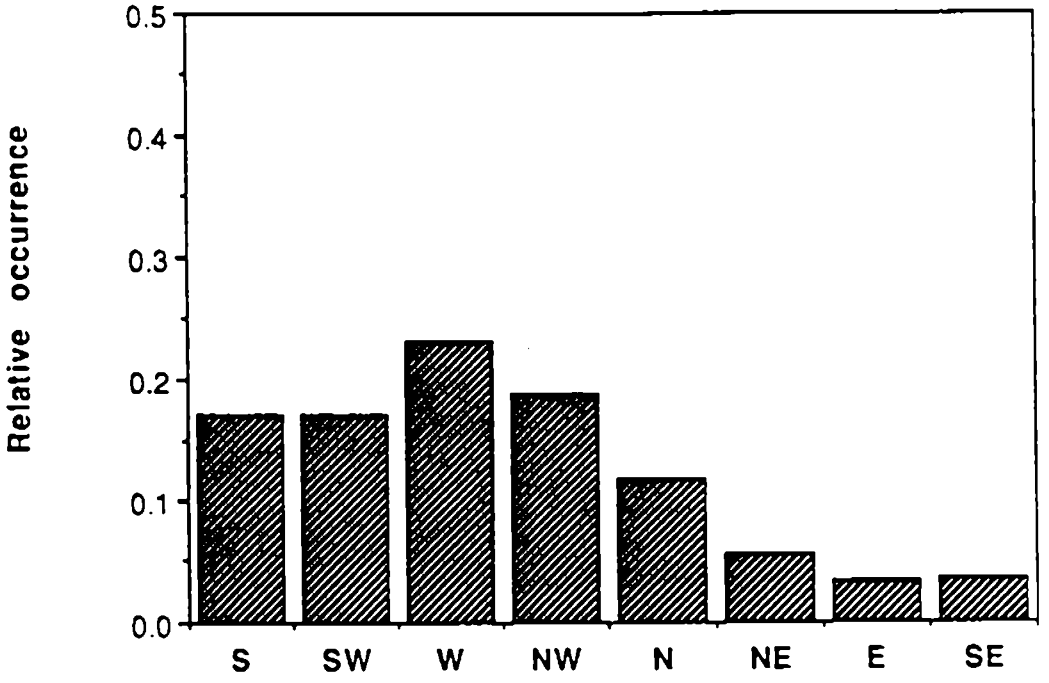


Figure 2.6 : Relative wind occurrence distribution for the 10 days measurement period in 1987.

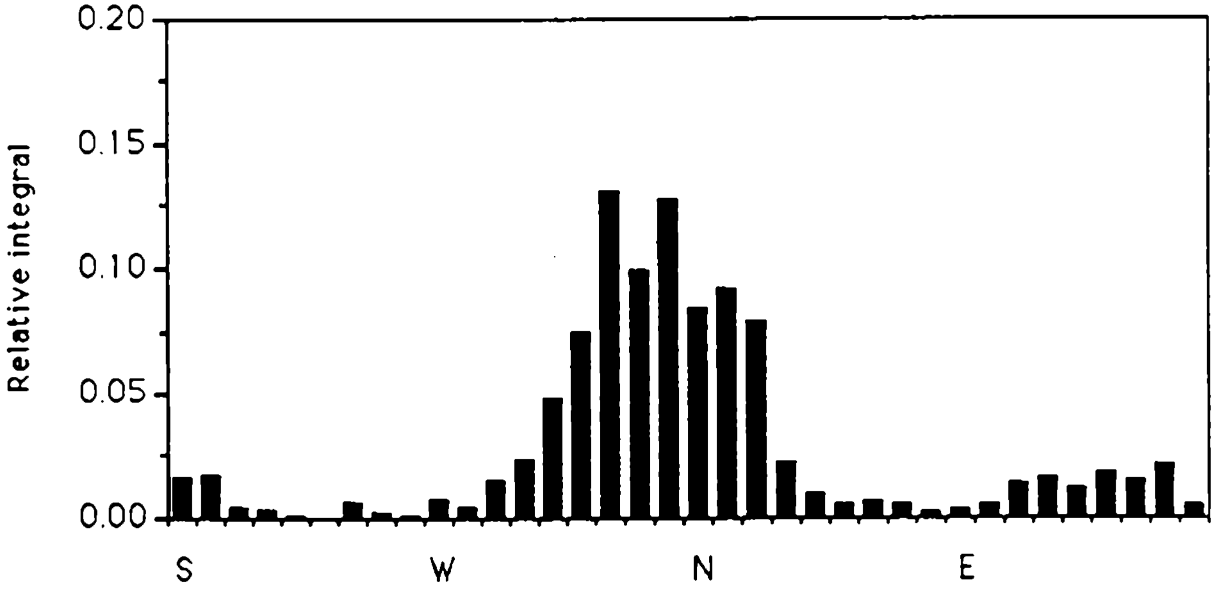


Figure 2.7 : Wind integral relative distribution for the measurement period B in 1988.

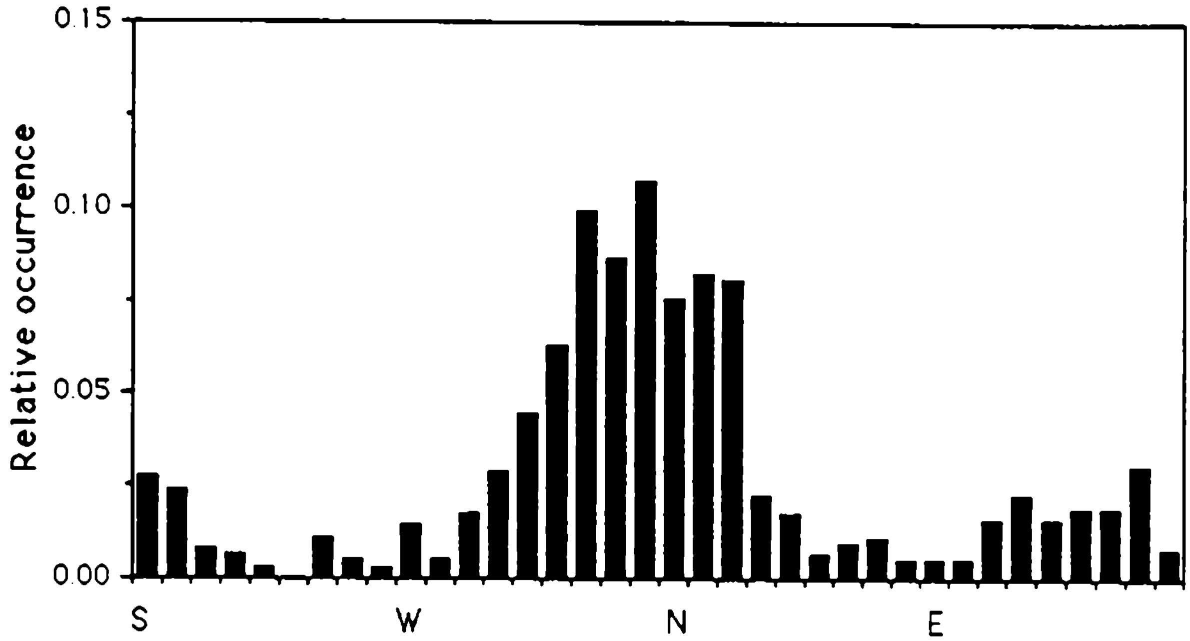


Figure 2.8 : Relative wind occurrence distribution for the measurement period B in 1988.

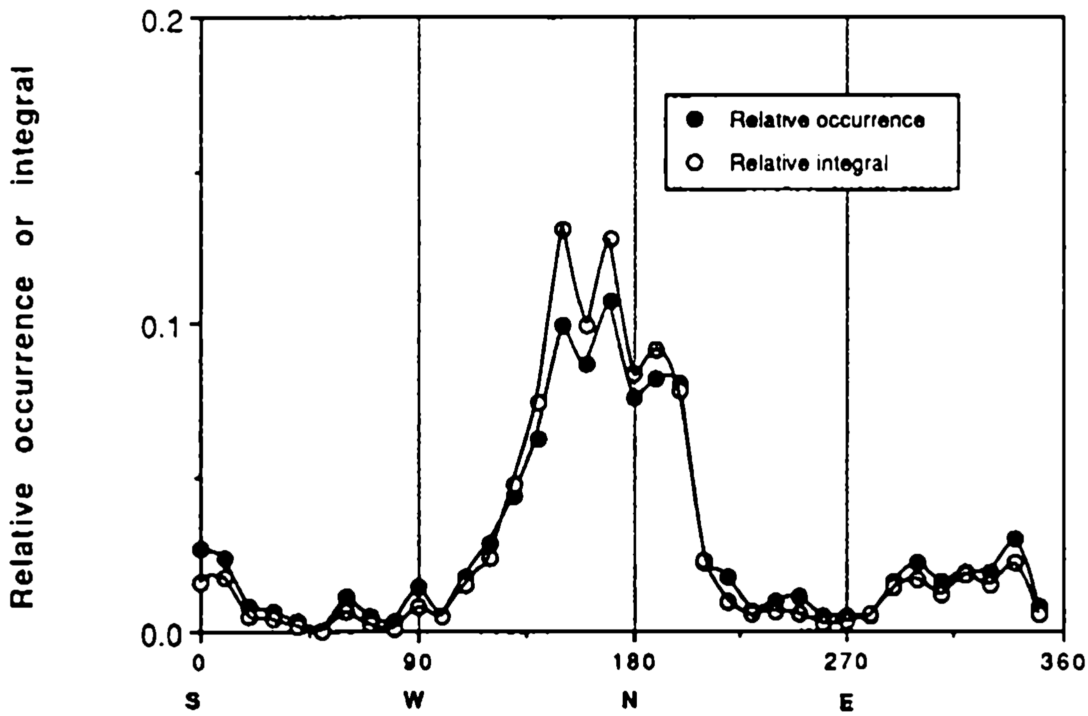


Figure 2.9 : Relative wind occurrence and integral comparison for the measurement period B in 1988.

Period	Date	External temp. [°C]	Wind speed [m/s]	South global vertical insolation [MJ/m²]	Relative humidity %
1987 A	23 déc. 87	4.2	1.8	-	81
	24	3.1	1.6	1.03	85
	25	4	1.3	.99	91
	26	5.4	1.6	1.24	88
	27	4.5	1.4	1.36	91
	28	3.8	1.4	1.40	93
	29	2.8	1.3	1.10	92
	30	2.8	1.3	4.85	91
	31	3.7	1.0	2.23	89
	1 jan. 88	6.1	1.5	1.10	88
	2	8.1	3.5	6.09	79
	3	7.6	4.3	5.48	77
	4	4.8	5.1	0.46	87
1988 A	24 déc. 88	8.2	2.3	-	77
	25	7.7	1.3	36.8	84
	26	4.5	1.8	50.45	86
1988 B	27	5	.8	2.97	89
	28	4.4	2	1.79	84
	29	1.5	2.9	44.9	92
	30	2.7	1.1	5.31	89
	31	0.8	2	2.75	93
1988 C	2 jan. 89	-0.2	3.9	-	84
	3	0	2.3	2.26	81
	4	-1.1	3.0	2.25	86

Table 2.1 : Daily averages (excepted for insolation : daily sum) of meteorological parameters during tracer gas measurement periods.

