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A Review of Building Airtightness and Ventilation Standards

September 1990

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AIVC

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Annex V Air Infiltration and Ventilation Centre

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T.N. 14 UPDATED

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 * XIV Condensation XV Energy Efficiency in Schools
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 Energy Efficient Communities XXII Thermal 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 agreement that infiltration was the area about which least was known. An infiltration group was formed drawing experts from most progressive countries, their long term aim to encourage joint international research and 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, Federal Republic of Germany, Finland, Italy, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and the United States of America.

INTRODUCTION

Since the first publication of this Technical Note in 1984, which collected together and summarised the standards from some twelve countries dealing with airtightness and ventilation requirements of buildings, there has been a greater emphasis on the need for energy efficiency combined with maintaining air quality. With the relatively high cost of energy still acting as a spur, and the greater use of energy both in the home and in commercial and industrial premises, more stringent measures are being promulgated to enforce the requirements of standards in many countries.

It is recognised that the improvements in the airtightness of buildings can lead to a reduction in the air quality, unless minimum ventilation rates are maintained.

This is also reflected in the specifying of concentration levels of pollutants in the air both inside and outside the building. Levels of carbon dioxide are used in some standards as a basis for the rate of ventilation prescribed and there are now in operation some mechanical ventilation systems that operate and are triggered when the level of carbon dioxide has reached a specified maximum value. Many countries are now employing heat recovery systems which extract heat from the exhaust air from a building and transfer it to the cooler fresh air required for ventilation. Standards on the use of these systems covering the testing of the equipment, and the installation have been in existence for a number of years and are likely to be more extensively specified.

This revised Technical Note brings together the current updated standards from 13 AIVC participating countries and adds the key standards on the subject from 1 non AIVC country together with those from other International Organisations.

The more pertinent aspects of the standards and regulations are reviewed and a subject analysis is shown in tabular form (see Table 1.) covering the airtightness and ventilation requirements of the various countries.

TABLE 1: REQUIREMENTS AND RECOMMENDATIONS FOR AIRTIGHTNESS AND VENTILATION RATES IN SOME COUNTRIES

	Scandinavia				Europe							America		Far East	
	Den.	Fin.	Nor.	Swe.	Belg.	Fra.	Ita.	Neth.	Swi.	UK.	FRG.	Can.	USA.	N.Z.	
Airtightness:															
Components	W	W	R	N	W	-	W	W	W	W	W	W+D	W+D	W	
Whole Buildings	N	N	R	R	N	-	R	N[1]	R	N	N	N[1]	N[1]	N	
Minimum Ventilation Rates:															
Dwellings	R	R	R	R	R[3]	R	R	R	N[2]	R	R	R	R	N[2]	
Other (Industrial/ Commercial	R	R	R	R	-	-	R	R	R[5]	R	R	R	R	N[4]	

Key:
- R = Recommendation exists
- N = No recommendation exists
- W = Recommendation for windows only
- W+D = Recommendation for doors and windows only

1 Draft standard in preparation
2 Recommendations exist for internal kitchens, bathrooms, toilets.
3 A voluntary standard that may soon be replaced.
4 Government legislation exists for bathrooms, toilets and laundries.
5 Only for some types of rooms.

Country Abbreviations:

Den:Denmark; Fin:Finland; Nor.Norway; Swe.Sweden; Belg.Belgium; Fra.France; Ita.Italy; Neth.Netherlands; Switz.Switzerland; UK.United Kingdom; FRG.West Germany; Can.Canada; USA.United States of America; NZ.New Zealand.

Section 1
REVIEW

AIVC PARTICIPATING COUNTRIES

Belgium

BELGIUM   Standards

Reference No.	Standard No.	Title
B 1	NBN B 62-003	Heat loss calculations. (Calcul des deperditions calorifiques) IBN Draft 1983 (final version will be published Summer 1984).
B 2	STS 52.0	External joinery - general principles. (Menuiseries Exterieures - Generalites) INL Draft 1983
B 3	STS 36	Metal-clad woodwork, windows, light-weight facades and window-frames. (Menuiseries metalliques, fenetres, facade legeres et huisseries). INL 1971.
B 4	STS 52	Timber cladding; windows, french -windows and light-weight facades. (Menuiseries exterieures en bois; fenetres et facades legeres). INL 1973.
B 5	NBN-B62-002	Calculation of heat transmission coefficients of walls. (Calcul des coefficients de transmission thermique des parois des batiments) IBN Janvier 1987.
B 6	NBN-B62-301	Thermal Insulation of buildings. Level of Global Thermal Insulation (Isolation Thermique des batiments. Niveau de l'isolation thermique globale). IBN 2nd Edition 1988.
B 7	NBN Draft	Ventilation requirements in Dwellings IBN 1st Draft November 1988.

BELGIUM

National Standards are issued by the Belgian Standards Insitute (Institut Belge de Normalisation) and are only mandatory for the public building sector, which comprises about 30% of the total building stock.

The Wallonia region has a regulation for calculating the heat demand of a building in which the air change rate is assumed to be 0.75 ach.

NBN B 62-003 (B 1) sets out a method for calculating heat loss from a building and includes an assumed ventilation rate of 1 ach or 20-30 m3/h per person in naturally ventilated buildings. The standard assumes that 10 m3/h per person can be heated up by the metabolic heat.

The public building sector also uses the "specifications Techniques Unifices" (STS), a series of building codes issued by the National Housing Institute (Institut National du Logement). STS 52.0 (B 2) Classifies windows in groups according to their air leakage performance and degree of exposure, and gives a maximum leakage value for each group at 100 Pa (See Table 1 and Fig.1). STS 36 (B 3) and STS 52 (B 4) also present these values for different types of window frame.

There are, however, no overall airtightness requirements for whole buildings. There is a general requirement for ventilation of workplaces of 30 m3/h per person.

Table 1. Maximum rate of leakage at 100 Pa for different grades of window according to STS 52.0

	Window Classification		
	PA2	PA2B	PA3
Exposure level - height of building in which the window is situated	0-10m	10-18m	>18m
Air permeability of joints per metre crack length (m3/h/m)	6	3	2

Canada

CANADA STANDARDS

Ref. No.	Standard No.	Title
CA 2	CSA F.326.1	Canadian Standards Association Preliminary Standard Residential Mechanical Ventilation Requirements 1989.
CA 3		The National Building Code of Canada Associate Committee on the National Building Code National Research Council of Canada, Ottawa 1985 Part 9 - Mechanical Ventilation
CA 4	NRCC22432	Measures for energy conservation in new buildings Associate Committee on the National Building Code National Research Council of Canada No. 22432 Ottawa. 1983
CA 5	RSQ.C.E-1.1 O.C 89-83	An Act respecting the conservation of energy in buildings in the Province of Quebec.
CA 6	R-2000	R-2000 Home Program Design and installation guidelines for ventilation systems (Revised January 1989).
CA 7	Can2-149.10 M86	Determination of Airtightness of Buildings by the fan depressurization method.
CA 8	C439-M1985	Preliminary Standard. Standard Methods of Test for Rating the Performance of Heat Recovery Ventilation.
CA 9	CAN3-A440-M84	Windows. Building Materials and Products
CA 10	C444-M1987	Installation requirements for Heat Recovery Ventilators.

Ref. No.	Standard No.	Title
		In the Course of Preparation during 1989
CA 11	CSA F.326.2	CSA Preliminary Standard. Residential Mechanical Ventilation. Systems Installation requirements.
CA 12	CSA F.326.3	CSA Preliminary Standard. Performance evaulation of Residential Ventilation Systems.
CA 13	CSA F.326.4	CSA. Residential Ventilation Systems. Design Guideline.
CA 14	C 260	Rating the Performance of Residential Mechanical Venting Equipment.

CANADA Ref:CA.2

Canadian Standards Association.

Preliminary Standard F326.1-M1989 January 1989

Residential Mechanical Ventilation Requirements

This preliminary standard is not intended to be referenced in building codes or regulations until such time when a formal standard is produced. It does however give the opportunity for industry to work with the requirements for verification before final decisions are made.

The standard defines the requirements for mechanical ventilation systems for providing minimum controlled rates of ventilation air to habitable spaces of single-family dwellings falling within the scope of Part 9 of the National Building Code and having individual heating, ventilating or air conditioning systems. It does not take account of uncontrolled air leakage or natural ventilation through open windows or other such openings operated by the occupants when sizing the ventilation system. Some infiltration is highly variable. Neither does it take account of air supply for combustion devices, these are covered by the appropriate installation code, but does take account of house pressure conditions for their safe operation. With regards to air quality, this standard assumes contaminants to be those normally encountered in residential dwellings at acceptable rates.

The minimum ventilation air requirements in litres/second are given in Table 1 and provide a base flow rate to the dwelling by the summation of the individual room requirements defined in Column 1, when the ventilation system is operated on a continuous basis. The minimum ventilation rate capability must be at least 0.3 air changes per hour, based on the conditioned volume of the dwelling unit.

Exhaust air given in columns 2 and 3 Table 1 shall be taken directly to outside and not recirculated, but this does not preclude the use of heat recovery devices provided that minimal leakage between supply and exhaust air streams of not more than 5% of the ventilation air is maintained.

A limitation is imposed on the positive and negative pressures in the dwelling relative to outside pressure, when the ventilation system is operated at the base flow rate condition. This is given as 10 Pa with the exception of dwellings incorporating Category 1 appliances where the combustion and dilution air is taken from inside the dwelling. In these cases, a negative pressure not exceeding 5 Pa below outside is imposed.

A full commentary on this preliminary standard is given in Appendix A.

Reference Publications:

This Standard refers to the following publications and where such reference is made it shall be to the edition listed below:

CSA Standards
B139-1976
Installation Code for Oil Burning Appliances;

CAN/CSA-B365-M87
Installation Code for Solid-Fuel Burning Appliances and Equipment;

CAN/CSA-F280-M86,
Determining the Required Capacity of Residential Space Heating and Cooling Appliances.

CGA* Standards

CAN/CGA-B149.1-M86,
Natural Gas Installation Code;

CAN/CGA-B149.2-M86,
Propane Installation Code.

ASHRAE^ Standard 62-1981,
Ventilation for Acceptable Indoor Air Quality.

National Building Code of Canada, 1985

* Canadian Gas Association.
^ American Society of Heating, Refrigerating and Air-Conditioning Engineers.

National Building Code of Canada Part 9
(Requirements for the 1990 edition).

A change is proposed in Appendix A which deals with "Mechanical Ventilation".

Due to the general tightening up of air leakage in building structures and the improved efficiency of heating systems, concern must now be given to the possible inadequacy of the natural air change in dwellings to provide a healthy environment. This led to current requirements for mechancial ventilation in all dwelling units regardless of the type of heating systems used. The capacity of the system must achieve 0.3 ach when operated continuously over any 24 hour period.

The Appendix deals with sizes of intake openings related to fan capacities to avoid excessive depressurization of the dwelling, and gives guidance on their location.

Further changes are planned for 1995 including consideration for adoption of proposed CSA Standard F326.1 "Residential Mechanical Ventilation Requirements".

Measures for Energy Conservation in New Buildings. 1983
NRCC No.22432

This publication based on ASHRAE Standard 90A-1980 but modified to reflect Canadian objectives and conditions, provides a basis for improving the energy use characteristics of new buildings, and are intended to be minimum requirements. It separates the buildings into those with low energy requirements and those with high energy requirements for lighting, fans and pumps, and stipulates the minimum thermal resistance values through the fabric of the buildings concerned.

Windows separating heated space from unheated space shall conform to the air leakage requirement in the applicable window standards as listed in Part 9 of the National Building Code 1980.

Manually operated exterior sliding glass door assemblies shall conform to the air leakage requirements in CGSB 82-GP-2m (1977) "Doors, Glass, Aluminium Frame, Sliding, Medium-Duty". In addition those buildings with high energy requirements must protect exterior doors with an enclosed vestibule, and shall be equipped with self closing devices.

Where mechanical ventilation is provided, the outdoor air quantities equal to that required in ASHRAE 62-81 "Ventilation for Acceptable Indoor Air Quality" must be controlled where energy is required to either heat, or cool the air.

Other parts of the publication deal with the design of heating, cooling and ventilating of buildings, together with service water heating, and the performance efficiency of the equipment. A small section deals with electric lighting with regards to switching and lighting levels for all occupancies with the exception of dwellings.

A builder is also free to design a dwelling to achieve the same energy targets without following the prescribed rules.

CANADA Ref:CA.5

(QUEBEC)
An Act respecting the conservation of energy in buildings and Regulations respecting energy conservation in new buildings. This Act is based on the 1983 Measures for Energy Conservation.

R.S.Q., C. E-1.1 - O.C. 89-83

CANADA Ref:CA.6

R-2000 Home Program Design and Installation Guidelines for Ventilation Systems.
Draft - Revised (January 1989)

R2000 homes are dwellings built to a specially high standard of airtightness and energy efficiency. This is a voluntary program.

This document outlines the required standard for ventilation of these homes.

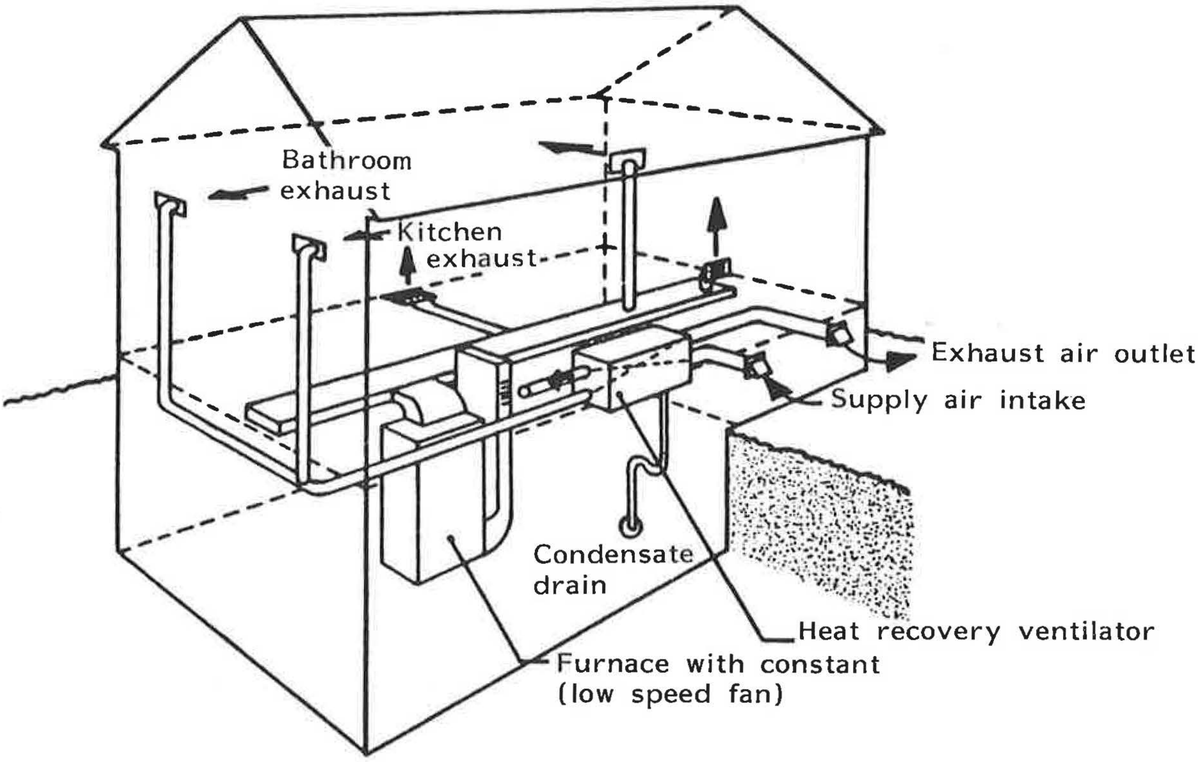
The publication was revised to conform more closely with CSA Preliminary Standard F.326.1 M1989 "Residential Mechanical Ventilation Requirements".

They provide guidelines to designers and installers with criteria for the selection, location and installation of ventilators, fans heat-recovery devices, ductwork, dampers, and terminal fittings for R-2000 homes designed and built with the Home Program Technical Requirements.

They are applicable to residential occupancies as defined under Part 9 of the National Building Code of Canada, and are in addition to the requirements of local or provincial codes or standards.

In addition to tables and diagrams giving the requirements to conform with the guidelines, five examples of ventilation and exhaust systems are shown, one of them being as in Fig.1 shown on next page.

Figure 1. Example of a ventilation system with heat recovery ventilator.



* Ventilation air is supplied by the HRV to the return air intake of an air recirculation system such as a furnace. The recirculation system fan operates continuously to distribute ventilation air to rooms.

* Indoor air is exhausted from the kitchen and bathrooms through the HRV to the outside to meet all the continuous ventilation and continuous exhaust capacity requirements.

* The HRV fans are operated at the continuous ventilation rate. "High speed" operation for higher capacity, intermittent operation activated by a humidity controller and a manual switch or timer can be considered as options.

* Makeup air would not generally be required because of the balance of supply and exhaust flows.

The reference standards are:

* CSA Preliminary Standard F 326.1-M1989, Residential Mechanical Ventilation Requirements.

* CSA Preliminary Standard C444-M1985, Installation Guidelines for Heat Recovery Ventilators.

* CSA Preliminary Standard C439, Standard Methods of Test for Rating the Performance of Heat Recovery Ventilators.

* CSA Standard C260.1-1975, Installation Code for Residential Mechanical Exhaust Systems.

* CSA Standard C260.2-1976, Residential Air Exhaust Equipment.

* HRAI Residential System Design Manual for Air Heating and Cooling Systems.

The following additional references/standards are related to the design of air distribution systems and room ventilation air inlets:

* ANSI/ASHRAE Standard 55-1981. Thermal Environmental Conditions for Human Occupancy.

* ASHRAE 1984 Systems Handbook Chapter 11, Air Distribution Design for Small Heating and Cooling Systems.

* ASHRAE 1983 Equipment Handbook, Chapter 2, Air Diffusing Equipment.

* ASHRAE 1981 Fundamentals Handbook, Chapter 32, Space Air Diffusion.

* Canadian Building Digest 102, Thermal Environment and Human Comfort.

* Canadian Building Digest 106, The Basic Air-Conditioning Problem.

