THE IMPLEMENTATION AND EFFECTIVENESS OF AIR INFILTRATION STANDARDS IN BUILDINGS

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PAPER 1

REVIEW OF BUILDING AIRTIGHTNESS AND VENTILATION STANDARDS

PETER J JACKMAN

The Air Infiltration Centre
Old Bracknell Lane West
Bracknell
Berkshire
RG12 4AH
England

SYNOPSIS

Increased attention to the reduction of energy consumption in buildings and greater awareness of the need to maintain acceptable standards of indoor air quality have led to the development of new or revised standards of building airtightness and ventilation requirements. In this review of the existing standards of twelve countries, an attempt has been made to compare their main features and criteria. In many cases, direct comparison is not possible because of different ways of expressing the significant parameters. However, where comparison is possible, some differences between countries are evident. Recognition and further consideration of these differences may be important in the further development of relevant national and international standards.

1. INTRODUCTION

The design and construction of buildings are governed by a broad range of standards, regulations, codes of practice and legal requirements to ensure that conditions for safety, health and well-being are maintained. In some countries standards are applied on a national basis, in others the primary enforcement is through regional or local codes with, sometimes, significant variations from place to place.

The requirement for reduced energy consumption in buildings, has resulted in new or more stringent standards covering many of the features which affect the efficient provision of an acceptable internal environment. Of these features, the ability of the structure to resist the leakage of air to and from outdoors is becoming recognised as one of increasing importance. In this respect, the lead has been taken by those countries which have the more severe climates and have been particularly vulnerable to the effects of increase in the price of oil. In others, airtightness standards have recently been, or are currently being, developed.

The specification of particular airtightness qualities requires the formulation of suitable test methods to enable the leakage characteristics of component, assemblies and whole buildings to be measured. Standard methods for testing the air leakage of windows have been in existence for many years, but more recently new standards have been developed for measuring the leakage of other components and, in two Scandinavian countries, of complete buildings. Further progress on the standardisation of measurement techniques is continuing.

While it is important to minimise extraneous air leakage, it is of paramount importance to maintain acceptable indoor air quality. For this, minimum ventilation rates have been specified for various types of building and occupancy. Recent concern about the over-tightening of naturally ventilated buildings and the current re-assessment of the basis of the early standards of ventilation, is leading to new appraisals of the ventilation rates appropriate to modern buildings and lifestyles.

As a background to consideration of these developments, this paper reviews the existing standards of the eleven countries participating in the Air Infiltration Centre. In addition, relevant standards from West Germany, the European Committee for Standardisation and the International Standards Organisation have been included as these are used as the basis for standards in other countries.

The main emphasis has been on mandatory standards, although it has not always been easy to distinguish between those which are legal directives, models for locally enforced codes or mere recommendations. At the commencement of each section is a list of those standards included in this review. Although the review has been made as extensive as possible, there is no claim that it is totally comprehensive.

2. AIRTIGHTNESS REQUIREMENTS

Belgium:	*STS 52.0* *External joinery - general principles* *INL Draft 1983*
Canada:	*Measures for energy conservation in new buildings* *Associate Committee on the National Building Code* *National Research Council of Canada, No. 16574, Ottawa, 1978*
Netherlands:	*NEN 3661* *Windows: Air permeability, water tightness, rigidity and strength* *Requirements* *Netherlands Standards Institute (NNI), 1975*
New Zealand:	*NZS 4211:1979* *Specification for performance of windows* *Standards Association of New Zealand, 1979*
Norway:	*Chapter 54. Thermal insulation and airtightness (revised 1980)* *Building Regulations of 1st August 1969* *Royal Ministry of Local Government and Labour*
Sweden:	*Chapter 33. SBN 1980. Thermal insulation and airtightness* *Swedish Building Code with Comments* *National Swedish Board of Physical Planning and Building (1981)*
	SIS 81 81 03 *Windows. Classification with regard to function* *Swedish Standards Commission, 1977*
Switzerland:	*SIA 180/1* *Thermal insulation of buildings in winter* *Swiss Engineering and Architectural Association, 1980*
United Kingdom	*BS 6375:Part 1:1983* *Performance of windows. Part 1: Classification for weathertightness* *British Standards Institution, 1983*

United States of America: *ASHRAE Standard 90-80*
Energy conservation in new building design
The American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., 1980

West Germany: *DIN 18055*
Windows: Air permeability of joints and driving rain (water tightness) protection. Requirements and testing
German Standards Institute (DIN), 1981

2.1 Whole Building

Currently Norway and Sweden are the only countries that have recommendations for the airtightness of whole buildings. As described in other papers presented at this Conference, there are proposals being discussed in Canada and USA on this subject.