Wind speed versus temperature

This information can be obtained from the full data-set, but is not shown here.

Solar radiation

Table 2.2 gives the list of the insolation measurements included in the data-set, since table 2.1 has exibited the daily averaged insolation during the tracer gas measurement periods.

Parameter		Channel	Unit
Global	Horizontal	can 102 SM	W/m^2
Diffuse	Horizontal	can 124 SM	W/m^2
Global	South	can 106 SM	W/m^2

Table 2.2 : Insolation parameters included in the data-set.

Figures 2.10 - 2.12 present three years of monthly averaged insolation and outside air temperature.

See following pages for figures 2.10 - 2.12.

Cloudiness

No information available.

Precipitation, humidity

No information on precipitation is contained in the set.

The Swiss meteorology institute gives for the region of Lausanne in 1988, 1249 [mm] of precipitation since the annual average between 1901 and 1960 is 1064 [mm] of water [10].

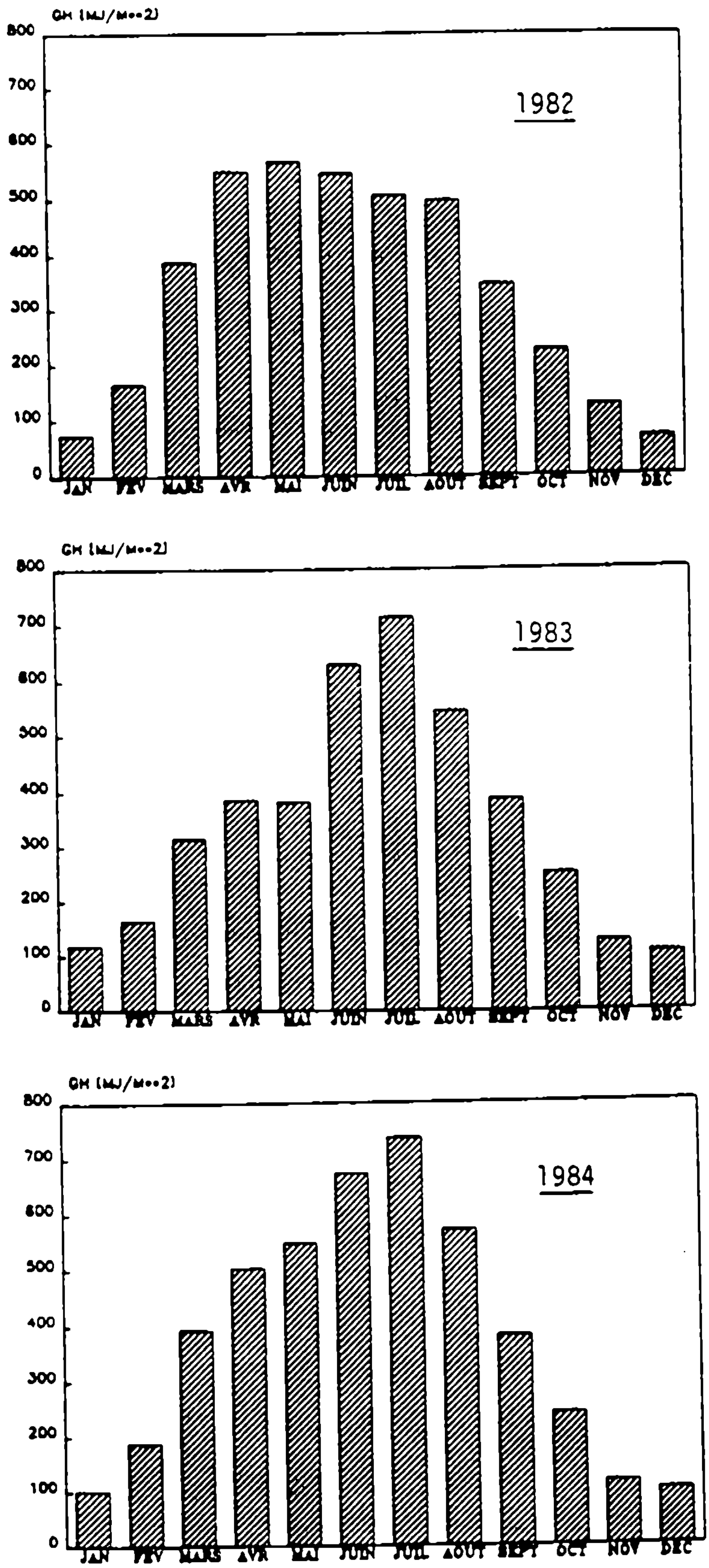


Figure 2.10 : Global horizontal insolation measured in the LESO.

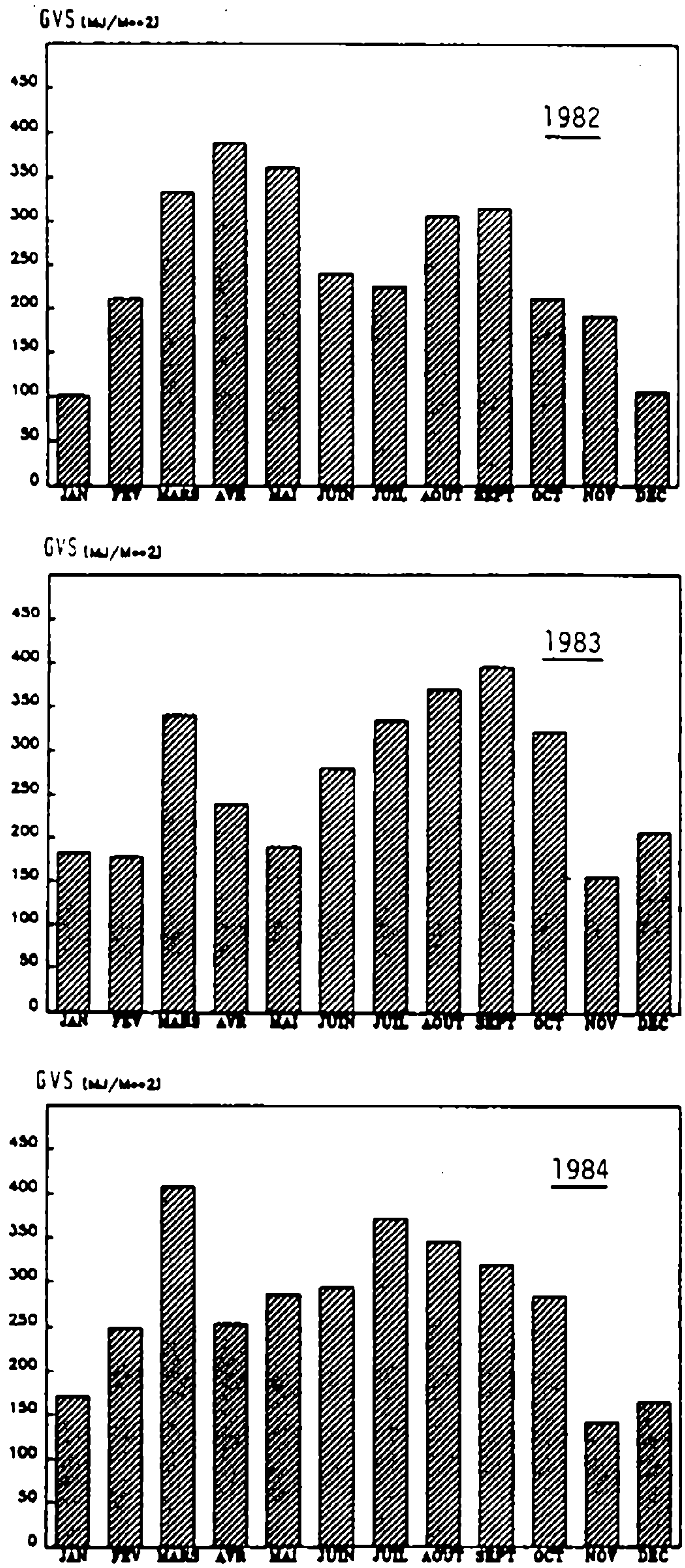


Figure 2.11 : Global vertical insolation measured in the LESO.

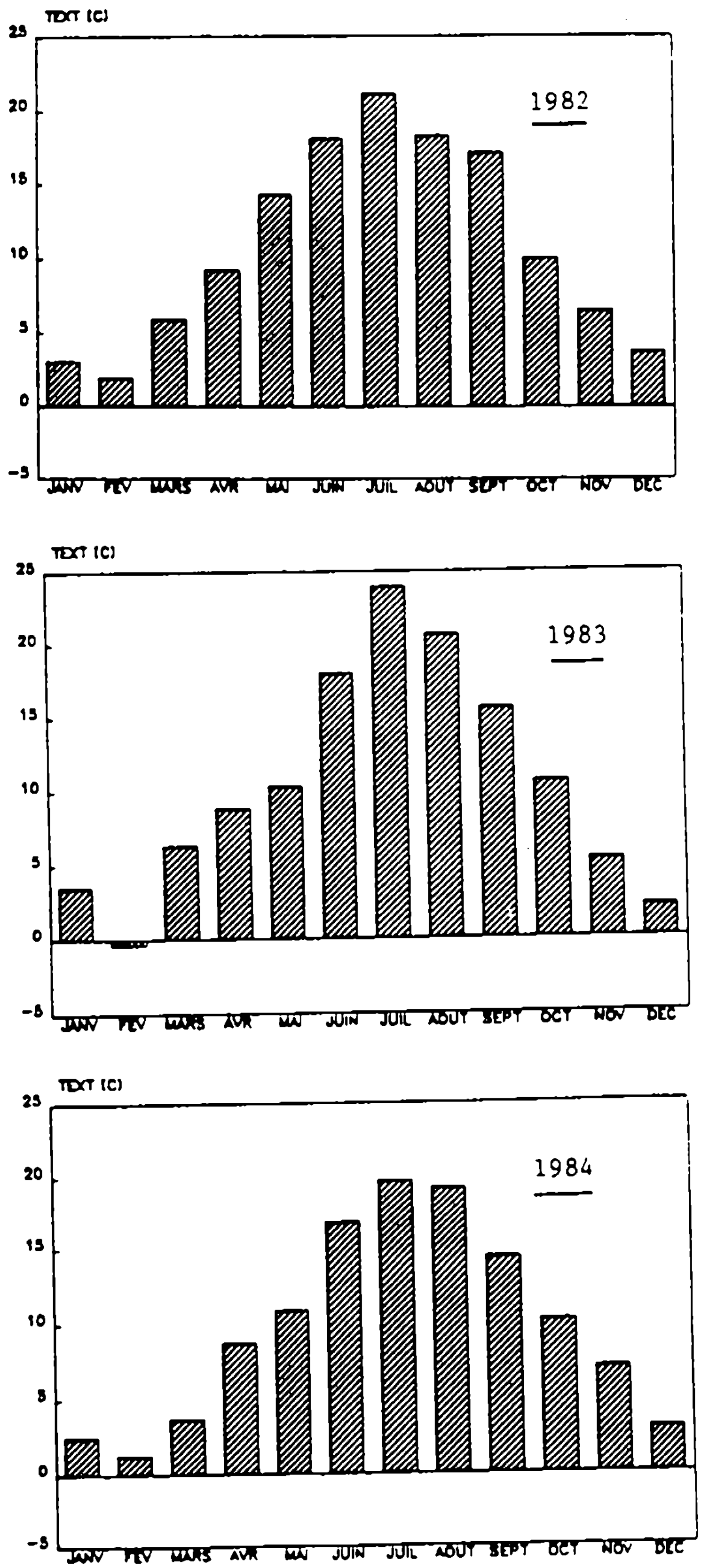


Figure 2.12 : Monthly averaged outside air temperature.