* NBS Technical Note 710-3, Building Research Translation, Ventilation Air Inlets for Dwellings.

* NBS Technical Note 710-3, Building Research Translation, New Regulations on Ventilation of Dwellings. Fixed Heating Facilities and Flues.

CANADA Ref:CA.7

Canadian General Standards Board

Determination of Airtightness of Buildings by the Fan Depressurization Method CAN2-149.10-M86

The Standard describes a method for determining the airtightness of a building envelope, aimed mainly at houses. It is not intended to be used for evaluating the actual air leakage which occurs through wind, or buoyancy pressures, or caused by ventilation systems. The intention is to subject the complete envelope under test to a simultaneous and similarly directed air pressure by fan or fans exhausting the air at a rate required to maintain a specified air pressure difference across the building envelope. When conditions have stabilized, the air flows and pressure differences are measured.

The setting up techniques, calibration of equipment, measurements to be taken, and the evaluation of the various parameters involved are dealt with in detail. Also the standard indicates the necessary calculation procedure to express airtightness in the form of an equivalent leakage area.

CANADA Ref:CA.8

Preliminary Standard C439-M1985

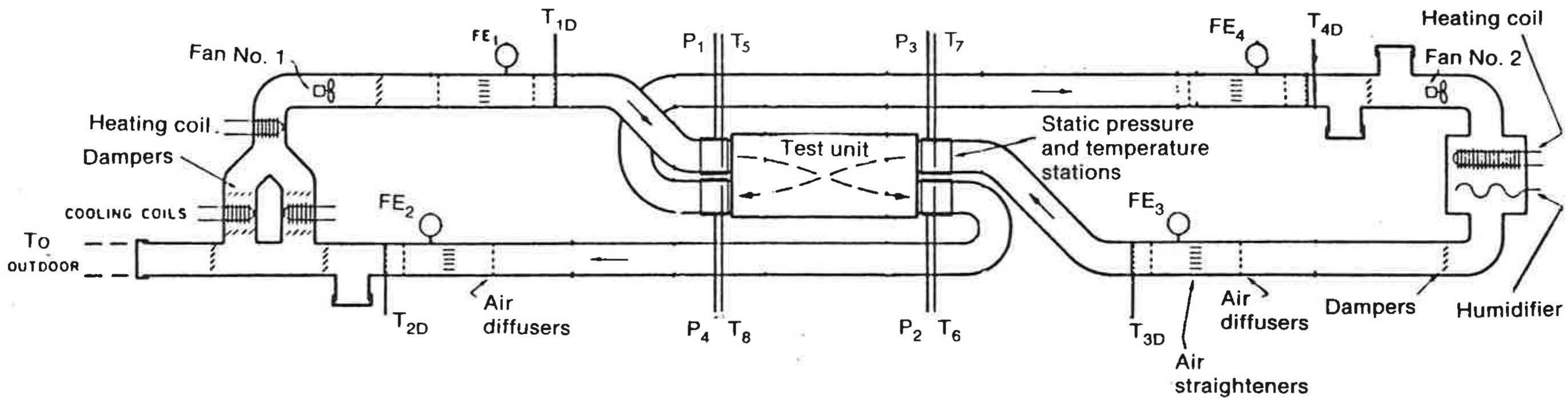
Standard Methods of Test for Rating the Performance of Heat Recovery Ventilation.

Issued by Canadian Standards Association May 1985.

This Standard prescribes the methods for rating the thermal effectiveness, air movement capacities, and leakage rates of air from heat recovery ventilators. It applies to factory assembled, self-contained units which have been designed to transmit heat between two isolated air streams.

A schematic view of the test apparatus is shown in Figure 1.

Figure 1: Schematic of Test Facility for Heat Recovery Ventilators.



Legend

FE_1 Flow element—Supply inlet
FE_2 Flow element—Supply outlet
FE_3 Flow element—Exhaust inlet
FE_4 Flow element—Exhaust outlet

T_{1D} Dew point temperature Station 1
T_{2D} Dew point temperature Station 2
T_{3D} Dew point temperature Station 3
T_{4D} Dew point temperature Station 4

P_1 Pressure—Supply inlet
P_2 Pressure—Supply outlet
P_3 Pressure—Exhaust inlet
P_4 Pressure—Exhaust outlet

T_5 Supply inlet temperature
T_6 Supply outlet temperature
T_7 Exhaust inlet temperature
T_8 Exhaust outlet temperature
T_9 Test unit ambient temperature

Station	Section
1	FE_1 P_1 T_{1D} T_5
2	FE_2 P_2 T_{2D} T_6
3	FE_3 P_3 T_{3D} T_7
4	FE_4 P_4 T_{4D} T_8

CANADA Ref:CA.9

Canadian Standards Association

CAN3-A440-M84

WINDOWS - Building Materials and Products

This Standard applies to both fixed and operable windows intended to be factory-assembled and installed in buildings. It covers window frames made of wood, steel, aluminium and vinyl and gives maximum air leakage rates for different window ratings as given in the following Table.

Window Classification

Window Rating	Maximum Air Leakage Rate $(m^3/h)m^{-1}$
Storm	8.35 (max) 5.00 (min)
A1	2.79
A2	1.65
A3	0.55
Fixed	0.25

CANADA Ref:CA.10

National Standard of Canada, CAN/CSA-C444-M87

"Installation Requirements for Heat Recovery Ventilators" issued by Canadian Standards Association June 1987.

It applies to heat recovery ventilators for installation in new and existing buildings, and deals with selection, minimum installation requirements and information to be provided by the purchaser.

Air leakage rate between the two isolated air streams is measured by tracer gas technique.

CANADA Ref:CA.11

CSA F.326.2 CSA Preliminary Standard.

Residential Mechanical Ventilation. Systems Installation requirements.

This standard is in the course of preparation and therefore no data available at time of going to press.

CANADA Ref:CA.12

CSA F.326.3: CSA Preliminary Standard.

Performance Evaulation of Residential Ventilation Systems.

This standard is in the course of preparation and therefore no data available at time of going to press.

CANADA Ref:CA.13

CSA F.326.4

Residential Ventilation Systems. Design Guideline.

This standard is in the course of preparation and therefore no data available at time of going to press.

CANADA Ref:CA.14

C 260: Rating the Performance of Residential Mechanical Venting Equipment.

This standard is in the course of preparation and therefore no data available at time of going to press.

Denmark

DENMARK Standards

Reference No.	Standard No.	Title
DK 1		The Danish Building Regulations (Bygningsreglement 1982), Ministry of Housing, Copenhagen. 1982
DK 2	DS418	Calculations of heat loss from buildings. (Beregning af bygningers varmetab). 1977
DK 3	DS/EN42	Methods of testing windows. Air permeability test (Vinduesprovning Luftaehed). 1976

DENMARK

The Danish Building Regulations 1982 (DK1) give construction standards for all new buildings, to a high level of energy efficiency. These standards are also being applied to existing building stock under the 1981 Act on reduction of energy consumption in buildings, issued by the Danish government.

Chapter 8 of the Regulations, covering thermal insulation, states that windows and doors should be constructed as tightly as possible so that heat loss through air infiltration will be reduced to a minimum. It recommends that thermal transmittance co-efficients for building components requiring insulation should be calculated on the basis of DS 418 (DK2), compiled by the Danish Society of Engineers (DIF). This gives a method for calculating ventilation heat losses which assumes an air change rate of 0.4 ach for 'tight' living rooms, 0.6 ach for normal living rooms and 0.7 ach for kitchens and bathrooms. It also states that, where airtightness of doors and windows is not known, an air leakage value of 0.5 $dm^3/s/m$ length of joint at 30 Pa should be assumed.

The only other standard concerned with component leakage is DS/EN42 (DK3) (based on European Standard EN42) which describes a pressure chamber method for testing the air permeability of windows in the laboratory.

Chapter 11 of the Danish Building Regulations covers ventilation requirements in residential and non-residential buildings. For residential buildings, fresh air supply should be by natural ventilation via exterior doors and windows. Exhaust air can be removed by natural or mechanical ventilation. Fresh air supply is defined in terms of area of ventilation opening and the rate of air exhaust is expressed in air flow in dm^3/s or by cross-section area of ventilation ducts (see Table 1).

TABLE 1: Ventilation rates for rooms in residential buildings according to the Danish Building Regulations

Room	Fresh air supply in terms of ventilation opening cm^2	Exhaust air	
		Cross-section of duct (natural ventilation) cm^2	Air flow (mechanical ventilation) dm^3/s
Kitchens ($7m^2$ and over)	30	200	20
Kitchens (under $7m^2$)	30	150	15
Bathrooms and WCs	100	150	15
Living rooms	30	-	-

Finland

FINLAND STANDARDS

Reference No.	Standard No.	Title
SF 1	D2	Indoor Climate and Ventilation in buildings. Regulations and Guidelines. National Building Code of Finland. The Ministry of the Environment.
SF 2	D5	Calculation of performance and energy requirements for heating of buildings. Guidelines 1985. National Building Code of Finland (in Finnish).
SF 3	C3	Thermal insulation. Regulations 1985. National Building Code of Finland (in Finnish).
SF 4	SFS 3304	Window, functional requirements, clarification and testing, 1978 (in Finnish).
SF 5	SFS 5511	Air conditioning. Indoor climate in buildings. Field measurements of thermal parameters. 1989 (in Finnish).
SF 6	SFS 5512	Air conditioning. Measurements of air flows and pressure conditions in air conditioning systems. 1989 (in Finnish).
SF 7	SFS 5517	Air conditioning. Commissiong of air conditioning system. Noise measurements. 1989 (in Finnish).

FINLAND

Introduction

National building code of Finland includes regulations and guidelines. The regulations are binding. The guidelines present acceptable examples for applying the regulations. As an example, the minimum air flow rates in ventilation regulations and guidelines D2 (ref SF 1) are mentioned in guidelines, but in practice they are almost always applied.

There are no numerical values for acceptable building air tightness in the building codes. However thermal insulation regulations C3 (ref SF 3) require that the air tightness has to be good enough to comply with the thermal indoor climate guidelines (in ref SF 1). The realization of thermal climate guidelines can be measured using the appropriate standard (ref SF 5).

There is a standard for classification of window air tightness (ref SF 4). The classification is voluntary but it is widely used among window manufacturers and builders.

The building component manufacturers can use type approval procedure to show that their product will comply with the regulations. At the moment there are type approval rules for outdoor air intake devices, heat recovery equipments, air filters, supply and exhaust air devices, air ducts and air flow rate measurement devices.

FINLAND Ref: SF 1

National Building Code of Finland D2

Regulations and Guidelines 1987

Issued by the Ministry of the Environment 67 pages

Notes

The regulations are to ensure that a satisfactory indoor climate is maintained in all occupied spaces under normal weather conditions and activities in the spaces. It covers the purity of the indoor air, the temperature and humidity which must be kept under control, as well as draft, noise and excessive radiant heat.

Temperatures (Section 2.2)

Temperature control in summer is referred to and indoor air must generally not exceed +27 Deg.C. An allowance is given however when outdoor temperatures exceed +22 deg C for a five hour maximum period. Residential buildings are allowed to deviate from these values.

For winter design temperatures, outdoor values are referred to in Section D5 of the National Building Code of Finland "Calculation of performance and energy requirement for heating of buildings", which gives values for various localities. Indoor design temperatures, however, are given for different types of buildings in Appendix 1. (page 52). Effective temperature is also referred to and covers those spaces with large window areas or with radiant heating.

Purity of Air (Section 2.3)

Impurities in the indoor air must be kept below the guide values given for outdoor air which include sulfur dioxide, nitrogen dioxide, and carbon mononoxide. Design indoor values are also given for formaldehyde, radon and carbon dioxide which must not be exceeded. The content of other impurities in non-exceptional spaces shall not exceed 1/10 of the content known harmful in working area air.

Table 1. Summary of Air Quality Requirements.

		annual ave.	daily ave.	hourly ave.
Sulfur dioxide	mg/m3	40	200	500
Nitrogen dioxide	mg/m3		150	300
Carbon monoxide	mg/m3		10	30
Particles	mg/m3	60	150	
1) 8 hours				
Formaldehyde	new buildings (existing buildings	0.15 mg/m3 0.30 mg/m3)		
Maximum	new buildings existing buildings	200 Bq/m3 800 Bq/m3		
Carbon Dioxide	2500 ppm (of which 1500 ppm is produced by metabolism).			
(If the outdoor air flows are controlled based on the carbon dioxide content of the indoor air, a maximum setpoint of 800 ppm (cm3/m3) may be used.)				

Humidity (Section 2.4)

Humidity levels must be controlled to prevent hazards to both health of the occupants and to the building structure. Some guidance is given on means of control and where humidification may be required.

Noise (Section 2.5)

Noise from mechanical ventilation plant must not exceed values given in Appendix 1 for the various spaces in different types of buildings. Section C1 "Soundproofing" of the National Building Code of Finland includes regulations concerning the total sound level caused by all HVAC equipment in combination.

Ventilation Requirements (Section 3 to 3.6)

These are dealt with in some detail covering 26 pages. It mainly deals with the mechanical ventilation in buildings and gives design guidance for both smoking and non-smoking areas. Energy saving considerations are taken into account by giving guidance on how both mechanical and natural ventilation can be controlled.

The rates of fresh outdoor air, and recirculated air are defined and values for the various spaces in buildings are given. Typical requirements for offices are reproduced in Table 2. Tables are included for 14 classifications of buildings.

Table 2. Summary of Office Building Requirements

Space/Use	Air temp.	Eff. temp.	Draft char.	Outdoor air rate (transfer air – s)		Retur air rate	
	°C	°C		dm³/s,pers	dm³/s,m²	dm³/s,unit	dB(A)
2.1 Office room	21	20	2	10	1		35
2.2 Open office	21	20	2	10	1.5		35
2.3 Conference Room	21	20	3	10	4		35
2.4 Drafting room	21	20	2	10	1.5		35
2.5 Spaces for public service	21	19	4	6	2		40
2.6 Exhibition space	20	18	4	5	1.5		40
2.7 Data processing rooms							
- processor room	21	19	5	4	0.4		55
- printer room	21	19	4	4	0.4		55
2.8 Archive, storage	20	18 (no work area)			(s)	0.35/m²	45
2.9 Cafeteria, rest rm.	20	19	3	10	5		40
2.10 Copying room	20	18			1	4/m²	45
2.11 Office corridor, lobby	20	18	5				40
2.12 Smoking room	20	19	3	10	5	10/m²	40
2.13 Classroom	21	20	3	10	4		35

Design Aspects

Also in dwellings the fresh outdoor air flow rates are given for each room. In bedrooms the minimum air flow rate is 4 litres per second per person or 0,7 litres per second per square metre floor area. In living rooms 0,5 litres per second per square metre is required.

Exhaust air flow rates are in kitchen 20, in bathroom 15 and in toilet 10 litres per second. these exhaust air flow rates can be reduced when these spaces are not in use provided that the air change rate in the whole dwelling is above 0,4 air changes per hour and the minimum air flow rates in bedrooms and in living rooms are fulfilled.

Appendix 2

Covers the instructions and ventilation of motor vehicle shelters, and applies mainly to car parks. They do not apply to vehicle repair or service shops, bus terminals or other spaces of continuous working activity integrated with the car parks.

FINLAND   Ref: SF 1

Air leakage of the building fabric

Whilst air sealing of fabric and windows are considered factors affecting the indoor climate, no values of allowable leakage rates are given in this document.

Such design aspects as air distribution, air pressures, outdoor air intake, and exhausts are all covered with guidance given. The discharge of exhaust air is based on five separate classifications with examples given of each. A table is given for the distances separating the location of the exhaust opening for the different classifications of exhaust air, and the site of other openings or areas in or around the building that the discharge might affect.

Leakage of the mechanical ventilation system is limited to 6% of the total system flow rate at operating conditions. Three classes of air sealing are given for ventilation ductwork operating at different pressures and in different locations.

Performance.

The ventilation system must be fully documented with all relevant information supplied. It must be commissioned and tested with permitted variations from design values given. It shall have been designed so as to facilitate the easy cleaning, maintenance and repair operations. It must be furnished with safety protection devices and suitable surveillance measuring devices, and shall be equipped with full operating instructions for the user.

Germany

FEDERAL REPUBLIC OF GERMANY STANDARDS

Reference No.	Standard No.	Title
D 1	DIN4701	Rules for the calculation of the heat requirements of buildings. (Regeln fur die Berecnnung des Warmebedorfs von Gebauden).March 1983
D 2	DIN18055	Windows. Air permeability of joints, water tightness and mechanical strain. Requirements and testing. (Fenster. Fugendurchlassigkeit und Schlagregendichtheit, Anforderungen und Prufung), 1981.
D 3	DIN4108 (Part 2)	Thermal insulation in tall buildings. (Warmeschutz im Hochbau). 1982.
D 4	DIN(EN42)	Methods of testing windows. Part 1: Air permeability tests 1981.
	DIN(EN77)	Methods of testing windows. Part 2: Wind resistance tests, 1981.
	DIN(EN78)	Methods of testing windows. Part 3: Form of test report, 1981.
	DIN(EN86)	Methods of testing windows. Part 4: Water tightness test under static pressure, 1981.
	DIN(EN107)	Methods of testing windows Mechanical tests, 1982.
D 5	DIN1946 (part 1)	Room ventilation, fundamentals (VDI ventilation rules) (Raumlufttechnik Grundlagen) Sept.1986
D 6	DIN1946 (Part 2)	Room ventilation technique; technical health principles (VDI ventilation rules) (Raumlufttechnik, Gesundheitstechnische Anforderungen). 1983
D 7	DIN1946 (Part 4)	Ventilation plants (VDI ventilation rules). Ventilation in hospitals. (Raumlufttechnische Anlagen; Raumlufttechnische Anlagen in Krankenhausen). 1978.

FEDERAL REPUBLIC OF GERMANY STANDARDS

Reference No.	Standard No.	Title
D 8	DIN 1946 (Part 5)	Ventilation in schools (VDI ventilation rules) (Luftungstechnische Anlagen Luftung von Schulen) 1967.
	DIN 1946 (Part 6)	Ventilation of dwellings (VDI ventilation rules). draft in preparation, published possibly March 1989.
D 9	VDI 2088	Ventilation installations in dwellings (Luftungsanlagen fur Wohnungen) 1976
D 10	DIN18017 (Part 3 & 4)	Ventilation of bathrooms and shower rooms without outside windows with ventilators; rules for the calculation of air flow requirements (Luftung von Badern und Spulaborten ohne Aubenfenster mit Ventilatoren; Rechnerischer Nachweis der ausreichenden Volumenstrome). 1974
D 11	DIN18017	Ventilation of bathrooms and WC's without outside fans; amendment 1, draft April, 1988.
D 12	VDI 2053	Ventilation plants for garages and tunnels, draft April, 1987.

