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Paper 40

REPORTING GUIDELINES FOR THE MEASUREMENT OF AIRFLOWS AND RELATED FACTORS IN BUILDINGS.

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SYNOPSIS

A set of reporting guidelines has been established. The guidelines take into account the need for data concerning airflow within buildings and air exchange between a building and its surroundings. They also deal with issues such as pollutant production and transport, thermal properties and measurements of buildings and comfort related issues. The comprehensive nature of these guidelines should enable a large amount of data to be accrued in a form suitable for computer modelling and validation work. The extensive use of computers in research has thus been considered and an application is under development to allow a research report to be entered directly into a relational database according to the framework of the guidelines. This will allow a research report to be directly accessible in the AIVC numerical database along side the data it refers to.

1 INTRODUCTION

One of the objectives 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. As part of the Centre's present work program, reporting guidelines (Ref.14) have been produced to provide a common reference, for research workers wishing to plan experimental work or catalogue their experimental data.

The guidelines attempt to provide the necessary parameters for the calculation of airflows within buildings and the necessary input parameters for the operation and validation of airflow models, including those that include pollutant factors, and for the running and validation of thermal models of building energy use. These parameters vary with the application and this has been taken into account in the guidelines. It is hoped that this will make more complete, structured information available for entry into the AIVC numerical database (Ref.1) for subsequent analysis or mathematical model development. The basic reference for the guidelines is AIVC-TN 6, (Ref.2), aided by work in IEA Annex XX.

1.1 Guidelines Structure

The structure of the guidelines 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. The Guidelines are split into eleven parts. The first ten cover different catagories of data concerning the test site, measurements taken, and results gained. The eleventh part gives two examples of the use of the guidelines. Each part is split into a number of sections detailing different aspects of the data catagory concerned. Each of these sections is in turn split into a number of subject headings under which the user enters the data parameters requested.
Some parameters are more important or more relevant to a particular area of work than others, and this has been highlighted using the Applicability Coding which is described in the following section.

1.2 Applicability Code

The Applicability Code defines the importance and relevace of a data parameter to a particular area of work and is stated in parenthesis following each subject heading. If the code is listed by a part or section heading it is assumed to apply to all subjects within that part or section. The applicability code consists of two parts; a priority code defining the importance of a parameter, and an application code defining its main area of use. These codes should be used as an indicator only, all data collected is useful and should not be excluded simply on the basis of a low prority code or seemingly inappropriate application code.

The priority codes are as follows:

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

Individual applications codes are:

- 1 = Parameters for airflow measurements and models; e.g. model validation, stock characterisation or design studies.

- 2 = Additional parameters for airflow 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 a flow model involving pollutants would have an applicability code of (I-2).

1.3 The Guidelines and Computers

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 being developed by the

Centre, textual data may be entered in the framework of the guidelines, stored on disk in dBASE IV format and a report produced. (See appendix I for an example) This application will be available from the centre on 3½" or 5¼" MS-DOS compatible 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.

1.4 Guidelines Format

The Parts, Sections and subject headings are printed on the right-hand pages of the guidelines technical note and are accompanied by explanatory notes on the left-hand pages. Points relevant to the use of the data, the required detail and usefulness 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 on disk 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 selected portions of the data will be available through the nominated organisations in the participating countries.

2 USING THE GUIDELINES

The following notes give the ground rules for information entry into the Guidelines.

2.1 Units to aid comparison of results.

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

2.2 Instrumentation and measurement accuracy

For all sections involving measurements, the instrument used and the accuracy of the measurements should be stated:

1) - with the data listing

2) - referenced to Part V of the guidelines "Measurements" (Ref.14)

3) - referenced to the AIVC Measurements Techniques Guide (Ref.4).

Date and time of measurements should be included in Julian format.

Attach relevant photographs, diagrams, tables, graphs to the final report, and give details of any disk based data files as requested in part VIII of the guidelines "Disk Data Files" (Ref.14).

2.3 Data entry in the Guidelines

Any entry for which the data supplied takes up much more space than has been allowed may be supplied as an appendix (not dBASE IV application), which should be clearly labeled with the same letter and number code as the corresponding entry on the form, and should be supplied in the same order.

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 sections, these need only be cited once in the appropriate position and referred to as necessary.

2.4 Numerical Data on Disk

If information is on disk it should be in MS-DOS compatible format on $3\frac{1}{2}$" or $5\frac{1}{4}$" disk. Please indicate file names contents and format (with short example if possible) and include a disk with the report.