BUILDING DESCRIPTION

Building name LESO (Laboratoire d'Energie Solaire)

Building type Administrative, office building

History

The LESO-building was built in 1983 to serve as laboratory and work office to the LESO-PB (Laboratory of solar energy and building physics) [9].

After few years of study on the thermal problems attached to the passiv solar systems, the laboratory has now expanded in domain to energy in buildings and a group is specialised on air infiltration research.

Construction

The building is constituted of nine south oriented cells with different façades and 10 [cm] insulation between the cells themselves.

The thermal insulation is very high : 20 [cm] between inside and outside. The structure is in concrete. The partition walls are non finished concrete blocs.

Figures 3.1 - 3.4 present the thermal conductances.

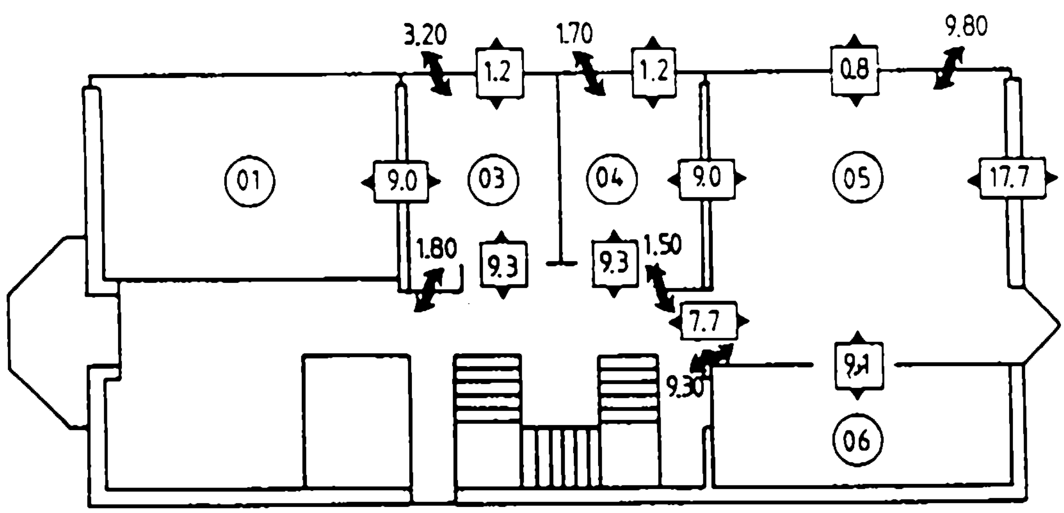


Figure 3.1 : Thermal conductances in [W/K] between rooms and also with outside. First floor.

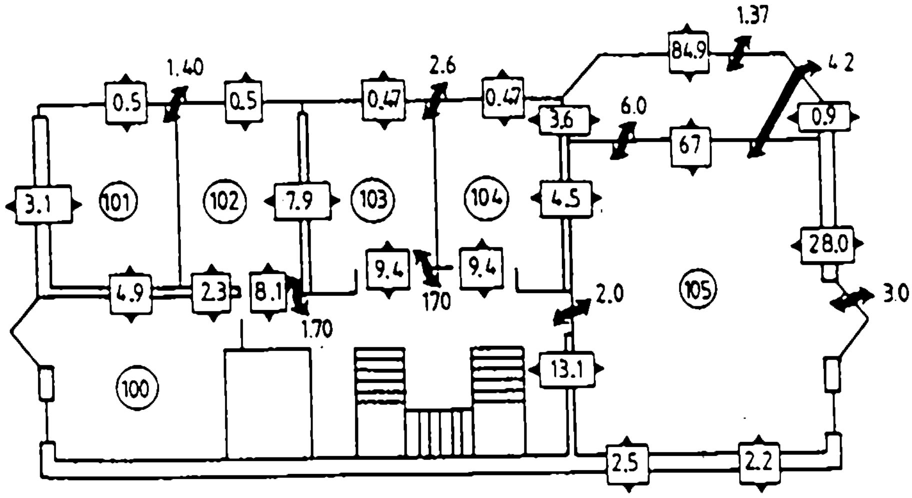


Figure 3.2 : Thermal conductances in [W/K] between rooms and also with outside. Second floor.

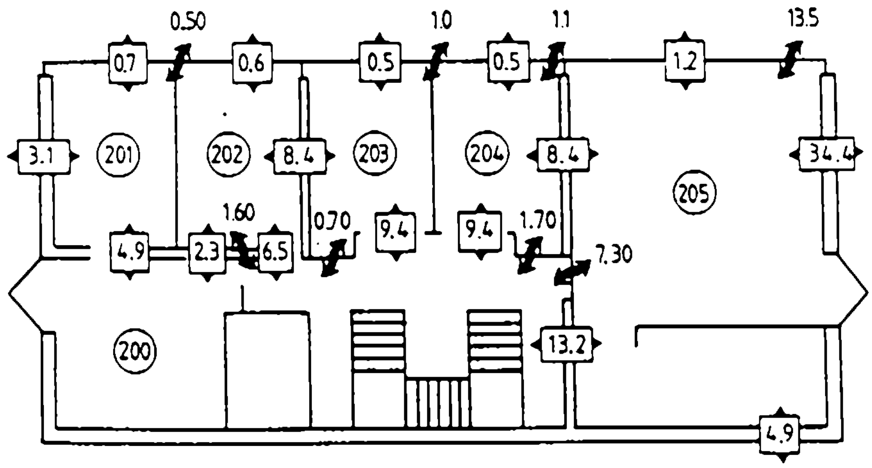


Figure 3.3 : Thermal conductances in [W/K] between rooms and also with outside. Third floor.

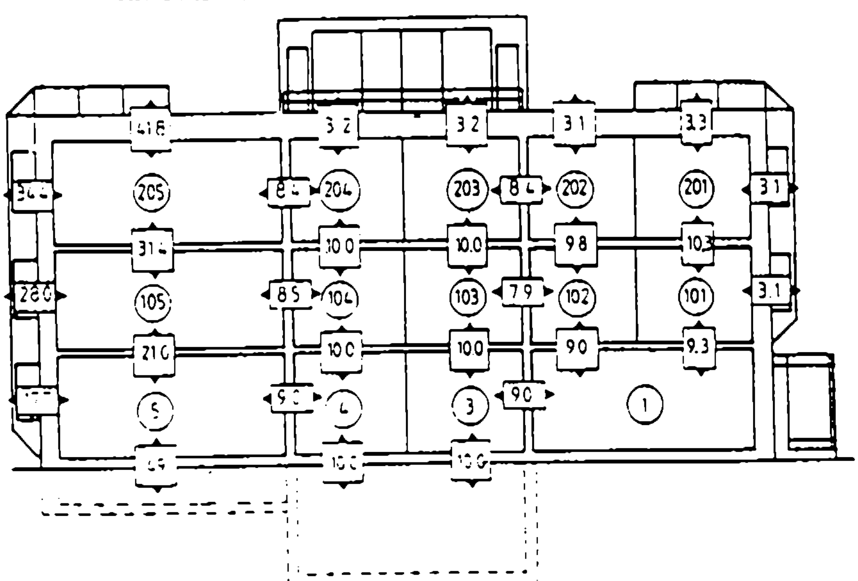


Figure 3.4 : Thermal conductances in [W/K] between rooms and also with outside (South elevation). Circles contain room number.

Windows

There are various types of windows. A comprehensive description is given in reference [9].

In 1988 the greenhouse has been removed (room 005, 105) and now a conventional façade replaces it.

Front door

The front door is an air lock in metal framed glas, built untight for purpose of natural ventilation (see fig. 3.5).

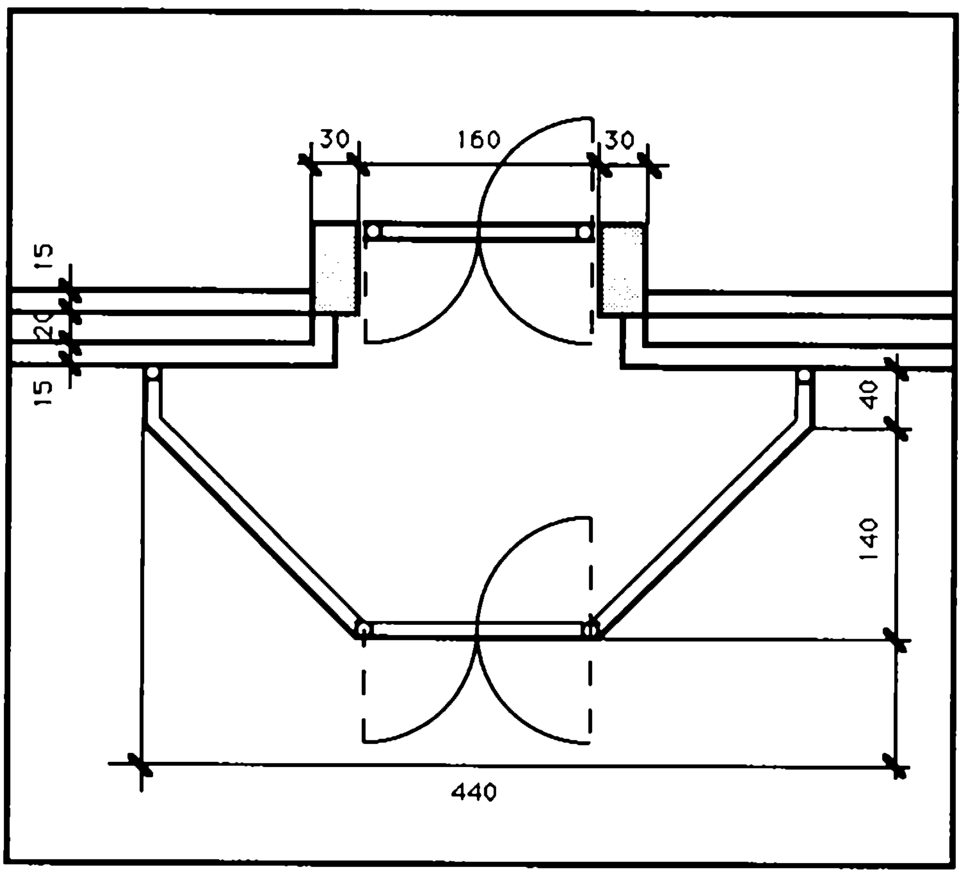


Figure 3.5 : The front door plan.

Rooms

Figure 3.6 presents the plan of the rooms.