FEDERAL REPUBLIC OF GERMANY

Building laws and regulations are often issued jointly by the Federal Government and the individual Federal States, but it is the responsibility of the States to enforce the regulations. Most standards are produced by the German Standards Institute (DIN) with more specialised guidelines being produced by the German Institute of Engineers (VDI). Laws, regulations, standards and guidelines are closely related and details of governmental decrees concerning building are often derived from, or set out in, relevant standards.

DIN 4701 (D 1), giving rules for the calculation of heat requirements of buildings, is related to the heating design regulations issued by the Government in 1978 (updated 1982) under the Energy Conservation Law of 1976. The heating design regulations give heating requirements for different building types and these are being applied to bring existing buildings up to a stipulated level of energy efficiency. DIN 4701 gives procedures for calculating ventilation heat loss (including effects of stack and wind pressure) and applies to all heated buildings. The calculation assumes a minimum air change rate of 0.5 ach per room and gives estimates for the air permeability of the building, including a table of permeability coefficients for doors, windows and other building components in m3/m/h/Pa2/3.

DIN 18055 (D 2) classifies windows by exposure level and gives acceptable air permeability values for each group under pressure. DIN 4108 (D 3) is also related to the heating design regulations as it gives standards for adequate thermal insulation and includes recommendations for sealing joints and installing vapour barriers. DIN (EN42) (D 4) gives a pressure chamber method for testing the air permeability of windows, based on European Standard EN42. Further standards deal with wind resistance tests etc.

There are a series of standards concerned with ventilation. The main publication is DIN 1946 which is divided into several parts. Part 1 (D 5) deals with fundamental concepts of ventilation; this includes general formulae and units for natural ventilation, and descriptions of different systems of natural ventilation. Part 2 (D 6) is concerned with indoor air quality and gives a minimum air flow rate of 20-30 m3/h/person to maintain acceptable air quality. Parts 4 and 5 (D 7 and D 8) give minimum air change rates for hospitals and schools using mechanical ventilation; the values for internal bathrooms and WC's have been incorporated into DIN 18017 (D 10) (see Table 1). But there are also several other standards, concerning e.g. ventilation in garages and tunnels (D 12).

FED.REP.OF GERMANY

Table 1: Minimum ventilation rates according to VDI 2088 and DIN 18017

Living Rooms	1 - 1.5 ach
Bathrooms and toilets	6 ach
Kitchens (exhaust ventilation)	120 m3/h
Internal bathroom (exhaust ventilation)	60 m3/h
Internal toilet (exhaust ventilation)	30 m3/h

Italy

ITALY STANDARDS

Reference No.	Standard No.	Title
I 1	Law 30.04.76 n.373	Energy Conservation in Building Heating.
I 2	UNI 7357	Calculation of heat requirements for building heating.
	Min.decr. 05.07.75	Ventilation requirements for residential buildings.
	Min.decr. 02.02.76	Ventilation requirements for schools.
I 3	EN 42	Methods of testing windows: Air permeability.
	UNI 7979	Classification of window performance.

ITALY Ref: I 1

Law 30.04.1976 n.373: Energy conservation in building heating.

This law applies to residential and commercial buildings of new construction (or buildings which undergo substantial refurbishing). A similar law applies to industrial buildings.

Constraints are applied on the installed power of the space heating plant, which may not exceed the following value:

$$Qmax = (Cd,max + Cv,max)\ V\ (Ti - To)$$

where:

Cd,max = maximum heat loss coefficient due to envelope heat transmission (W/m3 deg.C.)
Cv,max = maximum heat loss coefficient due to air infiltration and ventilation (W/m3 deg.C)
V = gross volume of the heated part of the building
Ti = indoor design temperature (normally 20 deg.C)
To = outdoor design temperature

The value of Cd,max is determined as a function of the surface-to-volume ratio of the building and of the degree-days of the town where the building is located.

The value of Cv,max takes on different values depending on the type of building and ventilation strategy which is considered.

a) Naturally ventilated residential buildings

Cv,max is given by the equation:

$$Cv,max = 0.35\ ACH$$

where ACH is conventionally assumed equal to 0.5; hence:

$$Cv,max = 0.175 \quad (W/m3\ deg.C)$$

b) Other building categories

The value of ACH must be calculated according to the existing standards and codes. Buildings must then be equippped with mechanical ventilation and heat recovery, if any of the limited given in Table 1 are exceeded.

The law further states that, if the heat recovery equipment is required, the recovered fraction of ventilation heat should not be less than 50%

ITALY Ref: I 1

Table 1.

1400-2100 degree-days > 2100 degree-days

Ventilation flow rate (m3/h)	Yearly hours of operation (h/yr)	Ventilation flow rate (m3/h)	Yearly hours of operation (h/yr)
2000	3400	2000	2400
7000	2400	7000	1700
12000	2300	12000	1600
30000	1900	30000	1350
60000	1800	60000	1250

Ventilation standards

1) Standard UNI 7357: Calculation of heat requirement for building heating

In the calculation of ventilation heat demand, the following prescriptions are recommended:

Minimum suggested natural ventilation rates

Kitchens:	1 ach
Bathrooms:	2 ach
Ante-bathroom:	1 ach

Entrance halls: 10 m3/h times the number of rooms accessible from the entrance.

Spaces of normal human occupancy (living rooms, bedrooms, etc.): 15 m3/h-person; if the number of persons is unknown, assume one person per 10 square meters of floor area.

The standard also provides equations for the calculation of natural ventilation/infiltration flow rates as a function of:

1) size and type of windows, doors and ventilation grilles,
2) building dimensions,
3) wind speed and,
4) indoor/outdoor air temperature.

Mechanically ventilated buildings

Reference is made to the binding prescriptions of Law 30-04-76 n. 373 (see IT 1).

2) Ministerial decree 05-07-75 (residential buildings)

In all dwellings, bedrooms, living rooms and kitchen must be provided with an openable window of area not less than 1/8th of the floor area (articles 2 and 5).

Where natural ventilation is unlikely to be satisfactory, mechanical ventilation shall be provided at points of production such as kitchens and bathrooms (article 6).

The bathrooms must be provided with an external opening, or must be mechanically ventilated.

3) Ministerial decree 02-02-76 (schools)

The following minimum air change rates are prescribed for schools:

Type of space	air change rate
Classrooms:	
Kindergartens	2.5 ach
Grammar Schools (1st-5th grade)	2.5
Intermediate Schools (6th-8th grade)	3.5
High Schools	5.0
Office spaces and corridors	1.5
WC's, gyms, cafeterias	2.5

An envelope air leakage value is specified: the infiltration rate across 1 square meter of exterior envelope should not exceed 10 m3/h at a pressure difference of 10 mm of water (98 Pa).

Standards on external windows issued by UNI - Ente Nazionale Italiano di Unificazione

1) Laboratory testing of window performance

Laboratory tests on windows are performed according to a set of standards grouped under the common heading "Methods of testing external windows". Among such standards, the European Standard EN42 "Methods of testing windows: Air permeability" is adopted in Italy as national standard.

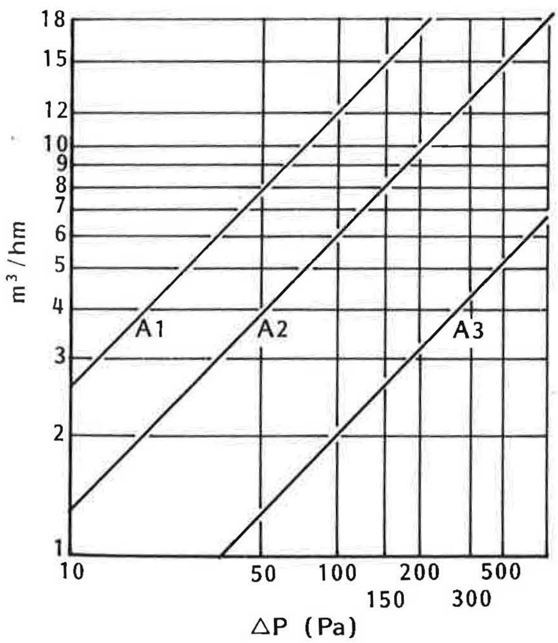
2) Classification of window performance

Standard UNI 7979 classifies external vertical windows according to air permeability, water tightness and resistance to wind action.

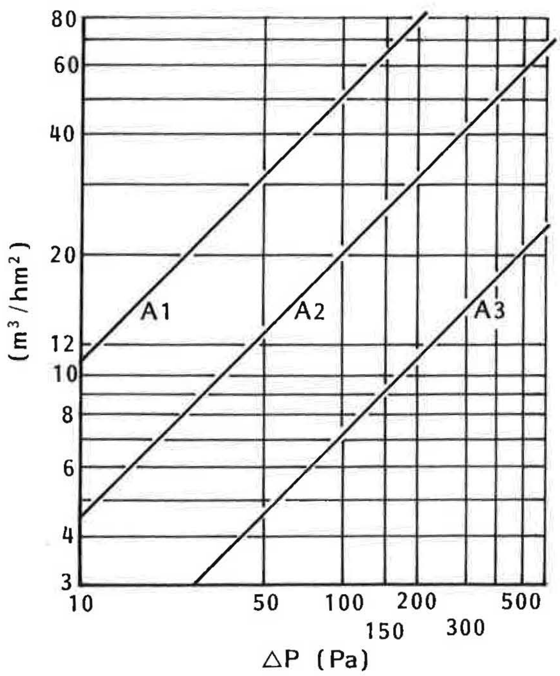
As for air permeability, windows are classified into three categories (A1, A2 and A3, in ascending order of air tightness), based on the results of a laboratory test performed according to the norm EN42. Results of the test are expressed in terms of air flow rate per unit length of opening (or per unit area of window) as a function of pressure difference, as shown in Figure 1. Windows performing worse than A1 are not rated.

Figure 1:

Air Flow Rate per Unit Length of Opening



Air Flow Rate Per Unit Area of Window



Netherlands

NETHERLANDS STANDARDS

Reference No.	Standard No.	Title
NL 1	NEN 2687	Air leakage of dwellings - Requirements - (Draft). (Luchtdoorlatendheid van Wongningen)-Elsen NNI 1987.
NL 2	NEN 1089	Ventilation in school buildings Requirements. (Ventilatie van Schoolgebouwen) Elsen. NNI 1986
NL 3	NEN 3661	Window frames -Air permeability, water tightness, rigidity and strength. (Gevelvullingen Luchtdoorlatendheid, Waterdichtheid stiffheid en sterkte) Elsen NNI 1988.
NL 4	NEN 2686	Air leakage of buildings - Method of measurement. (Luchtdoorlatendheid van gebouwen Meetmethode) NNI 1988.
NL 5	NEN 3660	Window frames - Air permeability, rigidity and strength. Methods of test. (Gevelvullingen Luchtdoorlatendheid, stiffheid en sterkte Beproevingsmethoden.) NNI 1988
NL 6	NEN 1087	Ventilation in dwellings. Requirements. (Ventilatie van Woongebouwen) NNI 1979+ amendment 1981.
NL 7	NPR 1088	Ventilation in dwellings: Indications and examples for constructional performance of ventilation supplies (Ventilatie van Woongebouwen Praktijtichtlijn) NNI 1975.
NL 8	NPR 1019	Ventilation in school buildings... examples of construction based on NEN 1089 (Ventilatie van Schoolgebouwen Voorbeelden van bouwkurdige oplossingen, afgestemd op) NEN 1089.

Standard NEN 2687 dated November 1987

Air Leakage of dwellings - Requirements (Draft)

This standard only applies to dwellings, but work is currently taking place for commercial buildings (NEN 2688).
The envelope airleakage rate at 10 Pa, is defined according to the type of ventilation system.
The systems are categorised A,B,C,D, as laid down in standard NEN1087. (also as NEN 1089) See Table 1.

Table 1.

Class	Ventilation System following standard NEN 1087
1	Natural Ventilation (System A)
	Natural supply with mechanical extract (System C)
2	Mechanical supply and natural extract (System B)
	Mechanical supply and extract (System D)

Table 2 outlines the maximum permitted air leakage at an applied pressure of 10 Pa while Table 3 lists the minimum permitted leakage.

Table 2. Maximum Recommended Air Leakage

Class	Building Volume m3		Flow Rate at 10 Pa
	Greater than >	Less than <	~~M3/hr~~ dm^3/s
1	-	250	100
	250	500	150
	500	-	200
2	-	250	50
	250	-	80

Remarks: It is advisable to have a minimum flow rate for hygiene (if ventilation system is switched off). Also natural ventilation shafts can be subjected to back draft if the facade of the building is too tight. Minimum airleakage levels are recommended as in Table 3.

Table 3. Minimum recommended air leakage.

Class	Building Volume m3		Minimal Flow rate at 10 Pa
	Greater than>	Less than<	dm3/s ~~m3/hr~~
1	-	250	30
	250	500	50
	500	-	50

A further Table in the standard gives comparison of flow rates at 10 Pa pressure difference compared with 50 Pa and with an equivalent leakage area.

Appendix C of the Standard gives a method to estimate ventilation and energy losses on the basis of airtight values.

It also discusses the influence of window opening on these losses.

NETHERLANDS Ref: NL 2

Standard NEN 1089 dated October 1986

Ventilation in School Buildings - Requirements

This standard applies to any building or part of a building used for educational purposes, and is based on hygiene requirements and carbon dioxide concentrations.
The fresh air requirements of 5.5 dm3/S/pupil is the minimum ventilation rate which approximates to a carbon dioxide concentration of 1200 parts per million.

Additional requirements are listed in Table 1.

Table 1: Ventilation Demands for Different Rooms Ref:NL.2

Space	Air Volume Flow	Remarks
Classroom	5.5 dm3/s per pupil	Refer 4.1 & 4.2.1.2
School Workshops	10 dm3/s per pupil	Local mechanical provisions for removal of air pollutants. Refer 4.1 & 4.2.1.2
Fire Cupboards	200 dm3/s per m2 of open area	At least by mechanical extract.
Gymnasium	1 dm3/s per m2 of floor area	
Administrative Office	10 dm3/s per person	Refer 4.1 & 4.2.1.2
Staff Room/ Meeting Room	15 dm3/s per person	At least by mechanical extract. Refer 4.1 & 4.2.1.2
Community Room Floor area<1.5 m2 per person Floor area>1.5 m2 per person	 6 dm3/s per m2 floor area 3 dm3/s per m2 floor area	 Refer 4.1 & 4.2.1.2
Kitchen < 10 m2 (Not classroom)	21 dm3/s	For kitchens more than 10m2 expert advice is required.
WC	7 dm3/s per toilet cubicle	
Washroom	14 dm3/s per shower 7 dm3/s per tap	Mechanical Extraction only. Refer 4.2.1.5
Changing Room	3 dm3/s per m2 floor area	
Cloakroom	1 air change per hour	
Stairways/Corridors	1 air change per hour	
Meter-Room		Refer 4.2.1.7
Boiler Room		Refer NEN 1078 & NEN3028
Elevator Shaft		Refer 4.2.1.6 Must not be used as ventilation shaft
Elevator for Fire Fighters		Refer NEN 1081
Lift Cabin*	1 dm3/s per person	Refer 4.1 & 4.2.1.2

* Though the elevator shaft might not be used as a ventilation duct (see 4.2.1.6), yet the ventilation-demand of the liftcabin will be reached because of the air volume of the elevator shaft being much greater than the air volume of the lift cabin, and because of the air exchange through cracks of the shaftdoors.

Tables 2 and 3 show the suitability of types of ventilation systems for different rooms in both low and tall buildings.

Table 2. Ventilation Systems for Rooms in Low School Buildings

(less than 13m to floor level)

Room Type	Room Location	Ventilation System A	B	C	D
Class room	facade	*	*	**	***
	internal	x	*	x	***
Gymnasium	facade	*	x	*	***
	internal	x	x	x	***
Gymnasium shower/ changing room	facade	x	x	*	***
	internal	x	x	**	***
Study/office commonroom	facade	*	**	**	***
	internal	x	**	*	***
Public/ common areas	facade	*	*	**	***
	internal	x	*	x	***
Kitchen (under 10m2)	facade	*	x	**	***
	internal	x	x	*	***
W C	facade	*	x	***	-
	internal	*	x	***	-
Cloakroom	facade	*	x	**	***
	internal	*	x	**	***
Staircase/ corridor	facade	*	*	**	***
	internal	*	*	*	***

x not satisfactory

* satisfactory

** more than satisfactory

*** good

Table 3. Ventilation Systems for Rooms in Tall School Buildings

(greater than 13m to floor level)

Room Type	Room Location	Ventilation System A	B	C	D
Classroom	facade	*	x	*	***
	internal	x	x	x	***
Gymnasium	facade	x	x	*	***
	internal	x	x	x	***
Gymnasium/ shower/changing room	facade	x	x	*	***
	internal	x	x	**	***
Study/office common room	facade	x	*	**	***
	internal	x	*	*	***
Public/ common areas	facade	x	x	*	***
	internal	x	x	x	***
Kitchen (under 10m2)	facade	x	x	**	***
	internal	x	x	*	***
W C	facade	x	x	***	-
	internal	x	x	***	-
Cloakroom	facade	*	x	**	***
	internal	*	x	**	***
Staircase/ corridor	facade	*	**	**	***
	internal	*	**	*	***

x not satisfactory

* satisfactory

** more than satisfactory

*** good

NETHERLANDS Ref: NL 3

Standard NEN 3661 dated August 1988

Window frames - Air permeability, water tightness rigidity and strength.

Requirements

In this latest issue the Table in the standard has been revised, and now gives air leakage through cracks in windows according to exposure level in 4 classes of test pressure for which the average leakage rate must not exceed 2.5 dm3/S per metre length of crack (Table 1). In addition there is a further requirement that the local leakage along any 100mm section of frame, should not exceed 0.5 dm3/s at the prescribed test pressures.