2.5 Dissemination Policy

Any information supplied to the AIVC will be regarded as freely available to any bona-fide inquirer with the under standing that the origin of the data set will be acknowledged.

3 THE GUIDELINES CONTENTS

The Guidelines are split into eleven separate parts I to XI, each of which is designed to describe one specific area of a project. These parts are in turn split into various sections, which are further divided into subjects. The eleven major parts are as follows:

I. General Information

II. Test Site Description

III. Building Description
IV. Operation/Function of Building

V. Measurements

VI. Economic Factors

VII. Numerical/Computer Models

VIII. Disk Data Files

IX. General Remarks

XI. Examples of Reporting Guidelines Application.

Below is a brief description of each part its sections and their subjects.

3.1 General Information

General information requires details of the project leaders and workers, and how to contact them. It also requests the basic project information such as start/end dates and the number of manhours required. It also emphasises the purpose and approach of a project and the reasons for selecting a particular test site. These pieces of information are considered important to aid the planning of future projects.

3.2 Test Site Description

Test Site Description is split into two sections:

A. Geographic Information

B. Climatic Information (General)

Section A (Geographic Information) requests the information necessary to describe the location of the test site and its surroundings. The basic climatic information for the site i.e. yearly or ten yearly averages for temperature, wind speeds etc., should be entered in section B (Climatic Information).

3.3 Building Description

Building Description consists of seven sections designed to provide a comprehensive description of the building under test. This third part of the guidelines primarily concerns known or easily observable properties of the building, details of which do not require complex measurements.

The seven sections are:

A. General Description

B. Dimensions

C. Air Leakage

D. HVAC Systems

E. Pollutant Sources

F. Pressure Coefficients

G. Furniture, Interior Fittings

Section A (General Description) concerns the general properties of the building, its type, history and construction. Section B (Dimensions) requires a more detailed description of its physical dimensions, including a plan. Volumes of spaces and areas of components should be detailed here. Section C (Air Leakage) requests details of any known air leakage paths within the building fabric. These are any obvious and measurable cracks or openings. An estimate of the non-measurable leakage (the background leakage) is also requested. Section D (HVAC Systems) allows the building's HVAC systems to be described including the balance report and supplied outdoor air rate for ventilation systems. Section E (Pollutant sources) requires notes on any known interior (due to the building structure itself) or exterior sources of pollutants. Any known pressure coefficients for the building should be given in section F (Pressure Coefficients). If these have not been measured in a previous investigation, estimated values from general datasets (Ref. 5) should be quoted, along with any assumptions made. Section G (Furniture, Interior Fittings) requests details of any furniture or interior fittings within the building so their effect on pollutant concentrations, thermal properties and ventilation within the building can be assessed.

3.4 Operation/Function of the Building

Operation/Function of the Building is split into five sections and aims to gather information on the everyday life of the building. It is essentially concerned with qualitative data from questionnaires or other sources. The five sections are as follows:

A. Occupant Related Data

B. Special Ventilation Requirements

C. Control Values

D. Pollutant Sources/Sinks

E. Additional Heat Sources

Occupation times, window opening and pollution generation by users are among those topics covered in section A (Occupant Related Data). Section B (Special Ventilation Requirements) is included to highlight any unusual purpose provided ventilation, such as that required for clean rooms, hospitals, laboratories, museums, or art galleries. Section C (Control Values) requires the user specified settings for the HVAC equipment, such as airflow rates, temperatures and humidities. Pollutants produced by processes occurring within the building should be detailed in section D (Pollutant Sources/Sinks). Section E (Additional Heat Sources) should be used to quantify any additional heat sources in the building other than those which are purpose provided.

3.5 Measurements

Any diagrams or photographs of the measurement procedures should be attached to the report, as should any relevant tables or graphs. Any disk data files should be named, and their structure and format described in detail in the relevant portion of the guidelines.

Measurements is split into ten sections, which are as follows.