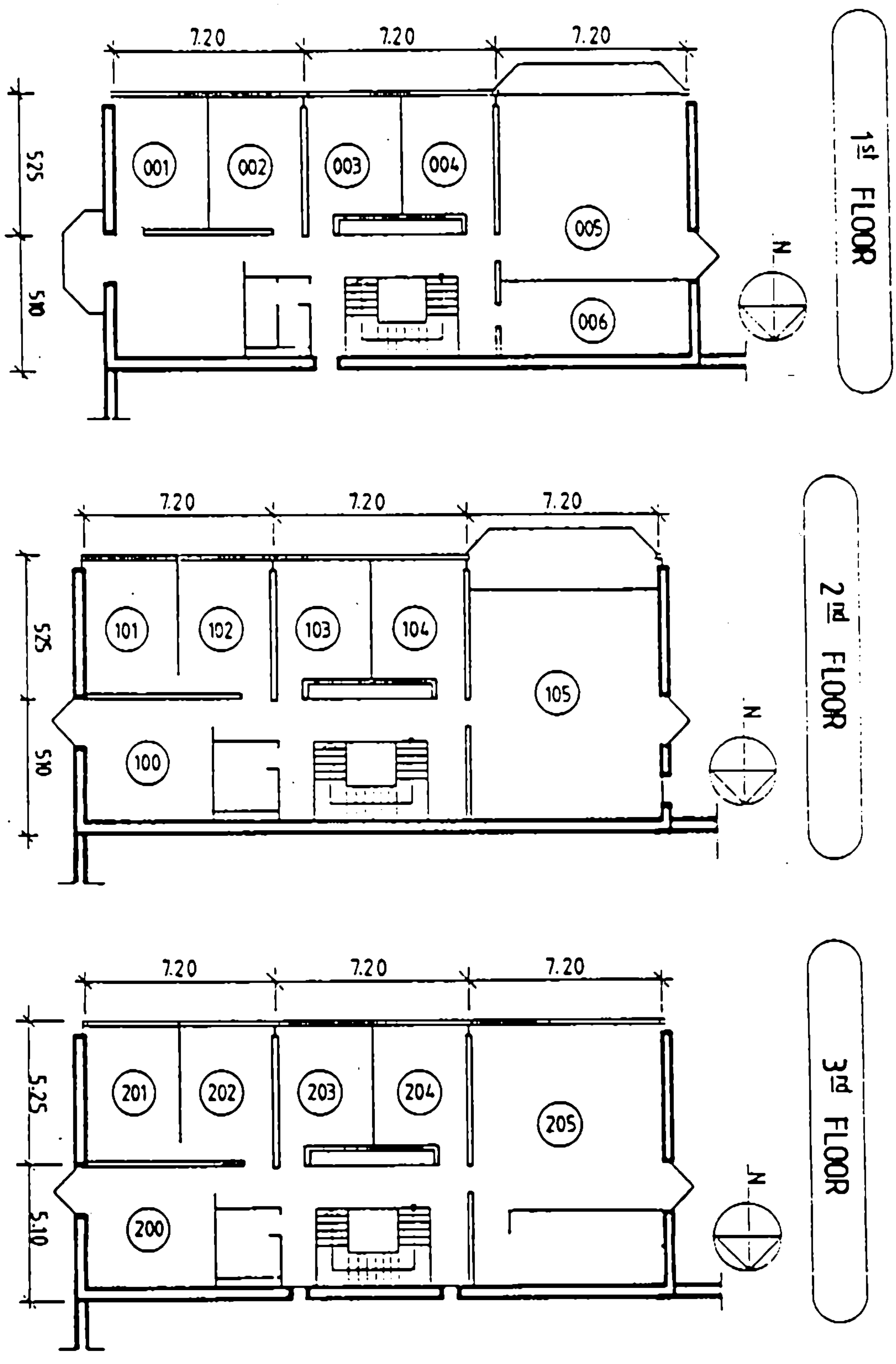


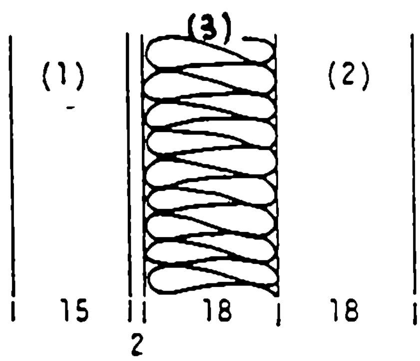
Figure 3.6 : Plan of the rooms in the LESO building.

Roof

The roof is flat with the excrescence of the stair case and two chimneys (see fig. 2.2). It is a concrete dam with external, 20 [cm] thick insulation, covered with grave or concrete slabs.

Wall thickness

Outside walls



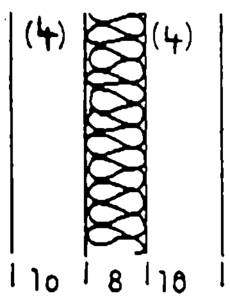
(1) Concrete blocs
39.5 x 19 x 15 cm^3 = 20.130 kg
268 kg/m^2

(2) Concrete blocs
39.5 x 19 x 18 cm^3 = 22.333 kg
298 kg/m^2

(3) Glass wool λ = 0.04 W/mK

Figure 3.7 : Outside wall structure.

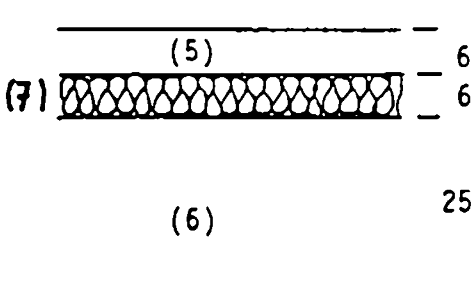
Lateral walls between cells



(4) Concrete blocs
49.5 x 19 x 10 cm^3 = 12.357 kg
132 kg/m^2

Figure 3.8 : Inside wall structure.

Deck between floors



(5) Covering (estimated)
132 kg/m^2

(6) Sample ϕ 16 cm h = 32 cm

weight 15.641 kg

2431 kg/m^3 608 kg/m^2

(7) Glass wool λ = 0.036 W/mK

Figure 3.9 : Floor structure.

Dimensions

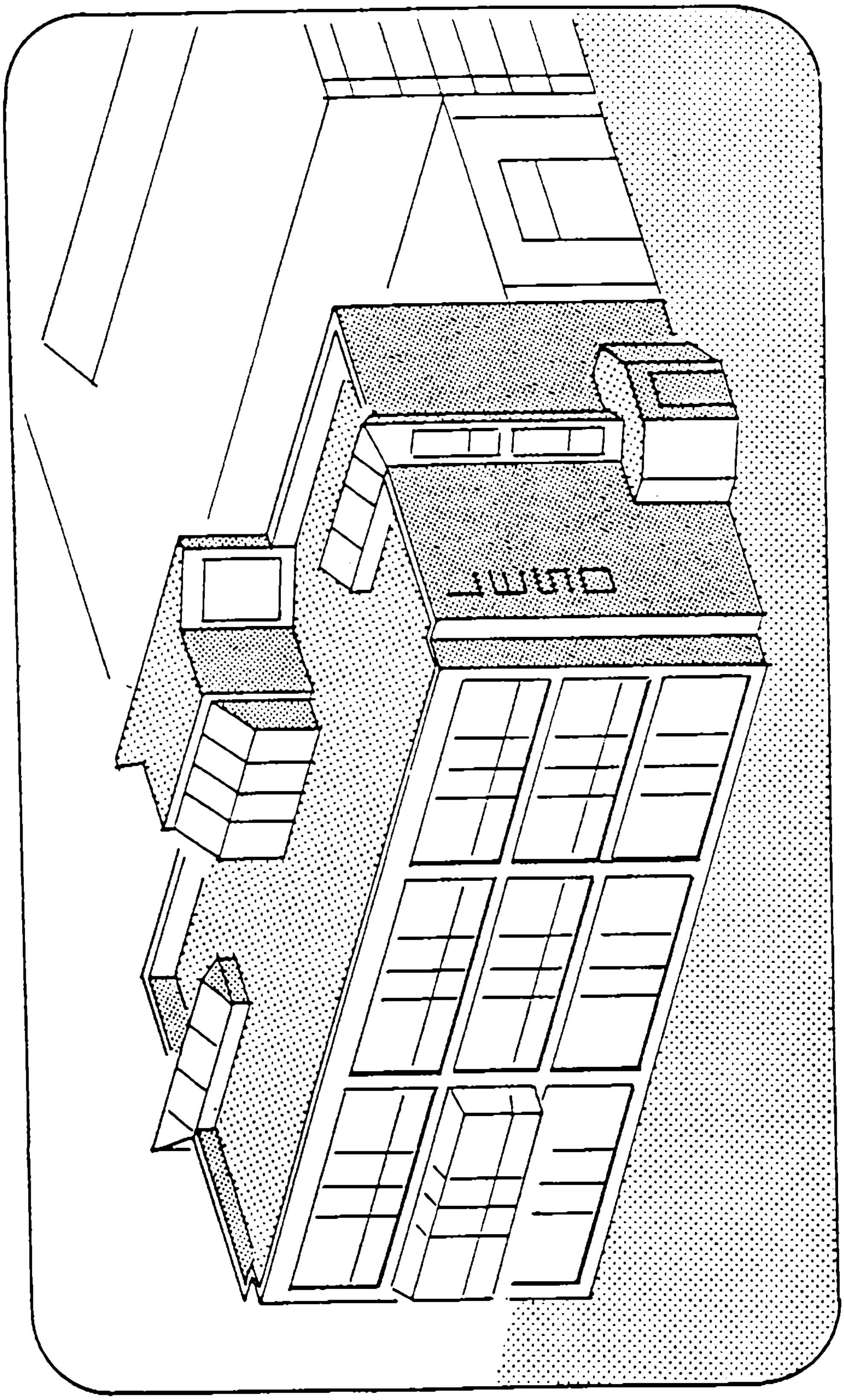
Plan See figures 3.5 & 3.6 and following pages for plan.

Elevation see figure 3.12

Global parameters

Total volume :		2 165	[m^3]
Floor area :		785	[m^2]
Window area :	South	118.3	[m^2]
	East	5.5	[m^2]
	North	2.1	[m^2]
	West	2.7	[m^2]
K :		.55	[W/m^2K]
Total external area :		833	[m^2]
Ground area :		346.5	[m^2]

General view of the LESO-Building.



General view of the LESO-Building.

Air leakage information

The air leakage information consists on the values of the air conductances of the major elements of the building. The vertical air conductances have been neglected.

The measurement have been performed using the guarded zone technique. The technique is presented in [5] and discussion on the error is made in [7]. The authors want to emphasize on the necessity to consider this item as seriously as required since errors in leakage parameters could reach 100% in very common situations.

Figure 3.10 presents the aeraulic net of the LESO, the nodes corresponding to the rooms and the "resistances" to the air leakage.