Table 1. Test Pressures for Different Window Categories for Which Air Leakage Must Not Exceed 2.5 dm3/s/m

Height of building in which the window is located (M)	Exposure	Pressure difference Pa
15	Normal	75
40	Normal	150
100	Normal	300
15	Coastal	300
40	Coastal	300
100	Coastal	450

Standard NEN 2686 dated July 1988
Air leakage of buildings - Method of measurement.

This is a pressurisation test method originally devised for dwellings but applies to buildings or parts of buildings up to 3000 m^3 volume, set by the practical limitation of fan capacities.

Tests should only be carried out when the natural pressure differential between inside and outside the building does not exceed 5 Pa. The equipment required to produce the pressure differences, and the instruments necessary to cover the range from 5 to 100 Pa is called for. For flow rates, the measuring accuracy in the range from 0.03 to 1.5 m^3/s should be within 5%.

Diagrams showing the configuration of the buildings and the way the test should be conducted is given.

Flow rates must be measured between certain pressure ranges to give a minimum of 5 points (see Table 1)

Table 1. Number of Measurement Points Required Per Pressure Interval

Pressure Range in Pa from	to	No.of points required
15	25	1
25	35	1
35	50	1 a 2
50	70	1 a 2
70	85	1 a 2
85	100	1 a 2

NETHERLANDS Ref.NL.4

The results must be presented in accordance with the given standard reporting format, and can be shown graphically, but the final result is a flow rate through the envelope at a pressure difference of 10 Pa.

For convenience an equivalent leakage area can be calculated using the equation

$$A_e = \frac{C \cdot V\rho}{1000 \cdot 2^{1/n}}$$

where:

A_e = equivalent opening area (m^2)

C = flow coefficient $dm^3/(s \cdot Pa^{1/n})$

ρ = density of air (kg/m^3)

n = flow exponent

This standard is specifically aimed at Architects, and examples of applications in its use are included.

NETHERLANDS Ref:NL.5

Standard NEN 3660 dated July 1988

Window frames - Air permeability, rigidity and strength
Methods of test.

There has been no change to the basic requirements of this standard since the previous issue of 1975.

NETHERLANDS Ref: NL 6 & 7

Ventilation requirements are documented in three standards. NEN 1087 (NL 6) gives minimum ventilation requirements for dwellings as 7 dm^3/s/person. It also sets out recommended ventilation rates for individual rooms in relation to floor area. NPR 1088 (NL 7) translates these flow requirements into openable window areas and size of ventilation ducts (see Table below). Most houses in the Netherlands are naturally ventilated, except for buildings above 13m tall which are required to have mechanical extract systems.

Table Minimum ventilation requirements for dwellings according to NEN 1087 and NPR 1088

Room	Air Flow per person [1] dm^3/s	Minimum ventilation openings [2] m^2
Living Room	21-42	0.02-0.04
Kitchen	21-28	0.02-0.03
Bathroom & W.C.	14	0.01

[1] Refers to NEN 1087
[2] Refers to NPR 1088

New Developments

Whole Building Regulations are to be changed and will become mandatory. Measurement Standards will be enforced, and minimum standards will be a legal requirement.

Guidelines covering new laws are being produced especially in relation to the Standard on the requirements for the ventilation of dwellings NEN 1087.

Multiblower door pressurisation testing is one of the options being considered for assessing ventilation system performance.

New Zealand

NEW ZEALAND STANDARDS

Reference No.	Standard No.	Title
NZ 1	NZS 4211:1987	Specification for performance of windows. Standards Association of N.Z.
NZ 2	NZS 1900	Model building by-law Standards Association of N.Z.
NZ 3	–	The Draining and Plumbing Regulations 1978 Dept of Health, Wellington
NZ 4	-	Factories and Commercial Premises Act 1981 Dept of Labour, Wellington

NEW ZEALAND

There are few standards in New Zealand concerned with building airtightness and ventilation rates. For domestic buildings there are no overall airtightness requirements, though windows must pass an air leakage test as set out in NZS 4211 (NZ1). This classifies windows into three levels according to air leakage performance and gives maximum rate of leakage at 150 Pa for each level. (see Table 1).

Table 1: Maximum rate of leakage at 150 Pa for different levels of window according to NZS 4211

	Rate of Air Leakage dm3/s		
	Level A	Level B	Level C
Per m. of opening joint length	0.6	2.0	4.0
Per m2 of total window area	2.0	8.0	17.0

As far as commercial buildings are concerned, there is no standard which details fabric tightness.

Ventilation requirements for domestic buildings are mentioned in Chapter 4 of NZS 1900 (NZ2). This does not specify ventilation rates directly but gives minimum area of openable window as 5% of the floor area in each room. Most local authorities in New Zealand have adopted NZS 1900.

The Drainage and Plumbing Regulations (NZ3) is government legislation specifying ventilation requirements in bathrooms, toilets and laundries in domestic and commercial buildings. This gives minimum openable windoe areas rather than minimum ventilation rates. There is no standard specifying minimum ventilation rates for commerical buildings, the closest approximation being found in 'Factories and commercial Premises Act 1981' (NZ4) which makes broad statements about the need for adequate control of the indoor environment with adequate fresh air.

Norway

NORWAY STANDARDS

Reference No.	Standard No.	Title
N 1		Chapter 53. Thermal Insulation and Airtightness (revised 1980) Building Regulations of 27th May, 1987. Royal Ministry of Local Government and Labour.
N 2	NS-INSTA 130	Airtightness of buildings. Test method. (Bygningers lufttetthet. Provingsmetode) NSF 1981
N 3	NS3206	Methods of testing windows. Airtightness. (Bestemmelse av vinduers lufttetthet) NSF 1974
N 4		Chapter 47. Ventilation and installation. (Ventilasjon og installasjoner) Building Regulations of 27th May 1987. Royal Ministry of Local Government and Labour.
N 5	NS3031	Energy and power demands for heating of buildings. Calculation rules. (Beregning av bygningers energi-og effektbehov til oppvarming) NSF 1986

NORWAY

The national building regulations give mandatory standards for airtightness and minimum ventilation rates. Chapter 53 (N 1) in the regulations gives quantified requirements for airtightness of whole buildings (see Table 1) based on a standard pressurization test method presented in NSINSTA 130 (N 2). This is almost identical to the Swedish Standard SIS 02 15 51.

Table 1. Maximum air change rate (ach) at 50 Pa for residential buildings according to the Norwegian Building Regulations.

Detached and terraced single-family houses.	4.0
Other residential buildings of not more than two storeys.	3.0
Residential buildings with three or more floors.	1.5

Chapter 47 of the building regulations covers ventilation (N 4), it consists of functional requirements and is supported by guidelines. For housing, the requirements are either a minimum sectional area of ventilation ducts from different rooms when using natural ventilation, or a specified air flow rate for rooms with mechanical ventilation (see Table 2). For other types of buildings the requirements are given as air flow rate per unit floor area. NS3031 (N 5) gives an assumed air change rate of 0.5 ach for a building when calculating ventilation heat loss.

NORWAY

Table 2. Minimum ventilation rates for dwellings according to the Norwegian Building Regulations.

Room	Fresh Air Supply	Exhaust Air	
		Cross-section of duct cm2	Air Flow m3/h
Living Rooms incl.Bedrooms	Openable windows or unrestricted ventilation opening of 30cm2 in external wall.	-	-
Kitchen	- as above -	200	80
Bathroom	Gap above/below door from adjacent room with unrestricted opening of 100cm2	150	60

Sweden

<u>SWEDEN</u> STANDARDS

Reference No.	Standard No.	Title
S 1	BFS 1988:18 Chapter 3:13 Chapter 3:14	Nybyggnadsregler."Air Tightness" and "Heat Recovery" National Swedish Board of Physical Planning & Building - 1989
S 2	BFS 1988:18 Chapter 4:1	Nybyggnadsregler. "Air Exchange" National Swedish Board of Physical Planning & Building - 1989
S 3	SS02 I5 51	Buildings - Determination of airtightness. 1987.
S 4	NT VVS 019	Method of determining the Local Mean Age of Ventilation Air in buildings - 1986.

These are new regulations covering airtightness requirements and Heat Recovery.

Standard BFS 1988:18

Chapter 3:13 Air Tightness

The average air leakage coefficient, q50, for that part of the enclosing surface which forms the boundary with outdoor air or an unheated area may not exceed 3 m2/m3h for dwellings and 6 m2/m3h for other premises at a pressure difference of 50 Pa.

A suitable method for determining the total air leakage at a pressure difference of 50 Pa is given in SS 02 15 51. The internal measurements of an enclosing surface are used when calculating the coefficient q50.

3:14 Heat Recovery

The building shall be provided with special devices which limit energy losses when operating its installations. The devices shall ensure that the building's energy demand is reduced by an amount that corresponds to at least 50% of the difference in energy content between the exhaust air and the outdoor air at standard air change rates during periods when there is a heat demand

In the cases of dwellings, the regulations are deemed to be complied with if the air treatment installations are provided with a suitably-designed heat exchanger or heat pump. A heat exchanger should transfer heat from the exhaust air to the supply air with at least 60% thermal efficiency. A heat pump should be capable of providing the dwelling's demand for domestic hot water or should provide at least the same reduction of the dwelling's heat energy requirement.

Devices are not required for buildings where the difference in the energy content between the exhaust air and the outdoor air at standard air change rates during periods where the heating demand does not exceed 2 MWh/year.

SWEDEN Ref:S 2

This Standard covers Air Exchange and Ventilation Requirements.

Standard BFS 1988:18

Chapter 4:1 Air Exchanges

A room shall have continuous air exchanges. Air exchanges shall be devised so that secretions from persons and building materials plus moisture, air pollution, unpleasant odours and hazardous substances do not accumulate.

The outdoor air flow to rooms with a normal ceiling height, occupied by persons on more than a temporary basis, shall be at least 0.35 l/s m2 of floor area. In the case of dwellings, the requirement applies to entire apartments as well as individual rooms. Rooms which demand a higher air exchange rate shall have at least the capacity stated in the following table. Areas which are occupied only temporarily shall have an air exchange rate which ensures that health risks or damage to the building or its installations do not occur.

Dwellings, hotels, etc.	
Bedrooms	0.4 l/s for each sleeping place
Kitchens, cooking alcoves	10.0 l/s forced with at least 75% capture area by the air device
Pantry	15.0 l/s
Bathroom with openable window	10.0 l/s[1]
Bathroom without openable window	10.0 l/s[1], forced to 30 l/s, or 15.0 l/s
Toilet	10.0 l/s
Laundry room, drying room leisure area	10.0 l/s[1]
Work areas, public assembly areas, shop premises, etc.	
Rooms for sedentary work	5.0 l/s per person
Rooms for mobile work	7.0 l/s per person
Rooms where smoking is permitted	10.0 l/s per person
Toilet facilities	10.0 l/s per toilet seat

Standard BFS 1988:18

Chapter 4:1

Utility Areas	
Cleaning rooms	3.0 l/s m^2 floor area but at least 15 l/s
Refuse rooms	5.0 l/s m^2 floor area
Refuse rooms for storing dry refuse	0.35 l/s m^2 floor area
Waste disposal chutes for 3 apartments	50.0 l/s
Waste disposal chutes for 4 or more apartments	75.0 l/s

1. If the floor area is greater than 5 m^2, the air change rate shall be increased by 1 l/s for each additional m^2.

A suitable method for testing the capture capacity of a cooker extractor fan or a kitchen hood is given in SS 433 05 01.

SWEDEN Ref: S 3

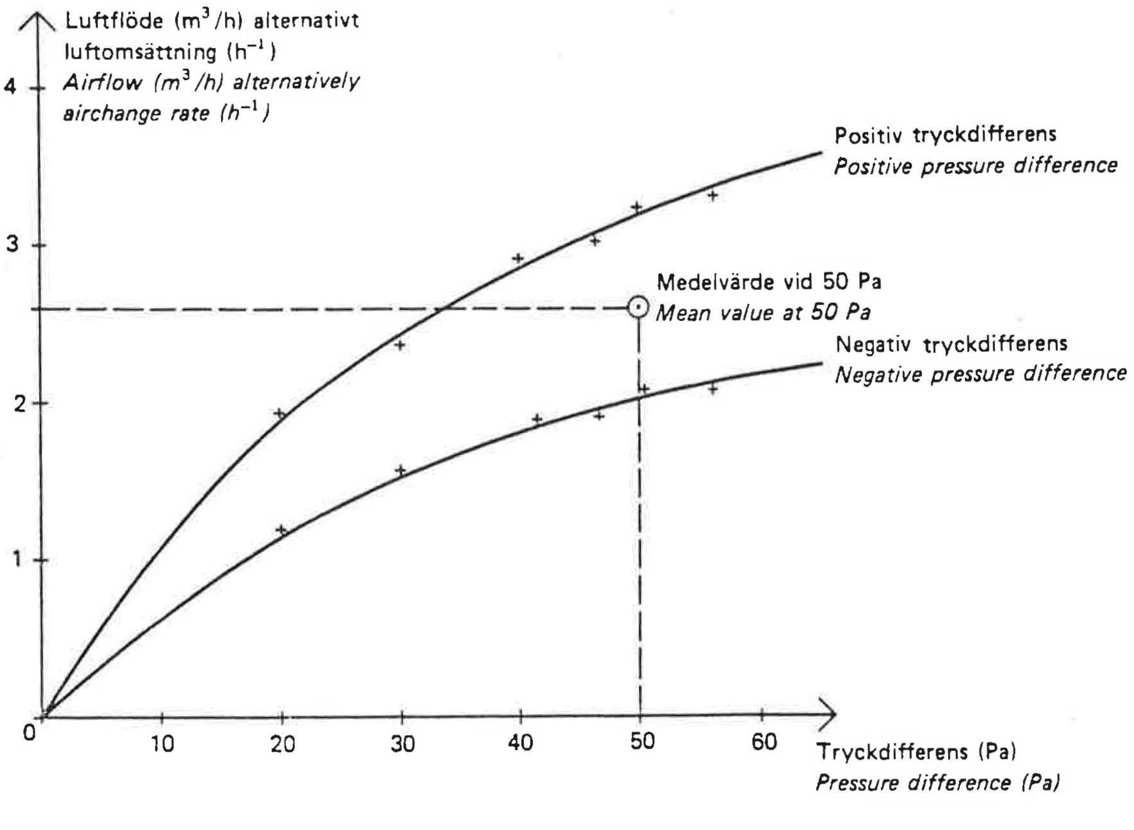
Standard SS 021551 - 1987

Buildings - Determination of airtightness

The previous issue of this standard applied only to detached one-family houses. This updated edition makes it applicable to all types of buildings and flats.

The method described is designed to measure the total air leakage through the building elements, or the envelope surrounding a specific building or part of building.
A fan is used to supply, or exhaust air from a building at rates required to maintain specified pressure differences across the envelope. The air flow rates relating to the pressure differences maintained are measured and recorded. Tests are carried out for pressure differences of 20, 30, 40, 45, 50, and 55 Pa and the results are presented in a table and a diagram form for both positive and negative pressures. See Fig.1.

Fig.1 Presentation of test results.



A Revision of NT VVS 019

NORDTEST Method of determining the Local Mean Age of Ventilation Air in Buildings.

This method is primarily applicable to spaces served by Mechanical Ventilation.

The Local Mean Age is defined as the time that elapsed since air molecules enter a room and pass an arbitrary point in that room.

By measuring the mean age of air at several points, it is possible to follow the distribution of ventilation air within the space, and to determine therefore whether the space surrounding the measuring point is well ventilated or not, or if stagnation exists. It also allows the movement of contaminants in the space to be determined and where they are concentrated.

The principle of the test is accomplished by liberating a tracer gas into the space and measuring the decay rate. The test is accomplished by releasing tracer gas into the actual space and letting it decay without disturbing the air movements created by the ventilation system and other natural sources. The tracer gas concentration is continuously recorded at the point, or points, of interest. From the concentration readings the area under the decay curve is calculated. From the initial concentration and the area under the curve the local mean age is then determined.

The apparatus required, and the procedure for carrying out the tests is laid down, and the method for expressing the results is given together with an example.

Switzerland

SWITZERLAND   STANDARDS

Reference No.	Standard No.	Title
CH1	SIA 180	Thermal protection of buildings Warmeschutz im Hochbau
CH2	SIA 331	Windows Fenster
CH3	SIA 380/1	Building energy performance Energie im Hochbau
CH4	SIA 382/1	Ventilation and AC Plants, technical requirements Luftungstechnische Anlagen, technische Anforderungen (Draft)
CH5	SIA 382/3	Ventilation and AC Plants, procedure to get permission to install cooling and/or humidification devices. Luftungstechnische Anlagen, Bedarfsnachweis
CH6	SIA 384/2	Heating load calculation Warmeleistungsbedarf von Gebauden
CH7	SWKI 85-1	Ventilation installations in indoor swimming pools Luftungsanlagen in Hallenbadern
CH8	SIA 384/1	Central heating plants, water heating systems Warmwasser-Zentralheizungsanlagen
CH9	SIA 380/7	Haustechnik

SWITZERLAND

Each canton and several cities have their own building and energy codes, which differ in content and style.

There is no legal possibility for the Swiss Government to implement federal building laws. Nevertheless, there are trends to cooperate in connection with the development of codes, on one side between different cantons and on the other side between engineering associations and governmental bodies.

Voluntary codes of practice in the field of ventilation are issued by the following organisations:

a) Swiss Standards Association.
   Schweizerische Normenvereinigung (SNV)

b) Swiss Society of Engineers and Architects
   Schweizerischer Ingenieur - und Architektenverein (SIA)

c) Swiss Association of Heating and Cooling Engineers (affiliated with ASHRAE)
   Schweizerische Warme - und Klimaingenieure (SWKI)

d) Swiss Institute of Public Health and Hospitals
   Scheizerisches Institut fur Gesundheit und Krankenhauswesen

The following summaries of standards will show that there has been an intensive development in the last few years.

Summaries of the main Standards

- SIA 180 deals with thermal protection, comfort and condensation problems for all seasons. Main issues with respect to the ventilation and leakage problems are:

- proper definitions of the key words in this field

- general guidelines for adequate ventilation

- provisional recommendations for N_{L50} - values (see Figure 1).

First experience with the application of N_{L50} - values shows that these values would need some refinement, especially in cases where different parts of the building shell differ considerably as to their leakage.