Tabulated summaries of the Norwegian and Swedish requirements are given below:

Norwegian Building Regulations	
Building type	Airchange rate/hr at 50 Pa
Single family dwellings	4
Buildings up to 2 floors	3
Buildings exceeding 2 floors	1.5

Swedish Building Code	
Building type	Airchange rate/hr at 50 Pa
Freestanding single-family houses and linked houses	3
Other residential buildings of not more than 2 storeys	2
Residential buildings of 3 or more storeys	1

The Swedish specifications are the more stringent.

2.2 Windows

The standards of several countries specify the maximum allowable leakage of windows with some grading according to application. In others, a leakage classification system is detailed but with no reference to acceptability for particular uses.

The following list summarises the requirements or classifications given in the relevant standards.

Belgium: Standard STS 52.0

Maximum rate of leakage at 100 Pa for different grades of window

	Window classification		
	PA2	PA2B	PA3
Exposure level - height of building in which window is situated (m)	0-10	10-18	>18
Air leakage m^3/h per metre	6	3	2
(dm^3/s m)	(1.67)	(0.83)	(0.56)

Canada: Measures for energy conservation in new buildings

Air leakage of windows is not to exceed 0.775 dm^3/s per metre of joint at a 75 Pa pressure differential.

Netherlands: Standard NEN 3661

Test pressures for different window categories for which air leakage must not exceed 5 dm^3/s m.

Height of building in which window is situated (m)	Exposure	Pressure difference Pa
15	Normal	150
40	"	200
100	"	250
15	Coast	300
40	"	350
100	"	400

New Zealand: Standard NZS 4211

The rate of leakage at all test pressure differences up to 150 Pa shall not exceed those in the Table below.

Grade	dm^3/s per m of opening joint	dm^3/s per m^2 of total window area
A	0.6	2
B	2.0	8
C	4.0	17

Norway: Norwegian Building Regulations - Chapter 54

Windows shall be sufficiently airtight so that air leakage at a pressure difference of 50 Pa does not exceed 1.7 $m^3/h\ m^2$ (0.47 $dm^3/s\ m^2$)

Sweden: Standard SBN 1980

The maximum air leakage of windows is specified as follows:

Pressure difference Pa	Leakage rate $m^3/h\ m^2$ ($dm^3/s\ m^2$) for windows in building height (number of floors)		
	1 - 2	3 - 8	>8
50	1.7 (0.47)	1.7 (0.47)	1.7 (0.47)
300	5.6 (1.56)	5.6 (1.56)	5.6 (1.56)
500	-	-	7.9 (2.19)

Standard SIS 81 81 03 (1977)

Windows are classified as A, B or C and the permissible air leakage (q) for windows in each class is determined by the equation:

$$q = kp^{2/3}$$

where
q = air leakage in m^3/h per m^2 of window area.
k = a coefficient (0.2 for Class A and 0.125 for classes B and C).
p = pressure difference in Pa between inner and outer surfaces of window.

The lines corresponding to these classes have been plotted in Figure 2.

The values quoted above from SBN 1980 coincide with classes B and C.

Switzerland: Standard SIA 180/1

Maximum leakage rates for the various classes of windows

	Class			
	A	B	C	D
Test pressure difference Pa	150	300	600	>600
Height of building m	<8	8-20	20-100	-
Allowable coefficient of air permeability $m^3/h\ m\ Pa^{2/3}$ ($dm^3/s\ m\ Pa^{2/3}$)	0.44 (0.12)	0.22 (0.06)	0.22 (0.06)	0.22 (0.06)

UK: Standard BS 6375 Part 1

Four categories are specified with the following test pressure classifications. The acceptable rates of air leakage are expressed graphically and are shown on Figure 1.

Class	Test pressure
I	150
II	200
III	300
IV	600

The standard also specifies that the air leakage through fixed lights shall not exceed 1 m^3/h (0.28 dm^3/s) per metre length of the visible perimeter of the glass when tested at the same pressures as for opening lights.

USA: ASHRAE Standard 90-80

Leakage rate of windows at 75 Pa pressure difference to be no more than 0.77 dm^3/s per metre of sash joint.

West Germany: Standard DIN 18055

The classification of windows is as follows:

	Window classification			
	A	B	C	D
Test pressure (Pa) up to	150	300	600	unspecified
Height of building (m) up to	8	20	100	

The air leakage requirements are presented graphically and these have been reproduced in Figure 1.