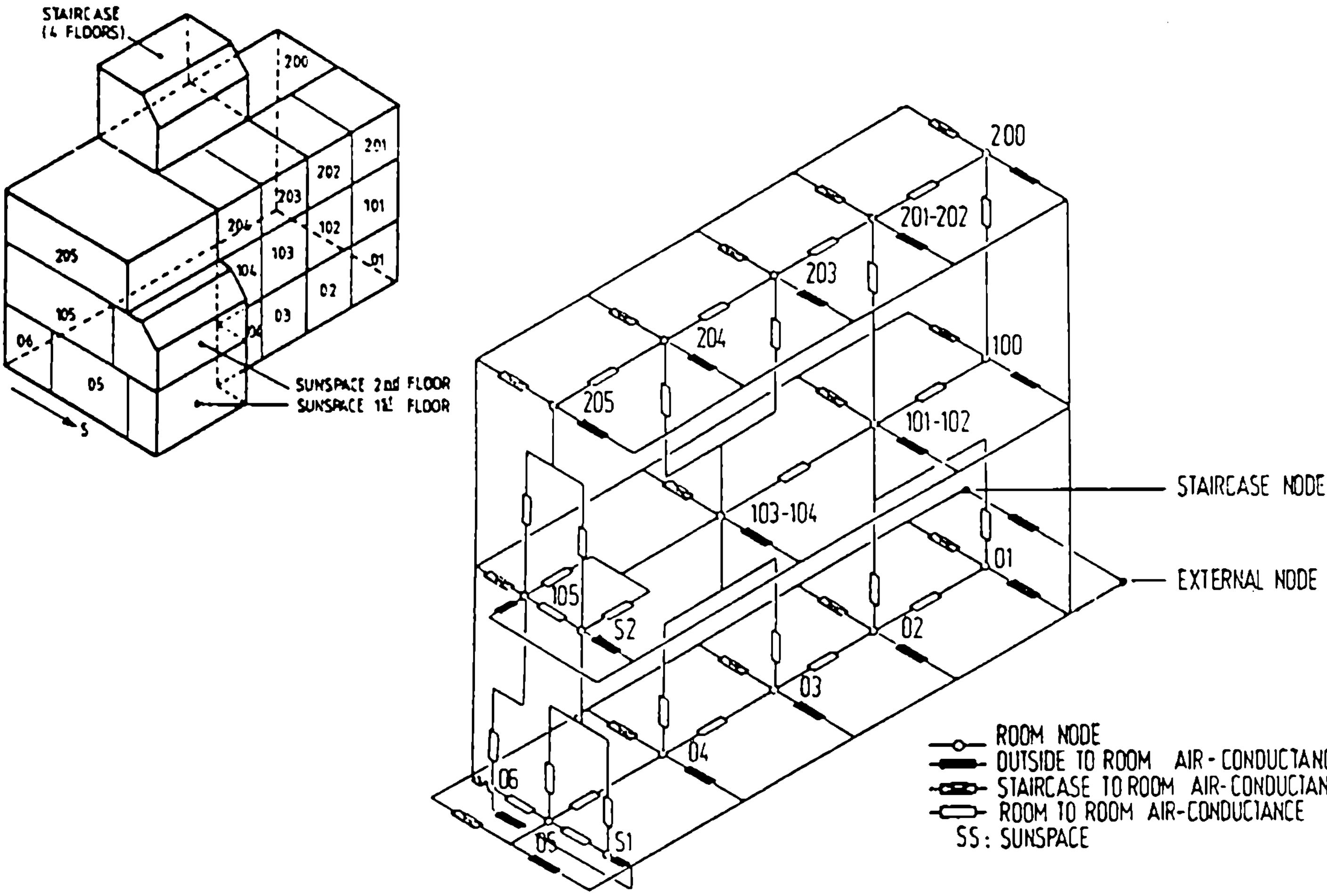


Figure 3.10 : Perspective of the LESO-Building (top) and corresponding conductances net (bottom).

MEASUREMENTS

Pressurisation Measurements - internal

Figure 3.11 presents the measurement results for C in [$m^3/h\ Pa^n$] and for n since tables 3.1 - 4 give the list of the leakage like they are modelled for G.C. Comis code (C in [$kg/s\ Pa^n$]). This data concerns the building how it was in 1987.

The transformations made in the current of 1988 needed to perform additional measurement which will be included in the data as soon as possible (Summer 1990).

Some elements have not been separatly measured and have been estimated from global measurements as it is the case for the south and west façades of rooms 005, 105 and 205. Their own measurement would need a very complex experiment.

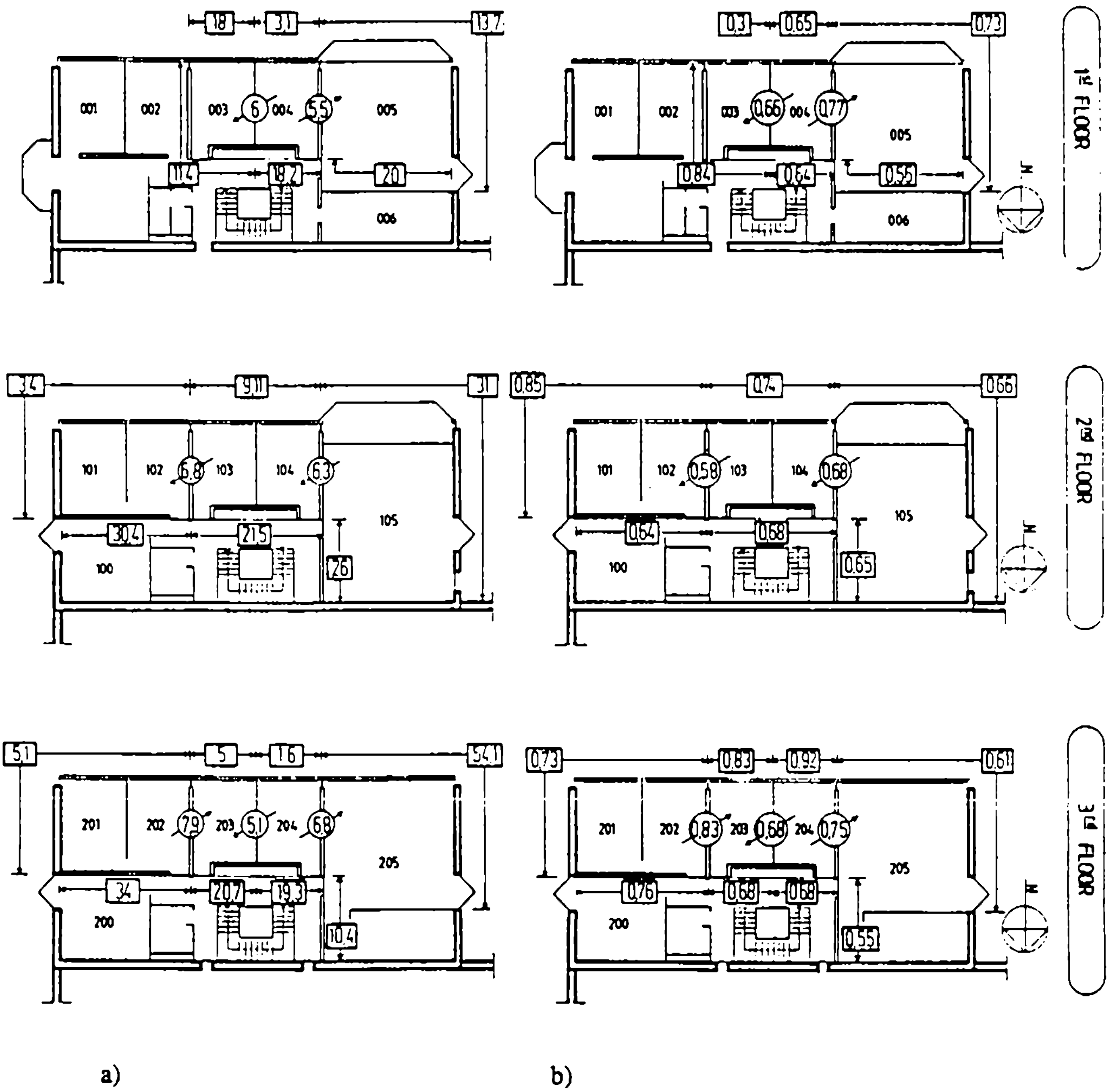


Figure 3.11 : a) C-values of the LESO-Building C [m^3/h Pa^n]
b) Exponents n [-].

☐ values for exfiltration from a room to outside or staircase.

∅ values for exfiltration from a room to another room with the sense of measurement.

Element	from	C [m³/h Paⁿ]	n [-]	comments
front door	STC to outside	96	.60	
façade S	(001 and 002) to outside	21	.60	
façade S	003 to outside	3.1	.65	estimated
façade S	004 to outside	3.1	.65	
façade S	005 to outside	6.8	.73	greenhouse*
façade W	005 to outside	6.8	.73	*
door N	STC to adjacent building	20	.60	*
wall + door	003 to STC	11.4	.84	
wall + door	004 to STC	18.2	.64	
wall + door	005 to STC	20	.56	
wall	004 to 003	6	.66	
wall	005 to 004	5.5	.77	

Table 3.1 : Air-conductances of the first floor of the LESO in 1987

STC means staircase
* means that result is arbitrarily parted between different elements
S,E,N,W mean South, East, North and West orientation of an element.

Element	from	C [$m^3/h\ Pa^n$]	n [-]	comments
façade E	100 to outside	15	.6	*
façade S	(101 and 102) to outside	4	.85	
façade S	(103 and 104) to outside	9.2	.74	
façade S	105 to outside	2.4	.66	*greenhouse
façade W	105 to outside	7.2	.66	*
window N	STC to outside	15	.6	*
wall + door	101 and 102 to STC	30.4	.64	
wall + door	103 and 104 to STC	21.5	.68	
wall + door	105 to STC	26	.65	
wall	103 to 101	6.8	.58	
wall	105 to 103	6.3	.68	

Figure 3.2 : Air-conductances of the second floor of the LESO in 1987

STC	means	staircase
*	means	that result is arbitrarily parted between different elements
S,E,N,W	mean	South, East, North and West orientation of an element.

Element	from	C [m³/h Paⁿ]	n [-]	comments
window E	200 to outside	15	.6	*
façade S	(201 and 202) to outside	5.1	.73	
façade S	203 to outside	1.6	.83	winter posit.
façade S	204 to outside	5	.92	summer pos.
façade S	205 to outside	9	.61	*
Façade W	205 to outside	7.2	.61	*
window N	STC to outside	30	.6	*
skylight	200 to outside	38.4	.61	vertical,*
skylight	205 to outside	38.4	.61	vertical,*
wall + door	201 and 202 to STC	34	.76	
wall + door	203 to STC	20.7	.68	
wall + door	204 to STC	19.3	.68	
wall + door	205 to STC	10.4	.55	
wall	203 to 202	7.9	.83	
wall	204 to 203	5.1	.68	
wall	205 to 204	6.8	.75	

Table 3.3 : Air-conductances of the third floor of the LESO in 1987.

STC means staircase

* means that result is arbitrarily parted between different elements

S,E,N,W mean South, East, North and West orientation of an element.

Element	from	C [m³/h Paⁿ]	n [-]	comments
window W	STC to outside	5	.6	*
window S	STC to outside	5	.6	*
window + door E	STC to outside	10	.6	*

Table 3.4 : Air-conductance of the roof level of the LESO in 1987.
STC means staircase
* means that result is arbitrarily parted between different elements
S,E,N,W mean South, East, North and West orientation of an element.