- SIA 331 contains upper limits for the leakage values of windows. In earlier versions of SIA standards this so called a-value (leakage value) varied according to the height of the building where the window would be used. In the recent editions there is only one value for a (0.2m3/h m Pa2/3). (Figure 2)

SWITZERLAND

Experience shows that new windows are easily 10 times tighter than this value; this prohibits in many cases a certain basic ventilation.

The new energy performance Standard 380/1 is basically a calculation procedure for the determination of the energy consumption of a building. The calculation has to be executed in the design stage. As an exception, small buildings may be designed by fixing some specific limit values (heat transfer coefficient, window - a - value) instead of the complete calculation. The building permit is based on reaching a certain energy consumption and some minimum efficiency for the plant inclusive of the distribution system.

For ventilation there are certain "standard ventilation values" inserted in the calculation, either for natural or for mechanical ventilation.

As a definite change, SIA started in the last few years to issue ventilation standards. The first 2 of the 3 expected standards have been printed in spring 1989 as drafts.

Standard 382/1 contains all major requirements of a ventilation/AC plant. One of the most interesting parts is a table of recommended ventilation rates for different room types (see Figure 3).

The second Standard (382/3) contains a method to check the need of installing cooling and/or humidification devices for certain buildings and uses. This standard is an important instrument to be applied, in order to get a building permit for these installations.

The so called "Heizlastregel" (SIA 384/2) contains a procedure to calculate the ventilation losses for the winter design situation. There is a rule, that either ventilation losses induced by windows or at least an air change rate of 0.3 h (in cases with very tight windows) have to be inserted for this design condition. This does not mean that air change rates will not be higher during the whole winter season.

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Besides the standards mentioned above there are standards applicable to some specific room types, as the one on swimming pools or the rules for the ventilation needs of garages or working rooms. The list of standards is not exhaustive and planners use, in many cases, the relevant German VDI rules, as these standards are much more refined.

Recent years have been productive in a creation of standards in this field. These activities have been supported by the efforts to save energy or by the needs of improving room air quality

Figure 1. Overall leakage of the building, openings closed

	nL 50-Values h-1	
	Lower Limit	Upper Limit
Single family home (with window ventilation)	2	4.5
Multi family home (with window ventilation)	2.5	3.5
New Homes with exhaust ventilation	2	3
Buildings with balanced ventilation or AC plants	-	1

The values or value ranges above are meant for a medium wind exposition of a building. In severe wind expositions or in strongly sheltered positions it is recommended for the first 3 categories to verge towards the appropriate ends of the ranges.

For buildings with window ventilation, where the leakage is lower than the lower end of the range, provisions have to be made, to guarantee the necessary basic ventilation rate.

In buildings with exhaust ventilation appropriate inlet openings have to be planned, in order to guarantee an appropriate ventilation of all necessary zones.

SWITZERLAND

Figure 2. Air Leakage (S1A 331)

Group	A	B	C
Pressure in Test in Pa)	150	300	600
Building Height in m)	0..8	>8...20	>20..100
Requirements:			
Max a-value [m(3)/hm.(2/3)Pa]	0.2	0.2	0.2
V max at test cond.[m3/h.m.]	5.65	8.95	14.25

Figure 3. Recommended Ventilation Rates Per Person (S1A 382/1)

Room type	Smoking	Recommended Outside air rate per person [m3/hr.Pa]
Schools	Prohibited	12-15 (1.15%CO2)
Offices	Prohibited	25-30 (0.10%CO2)
Offices	Yes	] 30.70
Open plan offices	Yes	]
Shops	Prohibited	12-15 (0.15%CO2)
Theatres,concert halls	Prohibited	25-30 (0.10%CO2)
Hotel rooms	Yes	30-70
Conference rooms	Yes	
Restaurants	Yes	40-50
Hospital (bedrooms)	Prohibited	20-50

Recommendation of a basic air change rate of 0.3 h in unoccupied rooms or rooms with low occupancy.

United Kingdom

UNITED KINGDOM STANDARDS

Reference No.	Standard No.	Title
UK 1		Building Regulations Part F. 1985 Department of Environment. Revised 1990.
UK 2		Building Regs Part J.1985 Department of Environment. Revised 1990.
UK 3		Scottish Building Regs Part K.1988 Draft. Department of Environment.
UK 4	BS5925:1990	Code of Practice for design of Buildings: Ventilation principles and designing for natural ventilation.
UK 5	BS5720:1979	Mechanical Ventilation
UK 6	BS5250:1989	Basic data for the design of buildings: the control of condensation in dwellings.
UK 7	BS6375:1983	Performance of windows.Part 1: classification of weathertightness.
UK 8	BS6229:1982	Practice for Ventilation of flat roofs.
UK 9		Determining air tightness of buildings.
UK 10	BS5368 Pt 1:1976	Methods of testing windows.Part 1 Air Permeability Test.
UK 11	88/13390 Draft	Specification for Draughtstrips for the draught control of existing doors and windows in housing (Including test methods) Anticipated Publication Feb/Mar. 1990.

UNITED KINGDOM Ref:UK.1

Building Regulations 1985 Part F. Revised 1990.

Department of the Environment.

This is a document approved by the Secretary of State as practical guidance to meet the requirements of the Building Regulations with regard to providing means of ventilation and to minimising condensation in roofs. There is no obligation to adopt any particular solution in the document, provided it can be demonstrated that the requirements have been met by other means.

Other Standards referred to:

BS.5925:1989.	Code of Practice for design of buildings: Ventilation principles and designing for natural ventilation.
BS.5720:1979	Code of Practice for mechanical ventilation and air conditioning in buildings.
BS.5250:1989	Code of basic data for the design of buildings: the control of condensation in dwellings.
BS.6229:1982	Code of Practice for flat roofs with continuously supported coverings.

F1 - means of ventilation

Adequate supplies of air for ventilation shall be provided for people in dwellings, rooms containing sanitary conveniences, and bathrooms.

The requirements will be satisfied if there is:

(a) for rapid ventilation one or more ventilation openings with a total area of at least 1/20th of the floor area of the room, and with some part of the ventilation opening at least 1.75m above the floor level, e.g. an opening window; and

(b) for background ventilation a ventilation opening (or openings), having a total area not less than 4000 square millimetres, e.g. a trickle ventilator. The opening(s) should be controllable and secure and located so as to avoid undue draughts.

Natural ventilation may be used, provided openings are based on the sizes given in Table 1.

Table 1. Natural Ventilation Ref:UK.1

Room or Space	Ventilation to be provided (Ventilation openings)
1. In dwellings: habitable rooms, kitchens and bathrooms	At least one ventilation opening with an area of at least 1/20th of the floor area of the room or space. Some part at least of the ventilation opening to be at least 1.75m above the floor level.
2. In buildings containing dwellings:	At least one ventilation opening with an area at least 1/50th of the floor area of the space.
3. In any building: Sanitary accommodation	At least one ventilation opening with an area of at least 1/20th of the floor area of the room or space.

Mechanical ventilation must provide the air changes listed in Table 2 if the requirements are to be met.

Table 2. Mechanical Ventilation

Room or Space	Ventilation to be provided (air changes per hour)
1. Dwellings	
(a) habitable rooms	1
(b) kitchens	3
(c) bathrooms	3*
2. In buildings containing dwellings	
(a) common spaces	1
3. In any building	
(a) sanitary accommodation	3*

* Note: The ventilation may be intermittent but should run for at least 15 minutes after the use of the room or space stops.

F2 - Condensation

This requirement applies only to dwellings and is to prevent excessive condensation in a roof void above an insulated ceiling.

It deals with both pitched and flat roofs and prescribes widths of continous openings at eaves level, and in some cases with outlets at high level, to promote a cross flow of ventilation to expel moisture laden air that has built up in the roof space.

Ventilation Openings in Roof Voids at Eaves Level

Roof	Width of opening at least equal to a continuous strip.
Pitched	10 mm
Flat	25 mm

UNITED KINGDOM Ref:UK.2

Building Regulations 1985 Part J

Department of the Environment.

This part of the regulation is to ensure that provision is made for supplying fresh air to heating appliances to give satisfactory combustion conditions and to expel the products of combustion from the building through flues.

Section 1 covers solid fuel and oil burning appliances with rated outputs up to 45 kw and Section 2 deals with gas burning appliances with rated inputs of up to 60 kw.

A Table showing the areas of openings for solid and oil fired appliances is given below:

Supply of air for combustion.
Section 1 Part A J/1/2/3

Table 1. Supply of Air for Combustion.

Type of Appliance	Type of Ventilation
Solid fuel burning open appliance	An air entry opening or openings with a total free area of at least 50% of the appliance throat opening area, - as defined in BS.8303:1986 Code of Practice for installation of domestic heating and cooking appliances burning solid mineral fuels.
Other solid fuel appliance	An air entry opening or openings with a total free area of at least $550mm^2$ per kW of rated output above 5kW. Where a flue draught stabiliser is used the total free area should be increased by $300mm^2$ for each kW of rated output.

UNITED KINGDOM Ref:UK.3

Scottish Building Regulations

Part K. Ventilation of Buildings Draft dated December, 1988.

The intention of this part is to ensure an adequate supply of air available for human occupation of a building which may be provided by natural means, natural with mechanical assistance, or wholly mechanical systems. It does not apply to buildings covered by the Factories Act 1961, but is intended for dwellings, garages and buildings other than dwellings or garages.

For dwellings ventilation must be supplied by either natural or mechanical means in accordance with Table 1.

Table 1. Ventilation Requirements for Dwellings

Space	Cross-sectional Areas Required for Natural Ventilation		Mechanical Ventilation
	Ventilator	Trickle Ventilator	
Habitable rooms	1/30th floor area *plus*	4000 mm2 *or*	3 air changes per hour(1)
Kitchens	-	4000 mm2(2)	Extract (1) 64 l/s at full speed
W.C.	1/30th floor area	- *or*	3 air changes per hour.
Bathrooms & Shower rooms	-	-	28 l/s at full speed

(1) must be able to operate continuously at low speed.

(2) must be provided if (1) above is not employed.

For buildings other than dwellings or garages, rooms must be provided with either means for natural ventilation or mechanical ventilation which is capable of continuous operation at low speed and designed in accordance with BS5720:1979 and the CIBSE Guide:1986.

Where natural ventilation is employed, the ventilator must have an opening area 1/30th of the floor area of the room.
See Table 2.

Table 2 Ventilation Requirements for Buildings Other than Dwellings or Garages.

Space	Cross sectional areas required for natural ventilation	Mechanical Ventilation
Room	1/30th floor area	Required if volume less than $5m^3$
Kitchens Cooking Prep.and wash up		Extract 20 air changes per hour 10 air changes per hour
Washrooms & W.C	1/30th floor area or	3 air changes per hour
Bathrooms & Showers		28 l/s at full speed
Communal laundry		Extract 10 ach (1)
Storage room more than $4m^2$ floor area	600 mm^2/m^2 of floor area	must be able to operate continuously at low speed.
Stairways and passages	800 mm^2/m^2 of floor area	must be able to operate continuously at low speed

(1) must be capable of continuous operation at low speed unless trickle ventilation provided.

Garages with floor areas greater than $30m^2$ must have provision for either natural or mechanical ventilation, and requirements are laid down based on their floor areas.

The locations of ventilation openings for both natural and mechanical ventilation is dealt with in the latter part of the regulation.

British Standards Institution BS 5925:1989

Code of Practice for: Design of Buildings : Ventilation principles and designing for natural ventilation.

The Code deals with ventilation of buildings for human occupation, and where possible, recommended quantative air flow rates are given for different types of buildings and rooms, characterized by usage. The basis for the choice between natural and mechanical ventilation is given, and guidance on the design of natural ventilation systems is included in this standard.

The design of mechanical ventilation systems is dealt with in BS 5720 (UK 5).

Outdoor air requirements based on degrees of activity are as shown in Table 1.

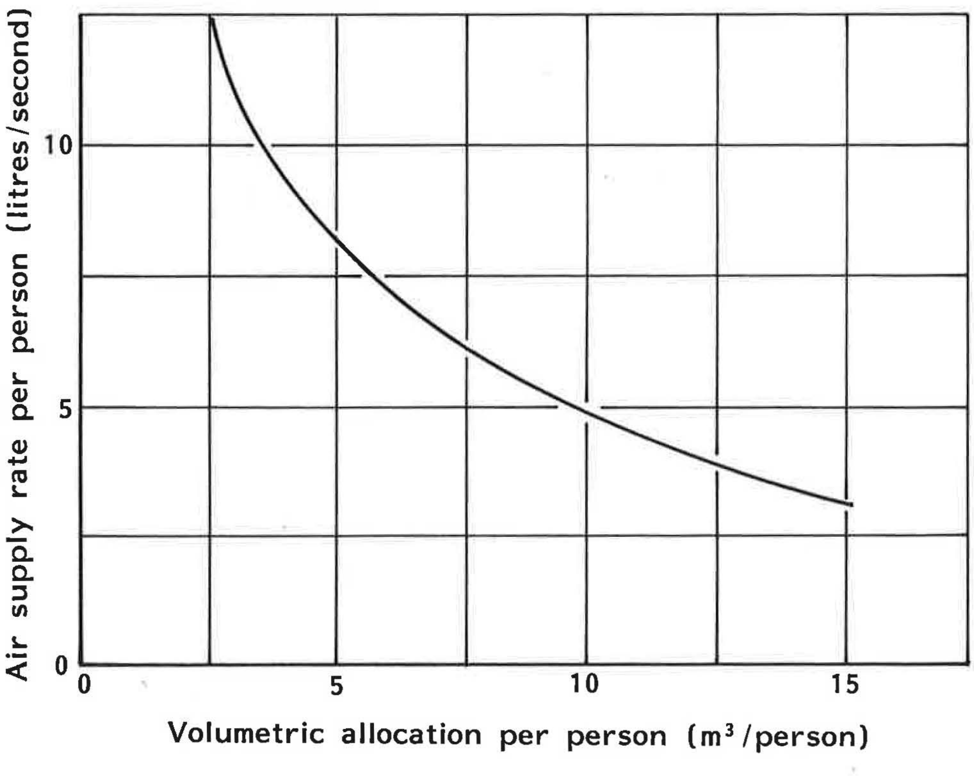
Table 1. Outside Air Requirements for Respiration

Activity (adult male)	Metabolic rate,M	Requirements for respiration; O concentration of 16.3% in expired air.	Requirements to maintain room CO2 at 0.5% assuming 0.04% CO2 in fresh air*
	W	litres/s	litres/s
Seated quietly	100	0.1	0.8
Light work	160 to 320	0.2 to 0.3	1.3 to 2.6
Moderate work	320 to 480	0.3 to 0.5	2.6 to 3.9
Heavy work	480 to 650	0.5 to 0.7	3.9 to 5.3
Very heavy work	650 to 800	0.7 to0.9	5.3 to 6.4

* The rate of production of CO2 in terms of metabolic rate M is 40 x 10 M litres/s where M is in watts.

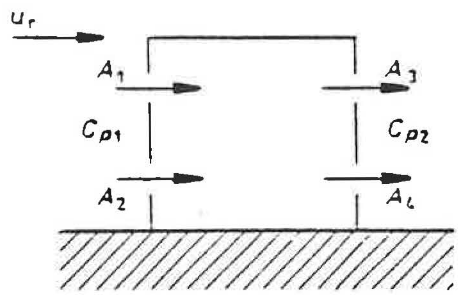
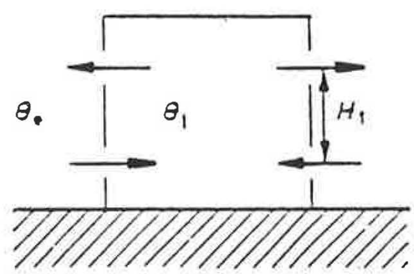
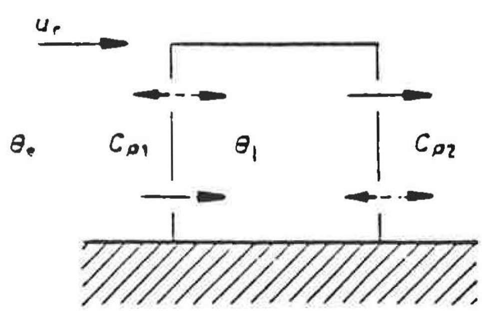
Contaminants in the air, particularly for industrial works, laboratories and commercial kitchens should be extracted mechanically as near the source as possible and is dealt with in BS 5720:1979. Odour and tobacco smoke nuisance is dealt with in more detail and a graph showing air supply rates per person based on the density of occupation is shown in Fig.1.

Figure 1. Air Supply for Odour Removal.



The design of natural ventilation is dealt with in depth covering the flow characteristics of openings such as windows of different types, air temperature, and wind speeds throughout the United Kingdom, and formula's for calculating flow rates for different arrangements of openings in simple buildings as shown in Table 2.

Table 2. Natural Ventilation of Simple Building.

Conditions	Schematic representation	Formula
(a) Wind only		$Q_w = C_d A_w u_r (\Delta C_p)^{1/2}$ $\frac{1.}{A_w^2} = \frac{1}{(A_1 + A_2)^2} + \frac{1}{(A_3 + A_4)^2}$
Temperature difference only		$Q_b = C_d A_b \left(\frac{2\Delta\theta g H_1}{\bar{\theta}}\right)^{1/2}$ $\frac{1}{A_b^2} = \frac{1}{(A_1 + A_3)^2} + \frac{1}{(A_2 + A_4)^2}$
(c) Wind and temperature difference together		$Q = Q_b$ For $\frac{u_r}{\sqrt{\Delta\theta}} < 0.26 \left(\frac{A_b}{A_w}\right)^{1/2} \left(\frac{H_1}{\Delta C_p}\right)^{1/2}$ $Q = Q_w$ For $\frac{u_r}{\sqrt{\Delta\theta}} > 0.26 \left(\frac{A_b}{A_w}\right)^{1/2} \left(\frac{H_1}{\Delta C_p}\right)^{1/2}$

* It should be appreciated that, in practice, some openings exist unintentionally, e.g. junctions between building components, and that such openings will contribute to the ventilation actually achieved.