A. Pressurisation Measurements - Internal

B. Pressure Measurements - External

C. Interior Conditions

D. Weather On-Site

E. Weather Off-Site

F. Infiltration - Tracer Gas Methods

G. Inter-Room Airflow Rates

H. Pollutant Concentrations

I. Duct Flow Rates & Temperatures

J. Other

Section A (Pressurisation Measurements - Internal) should detail any pressurisation measurements carried out on the building or its components. Measurements at several pressures and for several wind directions are recommended (Ref. 4). External or wind tunnel measurements of wind pressure coefficients for the building should be described in section B (Pressure Measurements - External) using references 3, 6 and 7 for guidance. Section C (Interior Conditions) covers measured internal temperatures, humidities, airflows (non-tracer gas methods) and pollutant concentrations. Section D (Weather On-site) allows the entry of full on-site climate conditions, including wind, temperature, humidity, radiation, and precipitation parameters. If full on-site weather conditions are not available any gaps should, if possible, be filled by entering data on off-site conditions into section E (Weather Off-site). On-site data must however, always be considered more valuable than off-site data. Section F (Infiltration: Tracer Gas Methods) requires details of any Tracer gas methods used to measure infiltration. This would be coupled in a full investigation with information in section G (Inter-room Airflow Rates) on flow rates between rooms. Measured pollutant concentrations should be detailed in section H (Pollutant Concentrations) these may vary significantly with time depending on the sources, the exterior/interior conditions of the test site, the HVAC systems within the building and building usage patterns. Known duct flow rates and temperatures should be detailed in section I (Duct Flow Rates & Temperatures). These can have a significant impact on heat and pollutant transfer as well as the overall ventilation of individual spaces within a building. Any other measurements carried out on the building or test space, such as Infra Red Thermography or Energy Consumption, should be detailed in section J (Other), which should be repeated for as many different types of measurement as were taken.

Sections A, B, C, F, G, H, I, and J are split into five main subject headings. These are as follows:

1) Technique employed.
2) Equipment used.
3) Calibration procedures/results.
4) Results
5) Comments

These are designed to provide a comprehensive reporting structure for any measurements, with specific emphasis on data quality being provided by subjects 2 and 3 on the instrumentation used and any calibration techniques used. Any diagrams, tables, graphs or photographs of the calibration/measurement procedures should be attached to the report. Any disk data files concerning the calibration of the equipment should be supplied with the report and should be detailed according to part VIII (Disk Data Files) of the guidelines.

3.6 Economic Factors

Economic Factors is concerned with the economics of various ventilation systems, including the resultant health effects on occupants. It is split into three sections:

A. Retrofitting Measures

B. Ventilation Energy & Health

C. Other Factors

Section A (Retrofitting Measures) allows the effects of retrofitting measures to be assessed details of the measures taken and the energy consumption before and after retrofit are required. Such measures as energy signatures (Ref.8), or normalised annual consumption (NAC) should be used for such comparisons (Ref.9). The relationship between ventilation, energy and health is covered in section B (Ventilation Energy & Health). These should include specific issues such as mould growth and such general issues as sick building syndrome. Any other economic factors affecting the building's energy usage or ventilation rate should be detailed in section C (Other Factors).

3.7 Numerical/Computer Models

Numerical/Computer Models concerns Computer models (Ref 10) and theoretical work not directly involving measurements, and is split into two sections:

A. Type of Model/Correlations

B. Other Theoretical Work of Interest

Section A (Type of Model/Correlations) requires a detailed description of the model in question, the assumptions and algorithms used, its speed and size. It also requires a description of the input data required and the eventual output of the program. Any comparisons carried out using actual data to validate the model are considered very important and should be described in detail. Section B (Other Theoretical Work of Interest) concerns any new algorithms which have been developed independently or from the measurement work described in part V.

3.8 Disk Data Files

Disk Data Files has two sections:

A. Measurements

B. Numerical/Computer Models

Section A (Measurements) concerns any disk based data files associated with the work detailed in part V. of the guidelines. Section B (Numerical/Computer Models) concerns the input/output files required by the computer models detailed in part VII of the guidelines.

Each section is split into four principle subject headings:

1) Nomenclature
2) File Names/Contents
3) File Formats
4) Comments

Nomenclature requires complete details of the structure of the disk file names and any variables used in the files. File names/contents should contain a list of all the files required or output along with a brief description of their contents. File formats should detail the exact structure of the files listed sufficient for any programmer to read the files and make use of the data contained within.

3.9 General Remarks

General Remarks allows any points not included in the preceding parts to be described. It also gives the report writer a chance to detail any recommendations or conclusions arising from the studies detailed in the rest of the guidelines.