Pressure Measurements - external

Pressure coefficients

Average pressure coefficients Cp have been measured by D. Dickeroff from LBL in the wind tunnel of the departement of Architecture in Berkeley University.

The measurement was made at a flow speed of 5 (m/s) on a 1:100 scale model.

The reference point for pressure and speed is settled at the top of the west chimney (fig. 2.2).

The wind profile simulated in the wind tunnel has an $\alpha = 0.152 \pm 0.09$ according to the law

$$V = \left(\frac{h}{h_{ref}}\right)^{\alpha} \qquad 3.1$$

The measurement have been physically averaged through a tank of 100 (litres).

Figure 3.12 shows the elevations of the building with the probe positions and tables 3.5 - 8 present the pressures coefficients Cp for different angles of wind incidences.

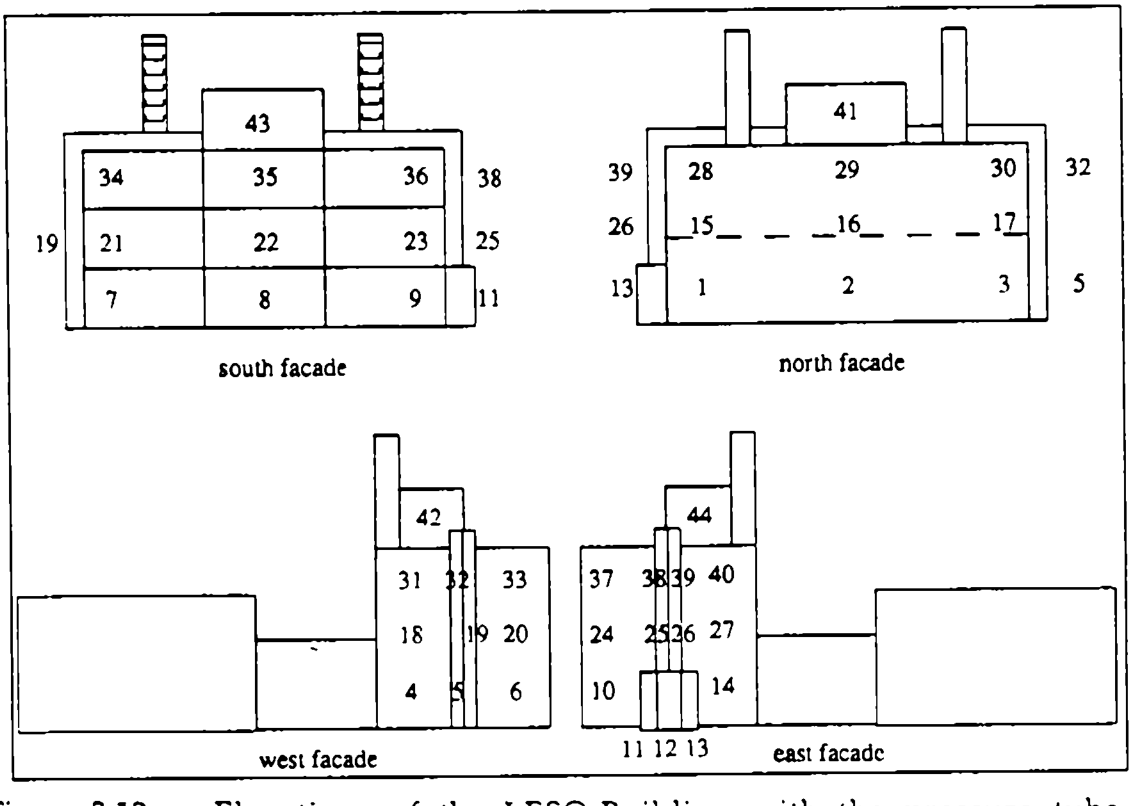


Figure 3.12 : Elevations of the LESO-Building with the pressure tube positions (number).

Pressure Coefficients from the LESO Model								
	North Wall Measurement Positions							
Angle	15	16	17	28	29	30	41	average
0	0.13	0.28	0.14	0.01	0.02	0.09	0.29	0.13
15	0.32	0.32	0.05	0.31	0.07	-.14	0.30	0.18
30	0.25	0.28	0.07	0.37	0.16	-.17	0.31	0.18
45	0.11	0.16	0.07	0.21	0.16	-.02	0.13	0.12
60	0.00	0.04	0.06	0.07	0.04	0.03	-.07	0.02
75	-.23	-.04	0.04	-.14	-.05	0.01	-.16	-.08
90	-.44	-.15	-.04	-.40	-.15	-.06	-.25	-.21
105	-.40	-.16	-.07	-.40	-.21	-.09	-.31	-.24
120	-.12	-.07	-.04	-.21	-.15	-.06	-.29	-.13
135	-.08	-.04	-.04	-.31	-.20	-.09	-.25	-.14
150	-.05	-.07	-.11	-.26	-.19	-.12	-.22	-.15
165	-.18	-.13	-.13	-.28	-.22	-.14	-.24	-.19
180	-.16	-.13	-.14	-.19	-.17	-.18	-.17	-.16
195	-.15	-.15	-.20	-.16	-.23	-.28	-.24	-.20
210	-.06	-.05	-.08	-.09	-.18	-.25	-.20	-.13
225	-.01	-.01	-.09	-.04	-.13	-.21	-.14	-.09
240	0.15	0.11	0.10	0.14	0.05	-.01	-.02	0.07
255	0.05	0.03	0.09	0.02	-.07	-.05	-.11	-.00
270	-.04	-.02	0.11	-.05	-.06	0.03	-.18	-.03
285	-.01	0.03	0.14	-.03	0.01	0.14	-.04	0.03
300	-.01	0.01	0.01	-.03	0.01	0.09	0.04	0.02
315	0.08	0.09	-.04	-.04	0.06	0.10	0.18	0.06
330	0.08	0.16	-.05	-.16	0.06	0.09	0.30	0.07
345	0.04	0.26	0.04	-.20	0.02	0.14	0.35	0.09
360	0.13	0.25	0.11	0.00	0.01	0.05	0.37	0.13

Table 3.5 : North façade mean pressure coefficients Cp for different wind incidences, 0° corresponding to North and 90° corresponding to East wind incidence. The probe position are shown in figure 3.12.

Pressure Coefficients from the LESO Model															
	East Wall Measurement Positions														
Angle	10	11	12	13	14	24	25	26	27	37	38	39	40	44	average
0	-.12	-.19	-.13	0.08	0.07	-.11	-.26	0.05	0.00	-.16	-.27	0.06	-.02	-.19	-.08
15	-.18	-.30	-.22	0.22	0.31	-.22	-.33	0.35	0.31	-.21	-.40	0.46	0.27	-.03	0.00
30	-.17	-.24	-.23	0.33	0.44	-.12	-.25	0.44	0.42	0.01	-.34	0.53	0.42	0.01	0.09
45	0.01	-.06	-.06	0.41	0.49	0.16	-.08	0.52	0.51	0.34	-.14	0.62	0.56	0.07	0.24
60	0.21	0.14	0.19	0.48	0.54	0.39	0.16	0.63	0.62	0.52	0.13	0.69	0.67	0.22	0.40
75	0.39	0.36	0.39	0.55	0.57	0.55	0.48	0.69	0.65	0.60	0.43	0.71	0.68	0.40	0.53
90	0.55	0.50	0.53	0.61	0.62	0.62	0.67	0.72	0.68	0.71	0.68	0.75	0.65	0.21	0.61
105	0.52	0.50	0.54	0.54	0.57	0.58	0.68	0.65	0.60	0.70	0.70	0.68	0.63	0.33	0.59
120	0.14	0.13	0.17	0.19	0.25	0.14	0.19	0.20	0.19	0.22	0.21	0.19	0.21	0.25	0.19
135	0.06	0.07	0.02	0.04	0.05	0.01	0.12	-.05	-.00	0.10	0.17	-.10	0.02	0.22	0.05
150	-.23	-.22	-.16	-.09	-.06	-.28	-.17	-.18	-.14	-.30	-.16	-.25	-.19	0.01	-.17
165	-.19	-.06	-.13	-.07	-.08	-.25	-.04	-.29	-.17	-.18	-.10	-.34	-.28	-.03	-.16
180	-.26	-.20	-.19	-.13	-.12	-.28	-.19	-.23	-.20	-.27	-.23	-.26	-.24	-.16	-.21
195	-.34	-.27	-.23	-.19	-.18	-.35	-.29	-.22	-.21	-.35	-.33	-.22	-.22	-.25	-.26
210	-.47	-.23	-.24	-.16	-.13	-.49	-.37	-.20	-.20	-.40	-.37	-.20	-.22	-.22	-.28
225	-.32	-.01	-.18	-.08	-.08	-.34	-.15	-.13	-.09	-.25	-.18	-.11	-.09	-.15	-.15
240	-.01	0.22	-.05	0.08	0.08	-.18	0.11	0.02	0.02	-.10	-.01	.01	0.00	-.06	0.01
255	-.02	0.08	-.02	0.01	0.02	-.06	0.06	0.02	0.02	-.05	0.00	0.02	0.03	-.05	0.00
270	-.14	-.12	-.10	-.09	-.08	-.14	-.13	-.11	-.12	-.13	-.14	-.11	-.10	-.16	-.12
285	-.14	-.13	-.10	-.08	-.07	-.15	-.14	-.11	-.11	-.16	-.16	-.13	-.12	-.21	-.13
300	-.16	-.14	-.12	-.11	-.10	-.16	-.14	-.13	-.11	-.18	-.15	-.14	-.13	-.28	-.15
315	-.11	-.10	-.10	-.07	-.07	-.11	-.10	-.09	-.10	-.12	-.12	-.11	-.11	-.28	-.11
330	-.10	-.12	-.17	-.17	-.16	-.14	-.13	-.19	-.21	-.14	-.13	-.19	-.18	-.27	-.16
345	-.13	-.15	-.13	-.12	-.09	-.14	-.19	-.13	-.23	-.15	-.19	-.17	-.20	-.31	-.17
360	-.14	-.18	-.14	0.06	0.07	-.13	-.29	0.01	-.04	-.19	-.29	0.03	-.06	-.22	-.11

Table 3.6 : East façade mean pressure coefficients Cp for different wind incidences, 0° corresponding to North and 90° corresponding to East wind incidence. The probe position are shown in figure 3.12.