UNITED KINGDOM Ref:UK.5

British Standards Institution BS5720:1979

Code of Practice for Mechanical Ventilation

This Code deals with the eowrk involved in design, installation, commissioning, operation and maintenance of mechanical ventilation and air-conditioning systems. The recommendations made in this code recognize the need to optimize the use of energy, reduce hazards and minimize effects detrimental to the environment. The increasing involvement of British engineers in projects overseas is noted and some guidance given in that context. In addition to this general section, the code is divided into the following seven sections:

Section 2. Fundamental requirements

Section 3. Design considerations

Section 4. Types and selection of equipment

Section 5. Installation

Section 6. Inspection, commissioning and testing

Section 7. Operation and maintenance

Section 8. Overseas projects.

For detailed design procedures, reference is made to:

1) Publications of the Chartered Institution of Building Services, particularly:

    The CIBS Guide
    CIBS Building Energy Code
    Technical Memoranda relating to fire and smoke control
    Practice Notes relating to provision of combustion and ventilation air for boiler installations;

2) The "Ductwork Specifications" published by the Heating and Ventilating Contractor' Association (HVCA);

3) ASHRAE Handbooks published by the American Society of Heating, Refrigerating and Air Conditioning Engineers.

For detailed commissioning arrangements:

1) CIBS Commissioning Codes;

2) BSRIA Application Guides published by the Building Services Research and Information Association.

UNITED KINGDOM Ref:UK.5

Recommended minimum fresh air supply rates for air conditioned spaces are as follows:

Table 1. Recommended minimum fresh air supply rates for air-conditioning spaces*.

Typical type of space	Smoking	Outdoor air supply†		
		Recom-mended	Minimum (the greater of the two should be taken)	
		Per person	Per person	Per m^2 floor area
		dm^3/s‡	dm^3/s‡	dm^3/s‡
Factories§‖	None			0.8
Offices (open plan)	Some			1.3
Shops, department stores and supermarkets	Some	8	5	3.0
Theatres§	Some			–
Dance halls§	Some			–
Hotel bedrooms‖	Heavy			1.7
Laboratories‖	Some	12	8	–
Offices (private)	Heavy			1.3
Residences (average)	Heavy			–
Restaurants (cafeteria) ‖¶	Some			–
Cocktail bars	Heavy			–
Conference rooms (average)	Some	18	12	–
Residences (luxury)	Heavy			–
Restaurants (dining rooms)	Heavy			–
Board rooms, executive offices and conference rooms	Very heavy	25	18	6.0
Corridors	A per capita basis is not appropriate to these spaces			1.3
Kitchens (domestic)‖				10.0
Kitchens (restaurant)‖				20.0
Toilets §				10.0

*For hospital buildings (wards, operating theatres, etc.), see Department of Health and Social Security Building Notes.
†The outdoor air supply rates given take account of the likely density of occupation and the type and amount of smoking.
‡1 dm^3/s = 1 litre/s.
§See statutory requirements and local bye-laws.
‖ Rate of extract may be over-riding factor.
¶Where queuing occurs in the space, the seating capacity may not be the appropriate total occupancy.

British Standards Institution BS 5250

Basic Data for the Design of Buildings: the control of condensation in dwellings.

This code of practice describes the causes and effects of condensation in buildings and gives recommendations for their control.

The principles of control and the recommendations given can be applied generally to all buildings, both new and existing, but those with internal environments or ventilation systems differing markedly from typical domestic situations may need special consideration and are outside the scope of this standard.

Methods are given to determine the occurrence and assess the effects of:

(a) surface condensation, or mould growth, one of its associated effects; and

(b) interstitial condensation.

Guidance is given on assessing whether any such condensation may be considered harmful.

Included within the code are typical ventilation rates for use in condensation calculations (see Table below) and details for ventilation provisions of roof spaces.

Table Typical ventilation rates

Description of Dwelling	Ventilation Rate ac/h
Well-sealed dwellings in sheltered position	0.5
Average dwelling in sheltered position	1.0
"Leaky" dwelling in sheltered position	1.5
Well-sealed dwelling in exposed position	1.0
Average dwelling in exposed position	1.5
"Leaky" dwelling in exposed position	2.0

British Standards Institution BS 6375:1983

Performance of windows. Part 1: classification of weathertightness.

This standard gives a classification of windows for weathertightness in terms of exposure categories related to test pressure levels for air permeability, watertightness and wind resistance.

It is applicable to all types of windows in which any frame member is not longer than 3 m, and includes windows in which the opening lights are not fully framed, e.g. adjustable glass louvres and sliding windows.

The standard excludes patent glazing curtain walls that span across horizontal structural members of floors but includes the opening lights within a patent glazing or curtain walling system.

Guidance on the selection and specification of windows for weathertightness is given. Methods of calculating design wind pressure are also given.

The test method and sequence of tests is described.

Exposure categories are listed in Table 1. the corresponding air permeability requirement are given in Figure 1.

Table 1. Exposure categories

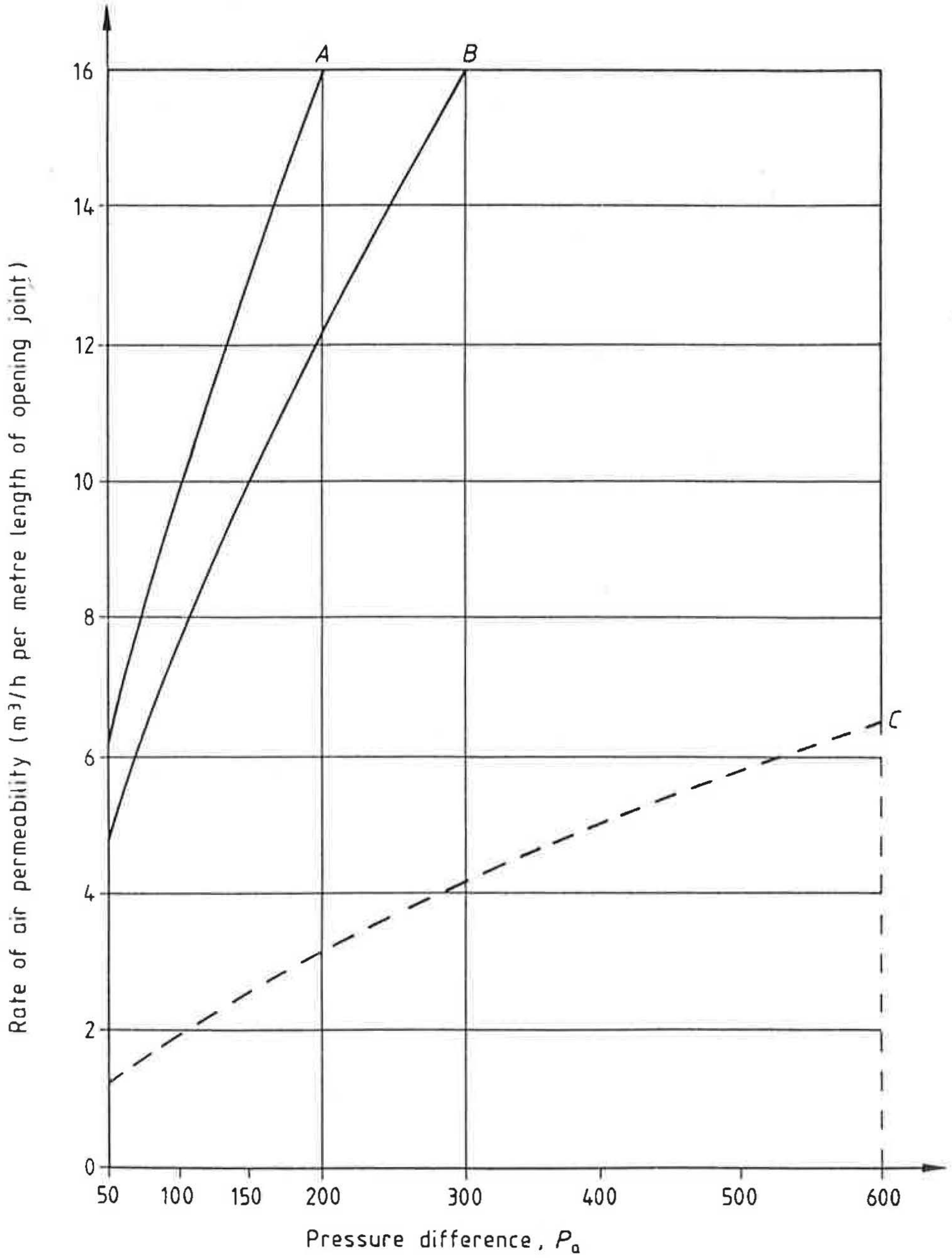
Exposure category (design wind pressure*)	Test pressure classes		
	Air permeability† (see figure 1)	Watertightness‡	Wind resistance
	Pa	Pa	Pa
1200 X	Up to 200 (graph A)	50	1200
1200	Up tp 200 (graph A)	100	1200
1600	Up to 300 (graph B)	200	1600
2000	Up to 300 (graph B)	200	2000
Over 2000 (state design wind pressure)	Up to 300 (graph B)	300	Equal to the actual design wind pressure

*The design wind pressure is calculated in accordance with the method given in appendix B.

†A test pressure class of 600 Pa (see figure 1, graph C) is applicable when stringent levels of performance are required, for example when exceptionally air tight windows are necessary as in air conditioned buildings. Where there is such a requirement the exposure category should be suffixed with 'special' e.g. 1200 special.

‡The watertightness test pressure classes given for the different exposure categories cover most situations. Windows of higher performance than stated in the table should be considered where there are local exposure conditions more onerous than those of the surrounding areas (see also note 3 to B.3).

Figure 1. Air Permeability Limits for Windows with Opening Lights



NOTE. The graph is based on the formula

$Q = kp^{2/3}$

where

Q is the leakage rate (in m^3/h);

p is the pressure difference (in Pa);

k is a constant:

k_A = 0.4678 (coordinates Q = 16 p = 200)
k_B = 0.357 (coordinates Q = 16 p = 300)
k_C = 0.0928 (coordinates Q = 2 p = 100)

British Standards Institution BS 6229:1982

Practice for Ventilation of Flat Roofs.

This code gives recommendations on the design and application of flat roofs with continuously supported roof coverings. Weathertightness, drainage, thermal and sound insulation, condensation control, structural support, fire precautions, maintenance and repair are considered.

Flat roofs are defined as those with roof coverings at slopes not exceeding 10 degrees to the horizontal. The recommendations given in this code may also be applied to roofs with slopes marginally greater than 10 degrees provided the design conditions are similar, but for steep roofs many of the recommendations may not apply.

This code does not deal with roofs with self-supporting coverings, nor with those for special purposes such as roof gardens, surfaces subject to heavy traffic, cold stores, and high temperature enclosures, nor with slated or tiled roofs.

Of specific importance is the ventilation of voids in cold roofs.

The code states that it is essential to ventilate the roof space in a cold roof to avoid the risk of condensation in the ceiling and the structural deck. The ventilation measures should provide a through path for the entry and exit of outdoor air.

Ventilation may be provided by holes or gaps through the fascia, soffit board or wall, detailed to avoid penetration of rainwater. Where insulation, fire stopping, cavity barrier or service installations prevent unobstructed ventilation between opporsite sides of the roof, it may be necessary to provide ventilation partly or wholly through the roof covering by means of suitable weatherproof roof ventilators.

Ventilation should be so arranged that all parts of the roof void are reached, avoiding stagnant air pockets, particularly at the upper parts of the void. Every void closed by imperforate beams, joists, fire stops, cavity barriers or other obstructions should be individually ventilated. In timber construction, the spaces between joists provide ventilation paths parallel to the direction of span, whereas the use of transverse purlins provide ventilation paths transverse to the direction of span; for ventilation purposes the choice of ventilation direction depends on the practicability of providing openings to the outside air at opposite ends (e.g. impractical at an abutment wall).

The desirable amount of ventilation varies with the external and internal climates, the thermal insulation provided and the resistance to air flow of the roof space (see BS 5925). Under average conditions, the total ventilation opening divided equally between opposite sides of the roof should be not less than 0.004 times the plan area of the roof. The roof void clear depth should be not less than 50 mm. To prevent entry of small birds, the gap width at the ventilation openings should not exceed 10 mm. To avoid excessive air flow resistance, the least dimension of any opening, including screen mesh apertures, should be not less than 8 mm.

Screen mesh materials should have adequate durability.

Wind-induced ventilation should not be relied upon for cold roofs exposed to continuous high indoor humidities; in such cases another roof type should be used, or warm dry air can be blown into the roof void at a sufficient pressure to prevent the entry of water vapour from the building.

UNITED KINGDOM Ref:UK.9

BUILDING RESEARCH ESTABLISHMENT

Determining the airtightness of buildings by the fan pressurisation method: BRE recommended procedure.
by R.K. Stephen BSc.

This publication is written in the form of a "code of practice" and covers the significance of the method and its use; the requirements of the equipment used; the preparation and carrying out of the test and the data analysis.

Copies of forms are shown which should be used to ensure that all the relevant details of the structure are recorded together with the measurements and data obtained during the procedure of the test.

In contrast to tracer gas techniques, the fan pressurisation method of measuring air leakage characterstics is simple and inexpensive. It is relatively insensitive to prevailing weather conditions and a normal test can be carried out in less than two hours excluding the noting down of the construction details.

The four basic uses put forward for this method are:

1) to compare the relative airtightness of several dwellings.

2) to identify air leakage paths and the rate of air leakage from different components in the same envelope.

3) to measure the effect of draughtproofing or joint sealing

4) to assess the potential for air leakage reduction in a dwelling.

The method is to mount a fan on a board which can be sealed in a door or window, and to blow air into the building at a sufficient rate to be able to maintain a pressure differential between inside and out of up to 55 Pascals A typical fan capacity is given as 4000 m3/h for a building of 260 m3 provided that obvious leakage paths such as flues, air bricks and extract fan openings have been sealed off. The test should not be undertaken if the average wind speed at the time is greater than Force 3 (about 5 m/s). The air flow rate is adjusted to give a range of pressure differentials at increments of about 10 Pascals, and recordings of measurements are made after conditions have stabilised. Values should be recorded close to pressure differences of 55, 50, 45, 40, 30, 20, 10 and 5 Pascals. The minimum pressure differential should be below 10 Pascals with the upper value not exceeding 55 Pascals.

Corrections to the air flow rates must be made to take account of the air temperature prevailing at the time of the test against that during calibration of the apparatus, and also if there is a temperature difference between indoor and outdoor in excess of 2.5 deg.C.

After the positive pressure test has been carried out, the apparatus is rearranged such that air is extracted from the building or depressurised in a similar way but in reverse order.

An example of graphical presentation of results is shown in Fig.1 and a schematic general arrangement of the apparatus is shown in Fig.2.

Figure 1: Example of graphical presentation of results (ficticious data)