3.10 Examples of the Guidelines Application

This final part of the guidelines gives two examples of how they can be implemented in practice. The first is a report on a Canadian HUDAC low energy house (Ref. 13). This was generated using the Guidelines Report Generator (a dBASE IV application) being developed at the Centre. The second is a report on the Swiss LESO laboratory, a three storey fully instrumented working office building (Refs. 11 & 12). The first of these examples is reproduced in Appendix I of this paper.

4.0 THE DBASE IV APPLICATION PACKAGE

To complement these guidelines a dBASE IV application is being developed. This consists of a relational database with a menu driven front end. This allows the user to enter data into the database via the framework of the reporting guidelines. Having entered the data the user can produce a printed report in the format of the guidelines (See appendix I). The program begins with a title screen and copyright message. This is replaced with the main bar menu, whose options are described below.

4.1 Name/Select Report

The first option of the main menu 'Name/Select Report' allows the user to select whether to start a new report or edit an old one, it also gives the opportunity to delete reports.

4.2 Enter/Edit Text

The second option of the menu 'Enter/Edit Text" produces an extensive series of popup menus, which the user can use to select the part or parts of the guidelines into which they wish to enter data. The selected parts of the guidelines are then displayed as one or more on screen forms. Each form shows the part, the section and the subject under which data is being entered. Notes on the required data, as shown on the left hand page of the guidelines, are displayed at the bottom of the screen.

4.3 Print Report

The third option 'Print Report' gives the user a number of options. These allow the user to print a report of all the guideline subjects (including part and section headings), or to print out the same report including the subject notes. Once data has been entered into a report the user can also print out a report of the parts, sections and subject containing data, or a complete report of all headings and any entered data. Appendix I is an example of the former; only printing those headings which contain data.

4.4 Exit

The fourth and final option of the main menu is exit this will return the user to DOS or whatever program he started the application from. It will also save any changes the use has made to the database, unless instructed otherwise.

5.0 CONCLUSIONS

A new set of reporting guidelines have been established. These take into account the need for data concerning airflow within buildings and air exchange between a building and its surroundings. They also deal with issues such as pollutant production and transport, thermal properties and measurements of buildings and comfort related issues. The comprehensive nature of these guidelines should enable a large amount of data to be accrued in a form suitable for computer modelling and validation work. The extensive use of computers in research has thus been considered and an application is under development to allow a research report to be entered directly into a relational database according to the framework of the guidelines. This will allow a research report to be directly accessible in the AIVC numerical database along side the data it refers to.

APPENDIX I

This example of the use of the guidelines was originally outlined in reference 13. It is presented here as a printout from a prototype of the dBASE IV application being developed at the centre. Relevant diagrams, photographs, and graphs are attached at the end of the report and referenced in the text.

GENERAL INFORMATION

Report date

1980

Principal Researcher

C.Y. Shaw

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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 Develoopement Association were participating in a joint programme to study energy conservation in four detached two-sorey houses. One of the

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, $1\frac{1}{2}$ 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 $1\frac{1}{2}$", 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 $l/(s.m^2.(Pa)^n)$, 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 CO2 concentrations to avoid introducing additional CO2 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 CO_2 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.