Pressure Coefficients from the LESO Model											
	South Wall Measurement Positions										
Angle	7	8	9	21	22	23	34	35	36	43	average
0	-.10	-.11	-.11	-.09	-.10	-.11	-.10	-.11	-.12	-.25	-.12
15	-.09	-.10	-.10	-.09	-.08	-.10	-.10	-.09	-.09	-.26	-.11
30	-.12	-.10	-.10	-.12	-.10	-.10	-.11	-.11	-.11	-.27	-.12
45	-.14	-.12	-.11	-.16	-.12	-.13	-.14	-.13	-.12	-.30	-.15
60	-.18	-.22	-.18	-.21	-.25	-.18	-.19	-.23	-.22	-.34	-.22
75	-.13	-.29	-.21	-.21	-.30	-.24	-.25	-.29	-.22	-.35	-.25
90	0.01	-.13	-.34	-.01	-.17	-.41	-.05	-.19	-.35	-.22	-.19
105	0.14	0.11	-.06	0.11	0.10	-.18	0.09	0.09	-.07	0.03	0.04
120	0.27	0.18	0.14	0.23	0.20	0.07	0.17	0.19	0.17	0.14	0.18
135	0.36	0.32	0.25	0.39	0.38	0.30	0.35	0.36	0.32	0.19	0.32
150	0.74	0.65	0.40	0.84	0.76	0.53	0.69	0.61	0.50	0.06	0.58
165	0.43	0.55	0.46	0.50	0.62	0.55	0.56	0.63	0.67	0.36	0.53
180	0.49	0.53	0.36	0.58	0.59	0.43	0.60	0.60	0.53	0.15	0.48
195	0.48	0.51	0.38	0.53	0.57	0.48	0.59	0.59	0.53	0.17	0.48
210	0.48	0.65	0.75	0.62	0.82	0.88	0.61	0.62	0.75	-.03	0.61
225	0.24	0.37	0.54	0.34	0.44	0.49	0.28	0.28	0.32	-.01	0.33
240	0.26	0.30	0.60	0.23	0.35	0.42	0.28	0.27	0.33	0.28	0.33
255	0.03	0.06	0.17	0.02	0.07	0.11	0.03	0.04	0.06	-.00	0.06
270	-.14	-.01	0.01	-.19	-.05	-.02	-.21	-.11	-.07	-.24	-.10
285	-.38	0.06	0.03	-.42	-.18	-.05	-.34	-.22	-.14	-.41	-.20
300	-.40	0.00	-.01	-.47	-.18	-.04	-.36	-.25	-.14	-.35	-.22
315	-.34	-.18	-.15	-.33	-.21	-.14	-.31	-.22	-.15	-.32	-.24
330	-.09	-.10	-.10	-.09	-.08	-.10	-.09	-.07	-.10	-.20	-.10
345	-.11	-.12	-.13	-.10	-.11	-.13	-.10	-.10	-.12	-.26	-.13
360	-.12	-.12	-.12	-.10	-.11	-.13	-.11	-.11	-.13	-.26	-.13

Table 3.7 : South façade mean pressure coefficients Cp for different wind incidences, 0° corresponding to North and 90° corresponding to East wind incidence. The probe position are shown in figure 3.12.

Pressure Coefficients from the LESO Model											
	West Wall Measurement Positions										
Angle	4	5	6	18	19	20	31	32	33	42	average
0	0.12	0.22	-.26	0.13	-.23	-.26	0.07	0.16	-.28	-.10	-.04
15	-.05	0.09	-.20	-.26	-.23	-.21	-.25	-.24	-.19	-.27	-.18
30	0.01	0.12	-.03	-.33	-.26	-.18	-.37	-.33	-.18	-.29	-.18
45	0.12	0.19	0.10	-.25	-.22	-.09	-.36	-.34	-.12	-.26	-.12
60	0.08	0.09	0.04	-.07	-.06	-.04	-.12	-.16	-.05	-.20	-.05
75	-.02	-.07	0.02	-.03	-.00	-.09	-.04	-.07	-.14	-.19	-.06
90	-.04	-.12	-.07	-.09	-.07	-.13	-.08	-.11	-.14	-.15	-.10
105	-.06	-.11	-.17	-.10	-.16	-.17	-.11	-.15	-.18	-.21	-.14
120	-.08	-.10	-.13	-.10	-.02	-.20	-.07	-.11	-.19	-.19	-.12
135	-.11	-.14	-.22	-.12	-.07	-.28	-.11	-.12	-.25	-.23	-.16
150	-.26	-.26	-.51	-.25	-.25	-.55	-.22	-.24	-.51	-.25	-.33
165	-.19	-.22	-.30	-.20	-.19	-.36	-.20	-.22	-.35	-.26	-.25
180	-.26	-.30	-.25	-.17	-.03	-.32	-.29	-.33	-.30	-.13	-.24
195	-.18	-.29	-.23	-.29	-.06	-.29	-.33	-.39	-.23	-.05	-.23
210	-.05	-.09	-.22	-.11	-.22	-.32	-.13	-.24	-.34	-.01	-.17
225	-.03	-.09	-.11	-.09	-.06	-.16	-.07	-.19	-.10	0.12	-.08
240	0.23	0.33	0.19	0.19	0.21	0.18	0.22	0.11	0.22	0.28	0.21
255	0.27	0.33	0.08	0.18	-.01	0.02	0.25	0.23	0.13	0.30	0.18
270	0.36	0.33	0.14	0.27	-.09	-.02	0.51	0.49	0.31	0.53	0.28
285	0.43	0.44	0.19	0.43	-.08	0.08	0.62	0.66	0.42	0.70	0.39
300	0.41	0.45	0.09	0.44	-.07	0.14	0.52	0.56	0.43	0.42	0.34
315	0.33	0.45	-.18	0.35	-.24	-.04	0.34	0.40	0.14	0.08	0.16
330	0.23	0.38	-.28	0.27	-.30	-.31	0.30	0.40	-.22	0.01	0.05
345	0.18	0.33	-.30	0.26	-.26	-.31	0.28	0.40	-.32	-.05	0.02
360	0.09	0.23	-.25	0.02	-.24	-.26	0.05	0.19	-.27	-.12	-.06

Table 3.8 : West façade mean pressure coefficients Cp for different wind incidences, 0° corresponding to North and 90° corresponding to East wind incidence. The probe position are shown in figure 3.12.

Infiltration - tracer gas methods

Tracer gas campaigns

During the tracer gas measurement periods the building is not inhabited. The ventilation is off, the windows are closed and the inside doors are opened or closed depending on the experimental plans presented in figures 4.1 - 2 and table 4.1. The heating system is controlled at 19 [°C] with a PID controller in each room.

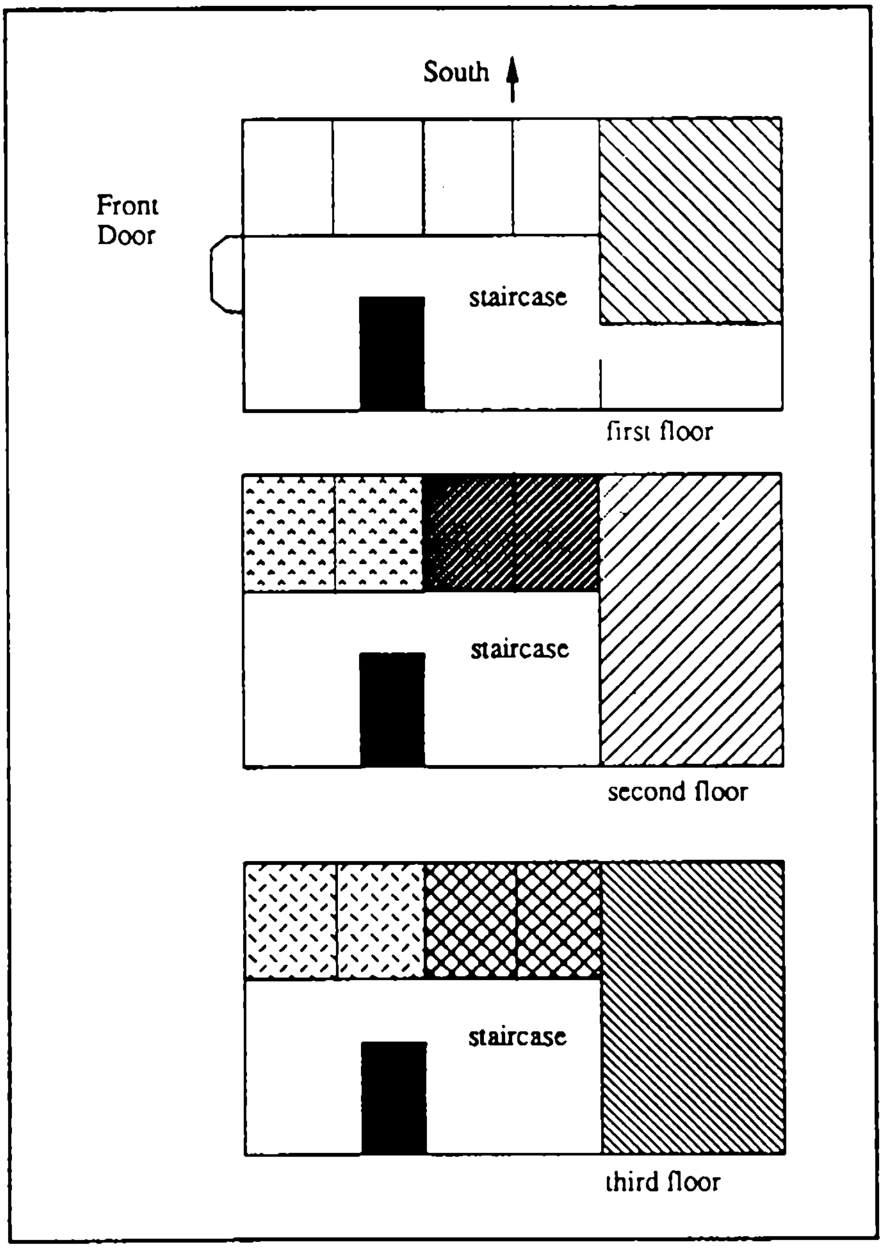


Figure 4.1 : Experimental plan for tracer gas measurement in December 87. The dashed surfaces represent the measured rooms.