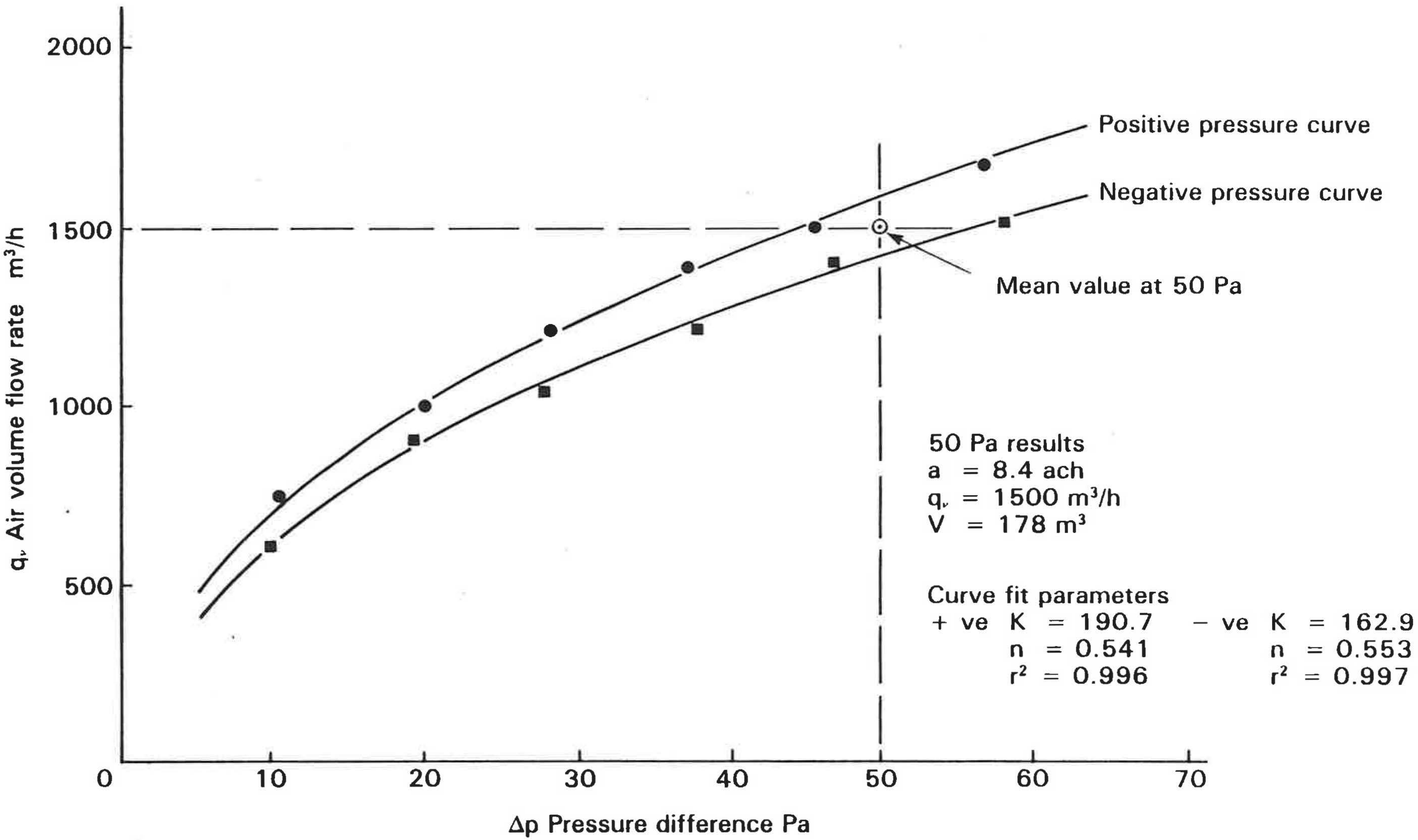
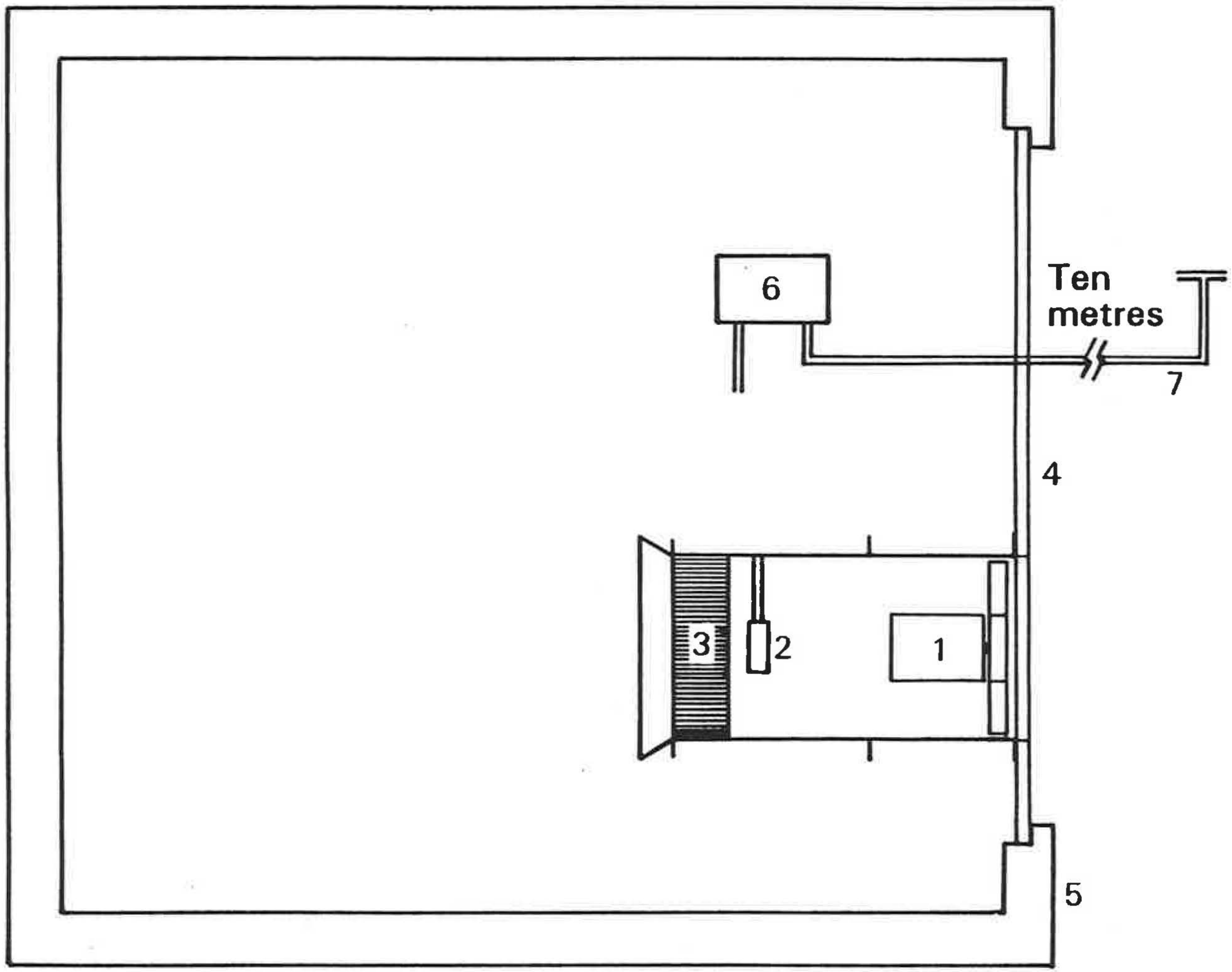


Figure 2: Schematic general arrangement of pressurisation unit installed in a building (shown depressurising)



Key:

1. Fan
2. Air flow measuring anemometer head
3. Honeycomb flow straightener
4. Mounting board
5. Building envelope
6. Pressure difference micromanometer
7. Pressure difference tube

British Standards BS5368 Pt.1:1976

Methods of Testing Windows.

Part 1. Air Permeability Test

1. Scope

This standard defines the method to be used for the air permeability test of windows to be fitted in exterior walls and supplied in the form of finished units in actual operating conditions.

This standard applies to all windows, including door height windows made of any material, in the actual operating conditions in which they should be used and fixed avccording to the manufacturer's recommendations as in a finished building, bearing in mind the conditions of test as defined hereafter. The standard does not apply to the joints between the windows and surrounding components and material.

The standard covers a description of basic test apparatus, preparation of window and testing conditions, and the method of conducting the test.

Test pressures are 50, 100, 150, 200, 300, 400, 500 and 600 Pa and canthen be increased in steps of 250 Pa maximum if the pressure required for the test is, exceptionally, higher than 600 Pa.

The pressures shall than be applied in the reverse order.

The air permeability readings at each pressure are recorded. The higher of the two readings at each pressure, increasing as well as decreasing, should be noted.

For each window tested, the volume of air flow passing through the specimen expressed as cubic metres of air per hour, should be recorded as follows:

(a) per metre of length of opening joint;

(b) per square metre of opening light;

(c) per square metre of total surface area of the window.

These should then be plotted on two graphs against rising pressure.

UNITED KINGDOM Ref:UK.11

British Standard (Draft) 88/13390

Specification for Draughtstrips for the Draught Control of Existing Doors and Windows in Housing (including Test Methods).

Anticipated publication date: February/March 1990.

1. Scope

This British Standard specifies requirements for draughtstrip products to fit the common types of installed doors and windows in housing not originally designed to incorporate draughtstripping, and applies to hinged doors and sliding windows in wood and hinged windows in wood and steel.

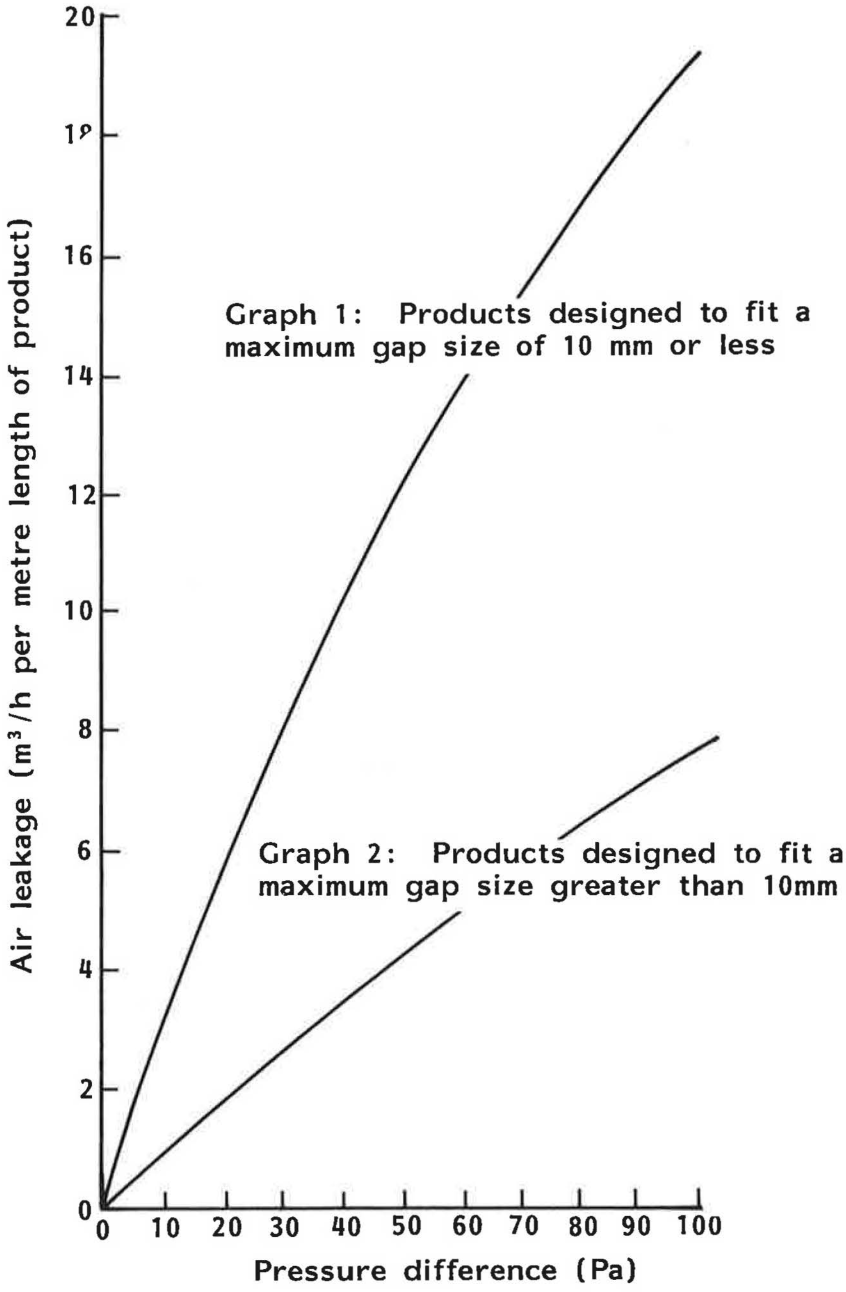
The Standard covers specification of:

- product information
- dynamic characteristics
- performance under sustained compression/deflection
- integrity of working section and carrier of draughtstrip
- air leakage through product
  - (a) for products designed to fit a maximum gap size of 10 mm or less
  - (b) for products designed to fit a maximum gap size greater than 10 mm
- resistance to wear.

Under each specification appropriate testing standards are described.

The airtightness performance/metre length of product is specified for (a) and (b) above, in the draft code, by the figure on the next page.

Figure 1: Maximum air leakage through product v. applied pressure difference.



United States of America

UNITED STATES OF AMERICA STANDARDS*

Reference No.	Standard No.	Title
USA 1	ASHRAE 62-1989	Ventilation for acceptable indoor air quality.
USA 2	ANSI/ASHRAE 119-1988	Air leakage performance for detached single-family residential buildings.
USA 3	ASTM E741-83	Standard test method for determining air leakage rate by tracer dilution.
USA 4	ASTM E779-87	Standard test method for determining air leakage rate by fan pressurization.
USA 5	ASTM E783-84	Standard test method for field measurement of air leakage through installed exterior windows and doors.
USA 6	ASTM E1186-87	Standard practices for air leakage site detection in building envelopes.
USA 7	ASTM E1258-88	Standard test method for airflow calibration of fan pressurization devices.

USA Ref: USA 1

ASHRAE Standard 62-89

Ventilation for Acceptable Indoor Air Quality

The application of different ventilation rates for smoking and non-smoking categories for the various spaces listed were found to be confusing in the earlier editions (62-1981). It is proposed therefore that only one value is given in the Ventilation Rate Procedure, and chosen to control CO_2 and other contaminants with an adequate margin of safety to accommodate various activity levels and health variations among the occupants, and with a moderate amount of smoking allowed. Tables are listed showing the outdoor air requirements for commercial and institutional facilities and these are given either for a volumetric rate per occupant or where applicable a rate per area of floor.

For residential facilities outdoor air requirements are given as set out in Table 1 below.

Table 1. Outdoor Requirements for Ventilation of Residential Facilities

Room	Outdoor Air Requirements	Comment
Living Rooms	Not less than 7.5 L/S per person	Occupant loading considered 1st Bedroom - 2 persons additional bedrooms - 1 person
Kitchens	50 L/S per room	Intermittent
or	12 L/S per room	Continuous
Baths, Toilets	25 L/S per room	Intermittent
or	10 L/S per room	Continuous

An alternative method provided in the Standard is the Indoor Air Quality Procedure. This procedure provides a direct solution by restricting the concentration of all known contaminents of concern.

Air Quality

Appendix C gives guidance for the establishment of air quality criteria for the indoor environment.

Standards applicable in the United States for common indoor air pollutants are given in tabular form covering the following:

Asbestos

Carbon Monoxide

Formaldehyde

Lead

Nitrogen Dioxide

Ozone

Radon

Sulfur Dioxide

Particulates and Carbon Dioxide

Where available, values are listed for indoor, outdoor, and workplace standards.

U.S.A. Ref: USA 2

ANSI/ASHRAE 119-1988

Air Leakage performance for detatched single family residential buildings.

The purpose of this Standard is to establish performance requirements for the air leakage of residential buildings to reduce the thermal load due to air infiltration. It provides a method to classify airtightness of these buildings and sets upper limits of leakage area.

The Standard does not apply to buildings occupied for less than 876 hours per year.

Considerations for adequate ventilation to provide combustion air for heating appliances and to produce acceptable indoor air quality is deemed to be the responsibility of the user, and is therefore precluded from the Standard.

Classification of leakage is given for a range of normalised leakage based on the following:

$Ln = 1000\ L/A(H/Ho)0.3$

where

Ln = the normalised leakage
Ho = the height of a single storey (8 ft)[2.5m]
H = the height of the building (ft)[m]
L = the leakage area of the space (ft2)[m2]
A = the floor area of the space (ft2)[m2]

Maps and tables show the regions and cities which have been given a leakage class based on the normalised leakage range as shown in the following table.

U.S.A. Ref: USA 2

ANSI/ASHRAE 119-1988

Table: Classification of Leakage

Normalised Leakage Range	Leakage Class
Ln<0.10	A
0.01<Ln<0.14	B
0.14<Ln<0.20	C
0.20<Ln<0.28	D
0.28<Ln<0.40	E
0.40<Ln<0.57	F
0.57<Ln<0.80	G
0.80<Ln<1.13	H
1.13<Ln<1.60	I
1.60<Ln	J

ASTM E741-83.

Determining Air Leakage Rate by Tracer Dilution

This standard describes a technique for measuring the air change rate of buildings under natural meteorological conditions using the tracer gas dilution (decay rate) principle. Two variants of the technique are presented. In the "on site monitor" variant, tracer concentration as a function of time is measured on site directly as air samples are obtained.

In the "container sample" variant, after the tracer has thoroughly mixed an initial air sample container is filled. The tracer is allowed to decay for a period of several hours during which a second and perhaps third sample container is filled. The samples can then be analysed at a remote laboratory and air change rates can be determined from the decay in concentration.

The document describes terms specific to the standard, explains the principle of the measurements and explains the significance and use of the technique. Apparatus particular to the method is described and the measurement procedure presented. The initial data analysis and the presentation of the final results are examined. Calibration and safety procedures are considered and a standard reporting format for the test is presented. A list of suitable tracer gases is included.

This Standard is currently under committee review with the aim to add all current tracer gas methods to the Standard.

ASTM E779-87

Determining Air Leakage Rate by Fan Pressurization

This test method describes a standardised technique for measuring air leakage rates through a building envelope under controlled pressurization or depressurization. The test method consists of mechanical pressurization or depressurization of a building and measurements of the resulting air flow rates at given indoor-outdoor static pressure differences. From the relationship between the air flow rates and pressure differences the air leakage characteristics of a building envelope can be evaluated.

The standard describes the significance and use of the test method, the apparatus required to perform the test, and the measurement and analytical procedures. Hazards involved in making pressurization measurements are noted, and a standard reporting format for the tests is presented.

This Standard is currently under committee review to update procedures.

ASTM E783-84

Field Measurement of Air Leakage through Installed Exterior Windows and Doors

This standard method deals with the determination of the resistance of installed exterior windows and doors to air leakage resulting from static pressure differences. The method is applicable to window and door assemblies only. However, with adaption, the method can be used to determine the leakage through openings between the window or door assemblies and adjacent construction. A test consists of sealing a chamber to cover the interior or exterior face of a test specimen, supplying air to or exhausting air from the chamber at a rate required to maintain a specified static pressure across the specimen, and measuring the resultant air flow through the specimen.

Pressure between the collection chamber and the room containing the component is not balanced, therefore the extraneous leakage through the collecting chamber must be evaluated before conducting the leakage test on the specimen.

The calibration procedure, which consists of sealing the specimen with a sheet of polythene film and performing a pressure test, is described in detail in the document. The document also contains sections dealing with the significance and use of the test methods, the apparatus required to perform the test, the preparation of the test specimen and the measurement procedure.

Calculations and the expression of the final results are examined in detail. Safety precautions and measurement accuracy are addressed and a Standard reporting format for the tests is presented.

U.S.A. Ref: USA 6

ASTM E 1186-87

Standard practices for air leakage site detection in building envelopes.

This describes the different standardized techniques for locating the sources of air leakage in building envelopes.

It is more concerned with the location of leakage sites than the actual rates of leakage.

Five methods of detection are presented and the advantages and limitations for each are given.

The methods are:

1) Combined building depressurization (pressurization) and infrared scanning.

2) Building pressurization (or depressurization) and smoke tracers.

3) Building depressurization (or pressurization) and airflow measuring devices.

4) Generated sound, and sound detection to locate air leakage sites.

5) Detection of tracer gas concentration after adding tracer gas upstream of the leakage site.

U.S.A. Ref: USA 7

ASTM E1258-88

Standard Test Method for Airflow Calibration of Fan Pressurization Devices.

This Standard describes the airflow measurement techniques for the calibration of four pressurization systems as used in measuring air leakage rates through building envelopes.

It is applicable to the system of measuring air leakage as described in ASTM E779-87 (USA).

The Standard includes two basic procedures, the preferred one being based on ASHRAE Standard 51/AMCA Standard 210 (Laboratory methods for testing fans for rating).

INTERNATIONAL ORGANISATIONS

C.I.B.

A survey of Building Regulations Worldwide
1988

BYGGDOK - The Swedish Institute of Building Documentation

This report contains the replies from 33 participating countries to a questionnaire requesting information relating to Building Regulations within their own country.
The following is some of the information given:

(i) Whether the Regulations and Standards are National, Regional or Local.

(ii) The Information Centres and Authorities dealing with Building Regulations.

(iii) Bodies providing information about Building Regulations and Standards.

(iv) Organisations where they can be bought or acquired.

(v) Catalogues, databases and other systems giving reference to Building Regulations.

(vi) The most important Building Regulations. These include a number of ventilation and airtightness requirements.