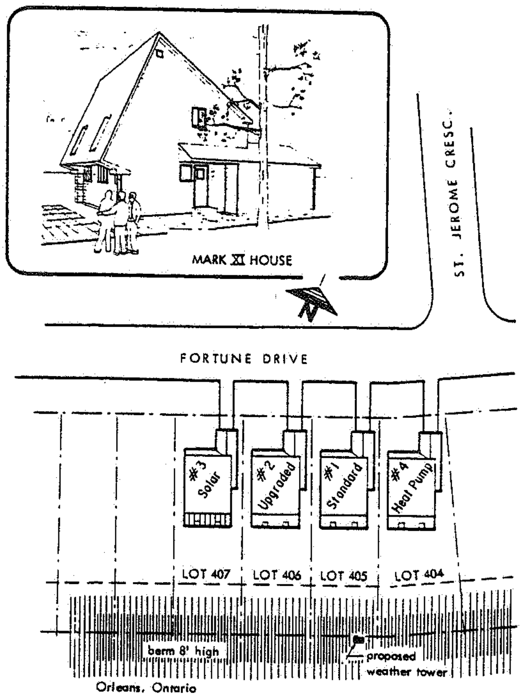

FIGURE 1

SITE PLAN - MARK XI PROJECT

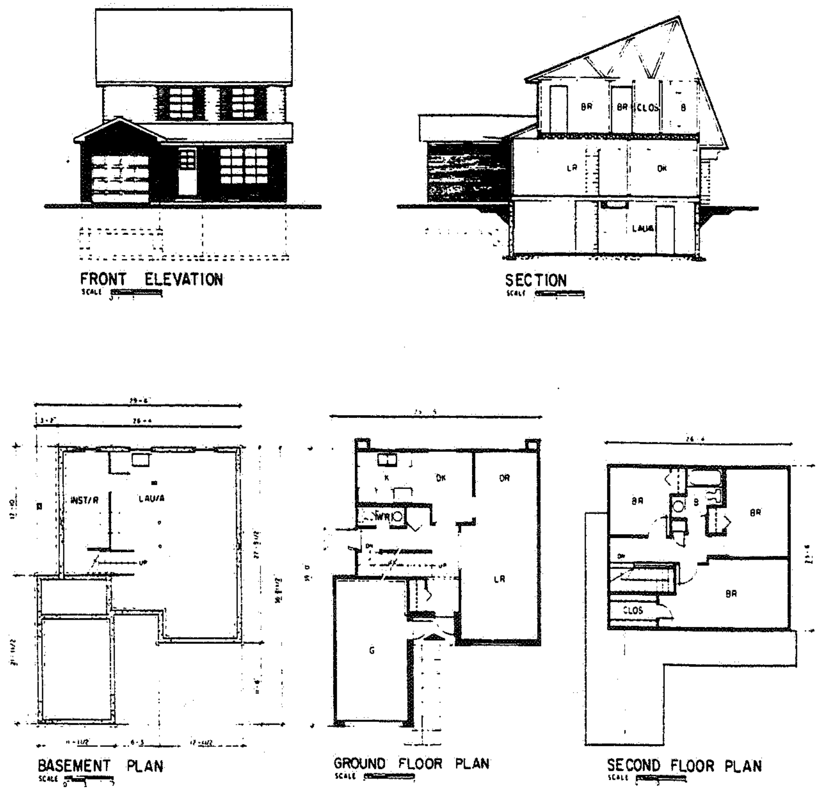

FIGURE 2

HOUSE NO. 1 - STANDARD CONSTRUCTION

(TYPICAL ARCHITECTURAL DESIGN OF ALL 4 HOUSES)

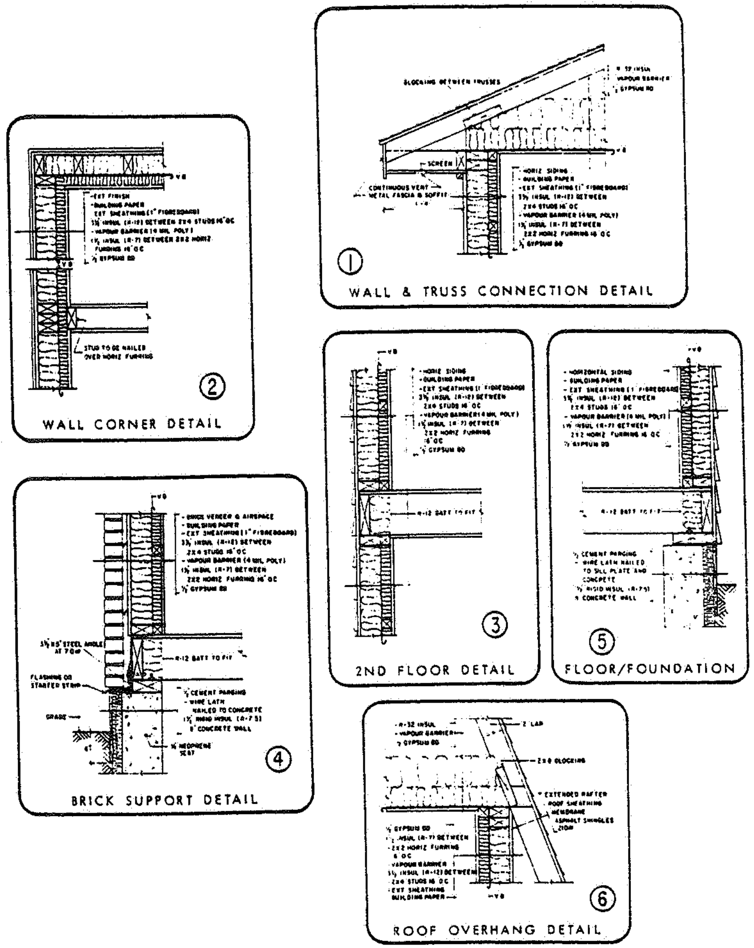

FIGURE 3

HOUSE NO. 2 - UPGRADED CONSTRUCTION

(CONSTRUCTION DETAILS FOR HOUSES 2, 3 & 4)