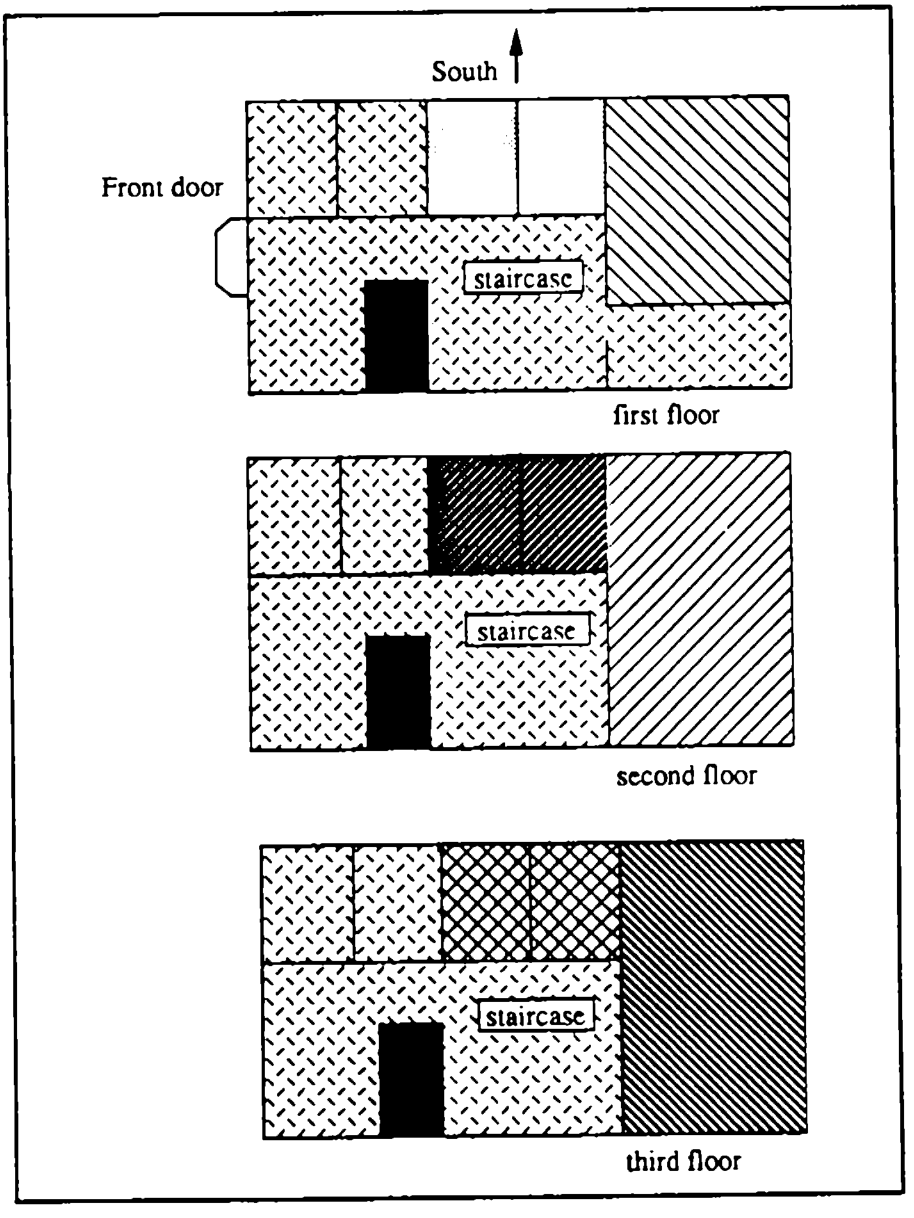


Figure 4.2 : Experimental plan for tracer gas measurement in December 88. The dashed surfaces represent the measured rooms. In 1988 N_2O has been also injected in the staircase.

Room	to	floor	Door 1987	position 1988
001	hall	1	open	open
002	hall	1	open	open
003	hall	1	closed	closed
004	hall	1	closed	closed
005	hall	1	closed	closed
006	hall	1	open	open
100	hall	2	open	open
101	102	2	open	open
102	hall	2	closed	open
103	hall	2	closed	closed
103	104	2	open	closed
104	hall	2	closed	closed
105	hall	2	closed	closed
200	hall	3	open	open
201	202	3	open	open
202	hall	3	closed	open
203	hall	3	closed	closed
204	hall	3	closed	closed
205	hall	3	closed	closed

Table 4.1 : Position of the doors during the tracer gas measurement campains.

Disk data files

Nomenclature

All data files concerning tracer gas measurements of air renewals and corresponding weather data are identified as follows :

LESO*aa*A*xxx*.*yyy*

with the meaning :

LESO measurements performed in purpose of validation of air infiltration codes

aa year of measurement (beginning)

A identification of the series of measurements. A serie being a continue following of measurements with a constant time step (1988 data has three periods A.B.C.)

xxx identification of the content (see later)

yyy format identification. The available files are written in our own data format, called GRES (Annex 1) identified by yyy = DAT.

Different files

The 1987-measurement files include measurement data collected between day 357 at 19h.15 (December 23rd, 1987) until day 369 at 14h.30 (January 4th, 1988).

The 1988 measurement files include three periods :

A, from day 358 at 21h.20 (December 24th 1987) to day 360 at 15h.40)
B, from day 360 at 18h.20 to day 365 at 24h.)
C, from day 367 at 19h. to day 369 at 14h. (January 4th 1989)

Measurements have been performed quarterly but the data files are available with a time step of 15 minutes or 30 minutes (version "30").

Format

(See full LESO report (Annex 1) for data format)

- Files LESOaaAVNR.DAT contain the weather data and building data (the comprehensive list is given in Annex 2)

  - Meteorological data
  - Room temperatures
  - Indoor-outdoor temperatures
  - Electrical consumption.

- Files LESOaaAREN.DAT contain the air flows Q_{Ai} incoming in each measured room (unity : $[m^3/s]$) and also the confidence intervals (cf. Annex 2).

- Files LESOaaANJI.DAT contain the η_{ji} coefficients of equation 4.1 describing the air flows between the room i and the staircase and also the adjacent rooms j

$$Q_{Ai} = Q_{oi} + \sum_{j=1}^{N} \eta_{ji} Q_{ji} \qquad 4.1$$

Q_{Ai}	:	measured air flow in room i
Q_{oi}	:	resultant air flow between the room and outdoor
Q_{ji}	:	resultant air flow between the rooms i and j

- Files LESOaaATEM.DAT give the mean temperature (high = 1.4 [m]) and the gradient between 0.5 [m] and 2.3 [m] for each room (unity [°C]).

Channel codification

The LESO-PB performing meteorological measurements since a few years, has developed his own standard codification to spot the different kinds of measurements in the records.

This codification is constituted by two letters (X, Y). The first (X) gives information on the ***physical quantity***. The second (Y) precises the ***type of record*** : the data logger scans the channels at short time intervals (***measuring intervals***) and records the data at longer intervals (***recording interval***). It has then the possibility to record on the tape for every recording interval either the ***instantaneous value*** or the ***integrated value*** which is the sum of the measurements performed during the recording intervals or the ***average value*** which is the integrated value divided by the measurements number. Table 4.2 gives the code for X and Y :

X :	P	→	Temperature (Pt100)
	E	→	Power (or Energy if integrated)
	K	→	Pressure
	S	→	Solar radiation
	G	→	Opening angle (window, doors)
	D	→	Wind direction
	W	→	Wind speed
	V	→	Wind projection (sin, cos)
	H	→	Humidity
	F	→	Flow
Y :	N	→	Instantaneous value
	M	→	Averaged value during the recording interval
	I	→	Integrated (sum) value during the recording interval
	S	→	Root mean square during the recording interval

Table 4.2 : Channel codification in the LESO data set.

Channel list

Annex 2 gives the list of the channels included in files described in paragraph 4.2.2 for 1987-data. 1988-data have some additional channels as a second static pressure probe (CSTB-probe) on channel 152 KM or the two ortogonal projections of the wind vector :

$$V_1 = |\vec{V}| \cos(\theta) \quad 4.2$$

$$V_2 = |\vec{V}| \sin(\theta) \quad 4.3$$

on channels 1 VM and 2 VM.

4.2.5 *Defects on channels*

The following channels have some defects in the file LESOaaAVNR.DAT :

C 451 KM, a differential pressure channel is defectuous from time 367/22:45 to 368/1:45 in 1987-data.

C 350 KM, a differential pressure channel is defectuous from time 363/4:45 to 364/12:00 in 1987-data.

C 21 PN is defectuous in all the data.

GENERAL REMARKS

This document, together with the cited references, constitutes the first quoted draft of the description of the LESO validation data set.

It contains the description of numerous data measured on the LESO Building. Some of these data are needed as input for multizone air infiltration simulation codes, like the building site description, the air leakage network and the pressure coefficients. Other data are provided, such as air flow rates and differential pressures, which can be compared with the results of the codes.

The confidence interval of most of the measurements are also given in order to evaluate the result of this comparison, that is to decide if the fit is good or bad.

A part of this set was used once before its publication in a validation exercise, and has proved to be useable. This does not mean however that it can be used for any code in any case. Therefore, the following important points are remembered here :

1) The potential user should take liaison with the authors, first to obtain the data set on a magnetic tape or disc and secondly to get the data which are unintentionally forgotten in this paper.

2) The users are kindly requested to send their comments to the authors, in order to enhance the quality and the usability of this set.

As the aim of this workshop is to finalize the structure of the Centre's database and explain data sources and needs, we give here some personal comments.

Infiltration codes steatily evoluate, taking into account more phenomenon as moisture and temperature gradients, air compressibility and turbulence effects. Nevertheless we would like to be simultaneously able to validate new codes with a data set. It is surely not an easy position; but before analysing some of its consequences we want to justify it.

The rapid evolution of the simulation codes is now mainly driven by the possibilities of the computers. Since there is very small experimental feedback, any new computer system allows to add new features to the codes without any information on either the necessity nor the accuracy of such new features. Moreover, it is not possible that way to ensure a good homogeneity in the accuracy of the various results of a given code. That code may have performant and accurate subroutines for some phenomena but be completely wrong for others.

We propose that the confrontation with measurements shall indicate the main directions to improve the codes. The measurements are certainly not perfect; they are contaminated with errors, as shown in reference [7], but measurements are the link with the reality and show the technical limits. Therefore, it does not appear necessary to calculate influences which cannot be measured.

Let us come back to the consequences of such a position. There is a need for an improvable data base. How to provide it ?

On one hand it is not possible to add a later measurement in a time dependant data set. On another hand, experiences have shown that it is unrealistic to measure every possible physical quantity without knowing how these measurements will be used. It is well known that such type of data usually ends in the rubbish bin.

Our proposal is to keep some instrumented buildings ready for measurement, improving that way steadily the quality of the measurements.

So the data base could evaluate together with the codes, being an element of constant dialogue and not, as today a difficult examination whose result is seldom clear.

That proposal looks expensive but may not really be as expensive as the use of not completely validated codes. Nevertheless, it is surely less expensive that new comprehensive measurements and a new data base for each code.

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XI. REFERENCES

(1) Piggins, J. "AIVC Numerical Database - The Objectives and Expected Contents.", AIVC - Air Infiltration Review, Vol.11, No.2, March, 1990.

(2) Allen, C. "Reporting Format for the Measurement of Air Infiltration in Buildings.", AIVC Document AIC-TN-6-81, 1981.

(3) 1984 Wind Pressure Workshop Proceedings AIVC Technical Note AIC 13.1, Document AIC-PROC-13.1-84, November 1984 (164 pages).

(4) Charlesworth, P.S. "Air Exchange Rate and Airtightness Measurement Techniques - An Application Guide", AIVC Document AIC-AG-2-88, August 1988.

(5) Liddament, Martin W. "Air Infiltration Calculation Techniques - An Applications Guide", AIVC Document AIC-AG-1-86, June 1986.

(6) 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.

(7) 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.

(8) 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.

(9) Fells M.F. (ed.) "Special Issue Devoted to Measuring Energy Savings; The Scorekeeping Approach", Energy and Buildings, Vol.9, Nos.1,2, 1986.

XI. REFERENCES

(10) Liddament Martin W., "Mathematical models of air infiltration - a brief review and bibliography.", AIVC Document AIC-TN-9-82.

(11) Furbringer J-M., Compagnon R. "Weather and Aeraulic Data Set for Validation: The LESO Building, Part 1: Content of the Data Set", LESO Internal Report, 1989.

(12) Furbringer J-M., Compagnon R., and Roulet C-A. "Weather and Aeraulic Data Set for Validation: The LESO Building, Part 2, Building Description and Measurement Report", LESO Internal Report, 1990.

(13) Liddament Martin, Allen Carolyn, "The validation and comparison of mathematical models of air infiltration.", AIVC Document AIC-TN-11-83.

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