The countries supplying information in this report are:

Algeria	Israel	Spain
Belgium	Japan	Sweden
Brazil	Mexico	Switzerland
Canada	Netherlands	Tanzania
China	New Zealand	Thailand
Denmark	Nigeria	U.K.(England & Wales)
Egypt	Norway	U.K.(Northern Ireland)
Ethiopia	Philippines	U.K.(Scotland)
Fed.Rep.of Germany	Poland	United States of America
Ghana	Portugal	Yugoslavia
Iceland	Rep.of Korea	

European Committee for Standardisation

Method of Testing Windows: Air Permeability

This standard describes a pressure chamber method for laboratory testing of the air permeability of windows. It has been adopted as a national standard in Denmark, Germany, Italy and the United Kingdom.

International Standards Organisation

STANDARDS ISO

Reference No.	Standard No.	Title
IS 1	ISO 6613-1980 (E)	Windows and door height windows - Air permeability test. 1980.
IS 2	ISO 6589-1981 (E)	Joints in building - Method of test for air permeability of joints. 1981
IS 3	DP 9972	Measurement of Building Airtightness using fan pressurization. Draft Proposal

INTERNATIONAL STANDARDS ORGANISATION (ISO) Ref: IS.1 & IS.2

ISO is an international agency for standardisation at present comprising the national standards bodies of 87 countries. Once international ISO standards have the approval of at least 75% of the members, it can be used in its original form in any of the participating countries or incorporated into a national standard.
There is generally an update every 5 years. All countries under review in this report are members of the ISO.

There are two ISO standards concerned with component leakage. ISO 6613 (ISI) covers air permeability of windows and describes a basic pressurization test in which the window is fitted to a test chamber and the air flow across it measured at different pressures. Air permeability is expressed as m3 air flow per hour:

- per m2 of surface area of window
- per m2 of opening light
- per m of length of opening joint

This standard has been approved by Canada, Denmark, Germany, Italy, Netherlands, Norway, Sweden and the UK but has not been approved by Belgium or the USA.

ISO 6589 (IS2) records a similar method for testing the air permeability of joints (air flow per metre length of joint). This has been approved by Canada, Germany, New Zealand, Norway, Sweden and the UK but not by Belgium or Denmark.

Draft Proposal: DP 9972 March 1988

Measurement of Building Air Tightness using Fan Pressurisation

This method of measurement characterizes the air tightness of components in the building envelope, the results of which can be used to estimate the air infiltration rate of the whole building by means of calculation.

It enables comparison between the relative air tightness of several similar buildings or components and can therefore be used to identify the source of excessive rates of air leakage, and the improvements made by sealing after retrofit measures have been taken.

It recommends that if a direct measurement of the air infiltration of the whole building is desired, other methods such as tracer dilution should be used.

The procedure for using the apparatus is described together with the analysis and presentation of the data obtained from the tests.

The method is to pressurise the building by means of a fan of suitable capacity such that a differential pressure between inside and outside is maintained whilst the air flow rate into the building to achieve this is measured. The range of the induced pressure difference shall be 10 times the zero-flow pressure up to 60 Pa depending on the capacity of the fan. Increments of no more than 10 Pa shall be used for the full range of induced positive pressure differences, and at least five data points are to be obtained within the range. If possible the test should be repeated in a similar manner with negative pressure differences. A Report Format lists the following information that should be included.

A. Description of the Test Specimen:

Building

1. Location.

2. Date built (estimate if unknown).

3. Floor area of conditioned space

4. Volume of conditioned space.

5. Other building data required to obtain derived results (such as the envelope area if tightness per unit area is required).

6. Condition of openings in exterior shell:
   (a) Windows (including storm windows) - locked or unlocked.
   (b) Windows (including storm windows) - latched or unlatched.
   (c) Ventilation openings - dampers closed, opened or sealed.
   (d) Chimneys - dampers closed, opened or sealed.
   (e) Condition of other openings during test (for example, broken windows, HVAC damper and louvre settings etc).

7. HVAC System
   (a) Furnace
   (b) Blower capacity
   (c) Duct location

<u>Component Test</u>

8. Component Description with diagrams.

9. Area of measured surface.

10. List of materials.

11. Component location in building envelope.

12. Component age.

13. Other pertinent information.

B. <u>Test Equipment</u>

1. Technique employed.

2. Equipment used.

C. <u>Test Data</u>

1. Date of test.

2. Times of beginning and end of test.

3. Table of induced pressure differences and corresponding air flows.

4. Inside and outside temperatures.

5. Atmospheric pressure (can be determined from altitute).

6. Wind speed (weather station or estimate from Beaufort scale).

D. Plot of air leakage graphs - Fig.3.

E. The leakage coefficients C and Co and exponent for both pressurisation and depressurisation determined by the method given along with their confidence limits. The leakage coefficient and exponent can be used to calculate the flows at the other pressures.

F. Other derived quantities such as a leakage area and building airtightness at a given pressure should be reported if required.

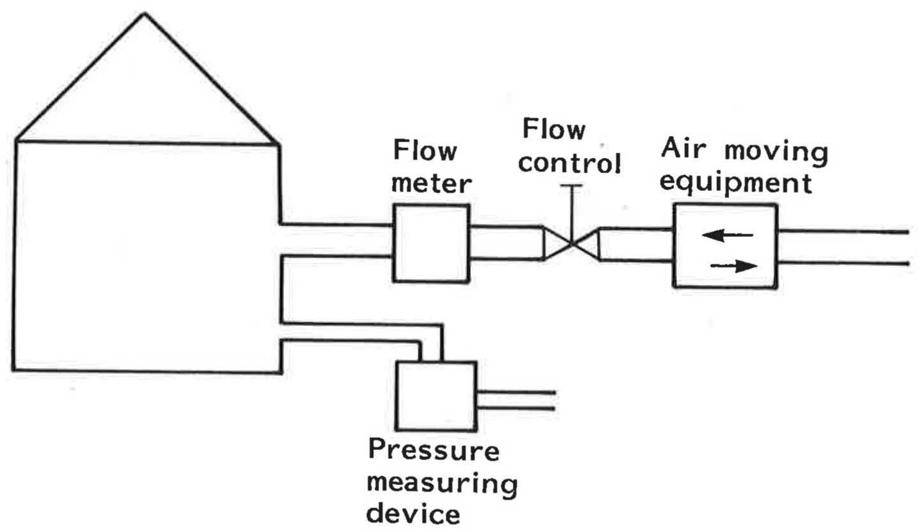


Figure 1: Schematic Layout of Equipment for Whole Building Test

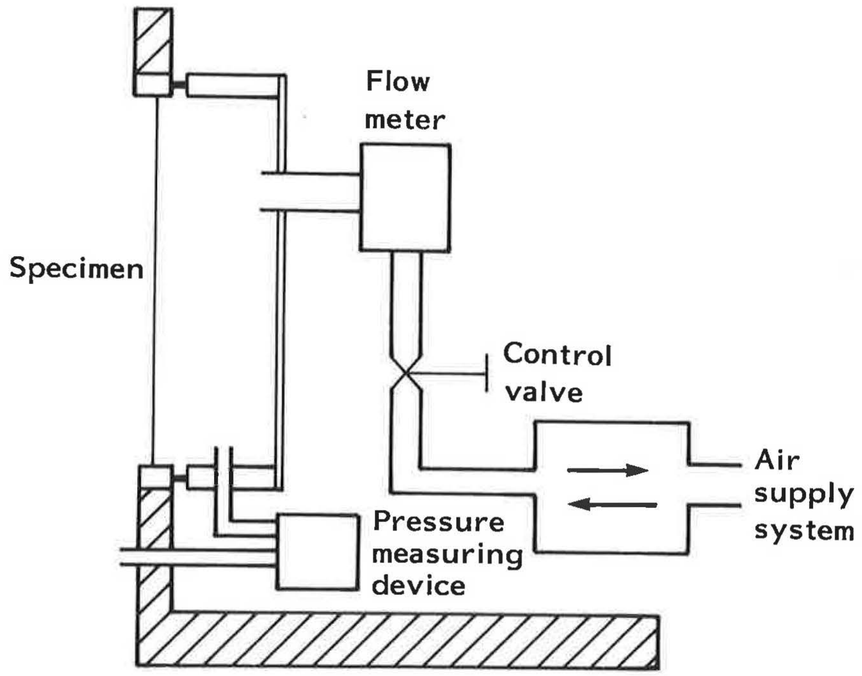


Figure 2: Schematic Layout of Equipment of Component Air Tightness Test Using a Pressurized Enclosure

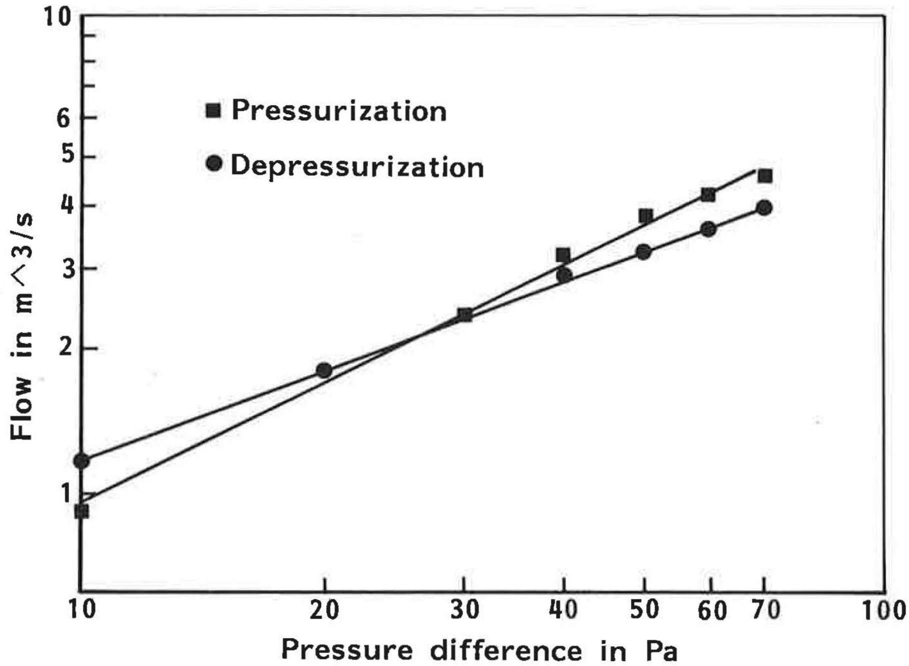


Figure 3: Sample of Air Leakage Graph

KEY STANDARDS

NON-AIVC COUNTRIES

France

Reference No.	Standard No.	Title
F 1		French regulations for ventilation of dwellings.

French Regulations for Ventilation of Dwellings.

Dispositions relatives a l'aeration des logements
27th March, 1982.

These regulations stipulate that the ventilation of dwellings should be general and permanent even for buildings having high acoustical treatment.

The methods by which the supply and exhaust air is provided to the dwelling is described together with the rates of air supply required based on the number of principal rooms in the dwelling.

Para.1 The ventilation of dwellings should be general and permament even when buildings have high acoustical insulation, and when windows are kept closed during cold weather.

The circulation of air has to be made mainly by supply of air into the principal rooms, and extracted through the service rooms.

Principal rooms considered - living rooms, bedrooms, etc.

Service rooms considered - kitchen, bathroom, toilets etc.

Para.2 The ventilation system must include air inlets in all principal rooms direct from outside through ducts with either natural or mechanical force. Extracts in the service rooms must be through vertical ducts by means of natural draught or fan assisted.

For collective buildings (i.e. blocks of flats) if the kitchen has mechanical extract (i.e. fan assisted) all other service rooms must also have one.

Where a principal room and service room are combined such as a bedroom with kitchen, an air inlet and exhaust outlet must be included.

Para.3 A table is given showing the air flows required in each service room as a function of the number of principal rooms. These must be met simultaneously or not for average winter temperatures by either natural, or mechanical ventilation.

See Table 1.

Table 1:

Number of Principal Rooms in the Dwelling	EXTRACTED AIR FLOWS M3/H (CFM)				
	Kitchen	Bathroom with or without water-closet	Other Bathroom	Water - Closet	
				Unique	Multiple
1	75 (44)	15 (9)	15 (9)	15 (9)	15 (9)
2	90 (53)	15 (9)	15 (9)	15 (9)	15 (9)
3	105 (62)	30 (18)	15 (9)	15 (9)	15 (9)
4	120 (70)	30 (18)	15 (9)	30 (18)	15 (9)
5 and over 5	135 (79)	30 (18)	15 (9)	30 (18)	15 (9)

If there is no dividing wall between the living room and one bedroom, the unique room will be considered as two principal rooms.

If there are at least two water-closets in the dwelling, they are considered as multiple, even if one of them is located in one bathroom.

Section 2
SUBJECT ANALYSIS

Table: Subject Analysis of Standards Covering Airtightness Requirements

	Airtightness Requirements	Techniques for measuring air leakage	Rules for the calculation of ventilation heat loss
Whole Buildings	NL1,NO1,SE1, IT1,US2	CA7,IS3,NL4,NO2, SE3,SE4,UK9,US3, US4.	BE1,CH6,DE1,DK2, IT1,NO5.
Components	BE2,BE3,BE4, CA3,CA4,CH1, CH2,DE2,IT2, NL3,NO1,NZ1, SE1,UK7.	BE3,DE2,DE4,DK3, EC1,IS1,IS2,IT2, NL5,NO3,NZ1,SE3 UK10,US5.	CH6.

Table: Subject Analysis of Standards Covering Minimum Ventilation Requirements

Requirements Ventilation for minimum ventilation rates in terms of:	Natural Ventilation		Mechanical	
	Dwellings	Other Commercial/ Industrial	Dwellings	Other Commercial/ Industrial
Air Changes/ hour	BE1,CH1, DE5,DK1, FR1,IT1, UK6.	IT1.	CA2,CA3, CH7,DE9 DE10,FR1, NO4,UK1.	CH7,DE7,DE8 FI1,IT1,UK1
Air flow rate per person or per unit floor area	NL6,SE2, UK4,US1	IT1,NL2, UK4,US2	DE5,DE9, DE10,NL6 UK3,UK5, US1	CH4,DE6,FI1 NL2,NO4,SE2 UK3,UK5,US1
Area of ventilation opening	CA3,DK1, IT1,NL7, NO4,NZ2, NZ3,SE2, UK1,UK3, IT2	DK1,NZ3, SE2,UK1 UK3	CA3	FI1,SE2

Appendix 1
Details of Issuing Organisations

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COUNTRY	ISSUING BODY	PUBLICATIONS PRODUCED
Belgium	The Belgian Standards Institute (IBN) Boulevard Saint-Lazare, 10 B-1030 Brussels	Belgian Standards
	The National Housing Institute (INL) (address as above)	Unified technical specifications (STS)
Canada	Associate Committee on the National Building code National Research Council of Canada Ottawa Ontario K1A OR6	National Building code
	Canadian General Standards Board (CGSB) C\o Dept of Supply and Services 11 Laurier Street Hull Quebec K1A OS5	Canadian standards
Denmark	The Danish Standards Association (DS) Aurehojvej 12 DK-2900 Hellerup	Danish standards
	Danish Society of Engineers (DIF) Organisation for Norms and Standards Vester Farimagsgade 31 DK-1606 Copenhagen V	DIF norms, some being published as Danish standards
	The Danish Ministry of Housing National Building Agency Stormgade 10 DK-1470 Copenhagen K	Danish Building Regulations

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COUNTRY	ISSUING BODY	PUBLICATIONS PRODUCED
Netherlands	The Netherlands Standards Institute (NNI) Kalfjeslaan 2 P O Box 5059 2600 GB Delft	Dutch standards
New Zealand	Standards Association of New Zealand (SANZ) Private Bag Wellington	New Zealand standards
	Dept of Health P O Box 5013 Wellington	The Drainage and Plumbing Regulations, 1981
	Dept of Labour Private Bag Wellington	The Factories and Commercial Premises Act, 1981.
Norway	Norwegian Standards Association (NSF) Haakon VII's gate 2 Oslo 1	Norwegian standards
	The Norwegian Council for Building Standardisation Kobenhavngt 10 Oslo 5	Construction standards
	The Royal Ministry of Local Government and Labour P O Box 8112 Dep. Oslo 1	Norwegian Building Code (BF)

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COUNTRY	ISSUING BODY	PUBLICATIONS PRODUCED
Sweden	Swedish Standards Institute (SS) Box 3295 S-103 66 Stockholm	Swedish standards
	The National Board of Physical Planning and Building Box 12512 S-102 29 Stockholm	Swedish Building Code (SBN)
Switzerland	Swiss Standards Association (SNV) Kirchenweg 4 8032 Zurich	Swiss standards
	Swiss Association of Engineers and Architects (SIA) Postfach 8039 Zurich	Swiss standards on thermal protection and heating ventilation and airconditiong problems.
	Swiss Association of Heating & Cooling Engineers (SWKI) Postfach 2327 3001 Berne	Recommendations for heating installations, ventilation, etc.
United Kingdom	British Standards Institute Linford Wood Milton Keynes MK14 6LE	British standards
	HMSO Books P O Box 569 London, SE1 9NH	Building regulations for England, Wales and Scotland
	Greater London Council The County Hall London, SE1 7PB	London building by-laws

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COUNTRY	ISSUING BODY	PUBLICATIONS PRODUCED
United States of America	The American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) 1791 Tullie Circle NE Atlanta GA 30329	HVAC standards
	American Society for Testing and Materials (ASTM) 1916 Race St Philadelphia PA 19103	Standards on materials, products, systems and services
	US Dept of Housing and Urban Development (HUD) 451 Seventh St SW Washington DC 20410	Minimum property standards
West Germany	The German Standards Institute (DIN) Burggrafenstrabe 4-10 Postfach 1107 1000 Berlin 30	German standards
	The German Institute of Engineers (VDI) Postfach 1139 4000 Dusseldorf 1	Technical guidelines
International	International Standards Organisation (ISO) 1 rue de Varembe Case Postale 56 CH 1211 Geneva 20 Switzerland	International standards
	European Standardization Committee (CEN) 5 Boulevard de l'Empereur B 1000 Brussels Belgium	European standards (EN)

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The Air Infiltration and Ventilation Centre provides technical support to those engaged in the study and prediction of air leakage and the consequential losses of energy in buildings. The aim is to promote the understanding of the complex air infiltration processes and to advance the effective application of energy saving measures in both the design of new buildings and the improvement of existing building stock.

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