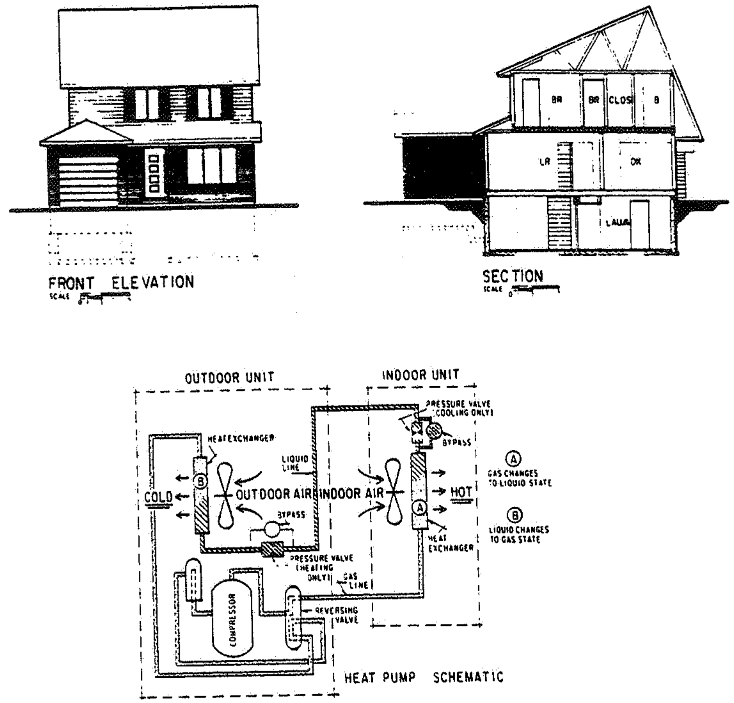

FIGURE 4

HOUSE NO. 4 - UPGRADED + HEAT PUMP

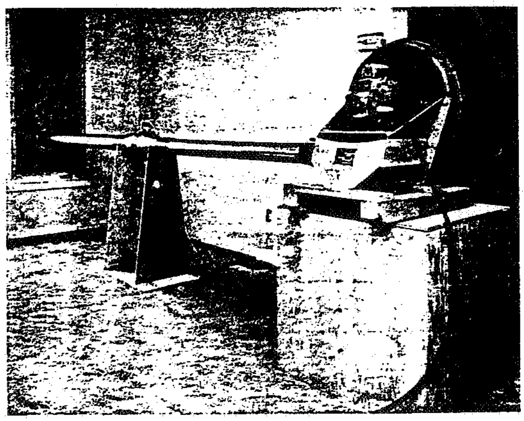

FIGURE 5 Equipment for fan-pressurization test

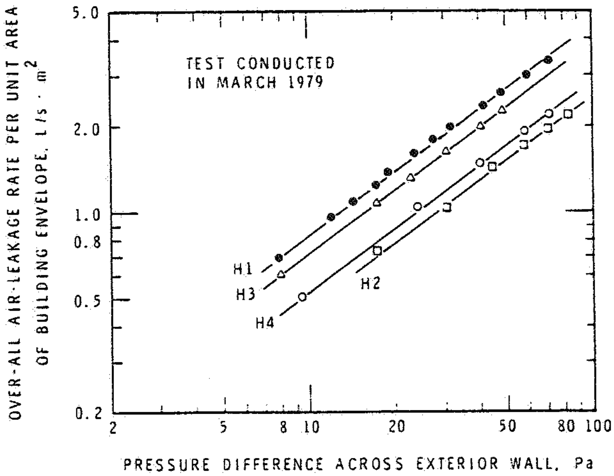

FIGURE 6

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

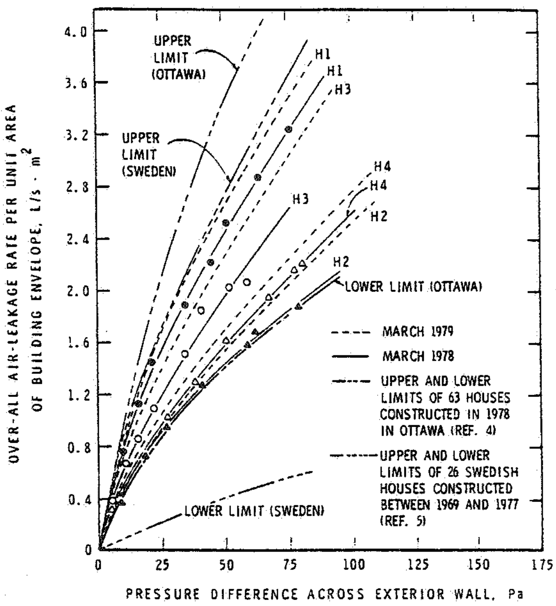

FIGURE 7

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

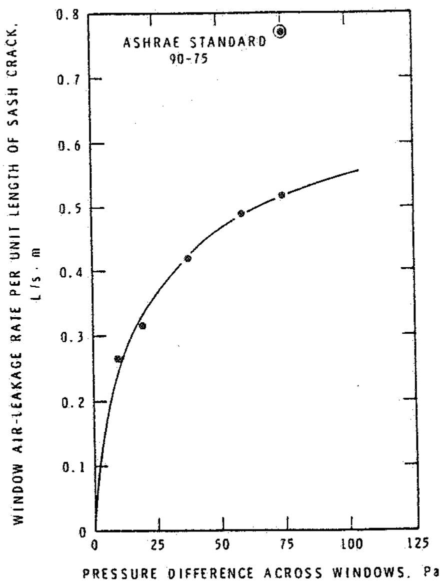

FIGURE 8

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

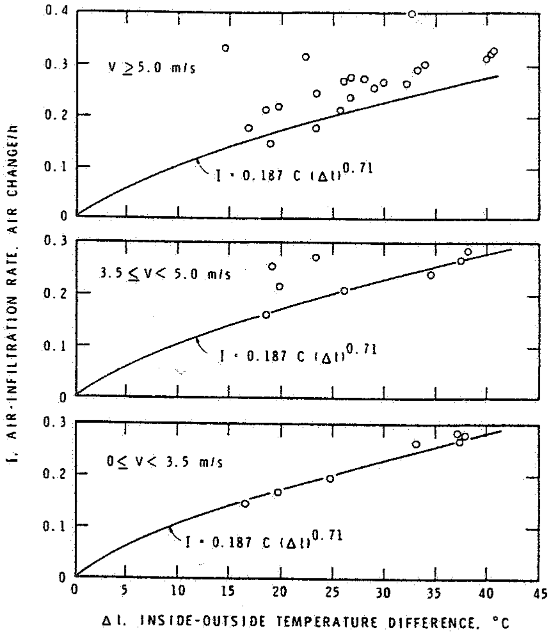

FIGURE 9

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

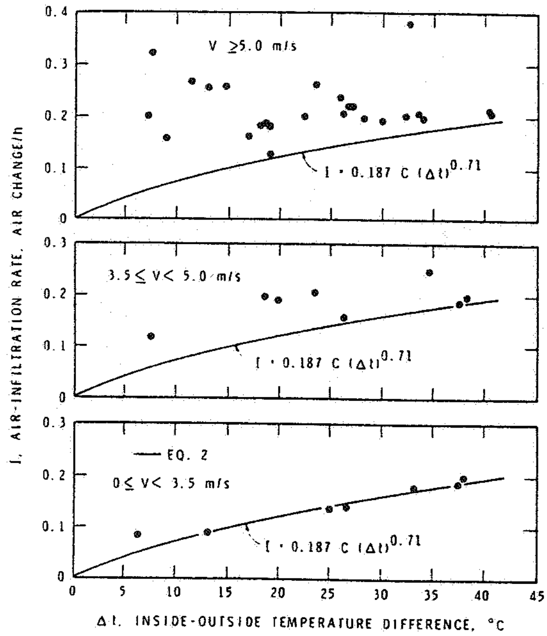

FIGURE 10

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

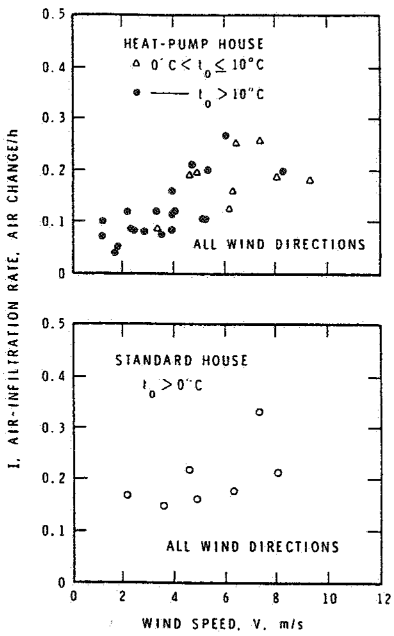

FIGURE 11

AIR-INFILTRATION RATE VS WIND SPEED

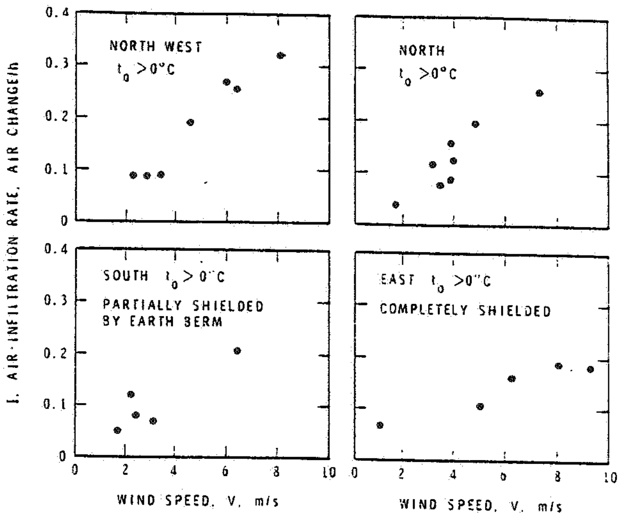

FIGURE 12

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

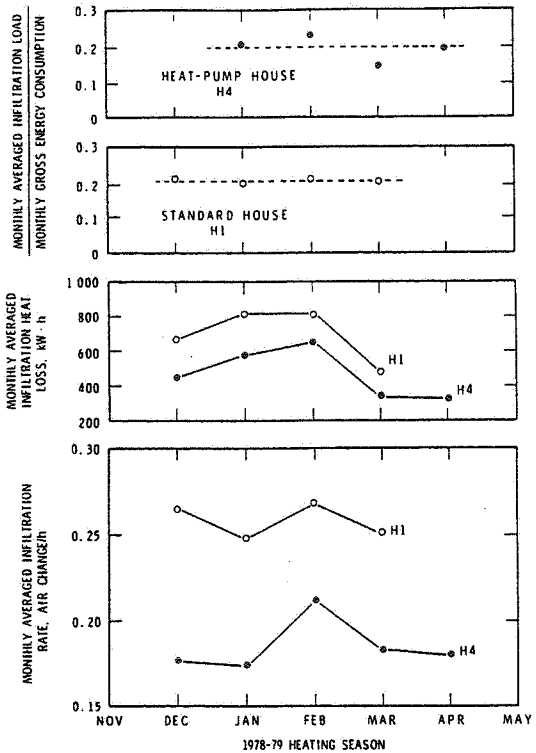

FIGURE 13

MONTHLY AVERAGED INFILTRATION LOAD AND ITS CONTRIBUTION TO TOTAL ENERGY CONSUMPTION

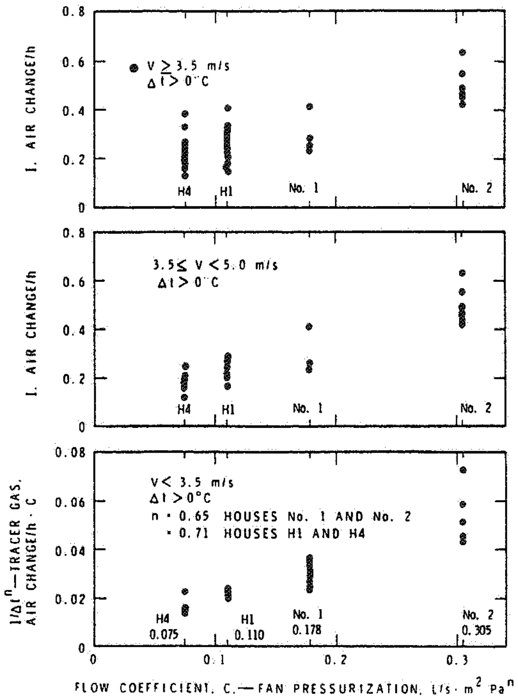

TABLE 1

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

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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)

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AIVC-AP-RG1-1990

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