Most standards specify the leakages in relation to unit length of the opening joint while a few specify them in terms of unit window area. Thus direct comparison of all the standards is not possible. However, comparison has been made in each of the two forms by plotting the allowable leakage values on Figures 1 and 2 . The plot of leakages expressed per metre of joint length show, surprisingly, that the highest classifications are to be found in countries having relatively mild climates, i.e. Belgium, New Zealand and UK. The high Scandinavian standards are evident in the other figure where they are compared with the New Zealand classifications which are expressed in both forms.

2.3 Doors

Canada: : "Measures for energy conservation in new buildings"

The following maximum air leakage rates at a pressure differential of 75 Pa are specified for doors separating heated spaces from unheated spaces or the exterior:

Manually operated sliding doors	2.5 dm^3/s per m^2 of door area
Swing doors (residential)	6.35 dm^3/s per m^2 of door area
Other types	17.0 dm^3/s per m^2 of door crack

Norway: : Norwegian Building Regulations

External doors are required to comply with the same requirements for airtightness as windows, i.e. 1.7 $m^3/h\ m^2$ (0.47 $dm^3/s\ m^2$).

Sweden: Swedish Building Code SBN 1980

Same classification is given for external doors and windows (see Section 2.2)

USA: ASHRAE Standard 90-80

Maximum air leakage rates at a pressure differential of 75 Pa are specified as follows:

Sliding glass doors (residential)	2.5 dm^3/s per m^2 of door area
Entrance swinging doors (residential)	6.35 dm^3/s per m^2 of door area
Swinging, revolving, sliding doors for other than residential use	17.0 dm^3/s per linear metre of door crack

These criteria are similar to those of Canada.

2.4 Building Sections

Leakage criteria for sections of buildings exposed to outdoors are only found in the following Scandinavian standards.

Norway: Norwegian Building Regulations

The maximum air leakage at a pressure difference of 50 Pa is specified as 0.4 $m^3/h\ m^2$ (0.11 $dm^3/s\ m^2$) for individual external building sections, i.e. external walls, ceilings and floors.

Sweden: Swedish Building Code SBN 1980

The maximum air leakage for various building sections is specified as follows:

	Pressure difference Pa	Maximum air leakage $m^3/h\ m^2$ ($dm^3/s\ m^2$) in building height (number of floors)		
		1-2	3-8	>8
Exposed walls	50	0.4(0.11)	0.2 (0.056)	0.2(0.056)
Roof and joist structures exposed to outdoors next to ventilated space	50	0.2 (0.056)	0.1 (0.028)	0.1(0.028)

3. TECHNIQUES FOR MEASURING AIR LEAKAGE

3.1 Whole Buildings

Canada:	*149-GP-10M* *Determination of airtightness of buildings by the fan depressurization method.* *Canadian General Standards Board. Fifth Draft. March 1983.*
Norway:	*NS 8200* *Airtightness of buildings. Test method.* *Norwegian Building Standard Council, 1981*
Sweden:	*SS 02 15 51* *Thermal insulation - determination of airtightness of buildings.* *Swedish Standards Commission, 1980*
United States of America:	*ASTM E779-81* *Standard practice for measuring air leakage by the fan pressurization method.* *American Society for Testing and Materials, 1981*
	ASTM E741-80 *Standard practice for measuring air leakage rate by the tracer dilution method.* *American Society for Testing and Materials, 1980*

With the exception of ASTM E741-80, these standards describe a basically similar test method involving the generation of measured air flow rates to produce a range of pressure differences between the inside and outside of a building. The Canadian Standard is the most detailed but it is the only one which limits the testing to depressurization; the others specify tests with both negative and positive internal pressures. The Norwegian and Swedish standards are almost identical.

There are no major differences in the specification of the equipment or the instrumentation except in respect of the measurement of external pressure. The Canadian standard specifies at least four pressure taps around the external facade of the building. Each pressure tap is connected to a suitable manifold to enable the measurement of an average pressure value. The two Scandinavian standards specify an external pressure sensing point 10m from the building. The external pressure sensing position is not clearly defined in the USA standard although the diagram of an acceptable test arrangement seems to indicate that a single pressure tap in a door would be sufficient.

The Canadian standard is unique in that it specifies a procedure for verifying the test data. If any one of four conditions is not met then the test is considered invalid.

One of the most significant variations in the prescribed methods is the detail of the preparation required before testing commences. The Canadian procedure is the most detailed as it includes a listing of the preparation required for all of the purpose-provided openings and vents such as fireplaces, exhaust fans, water traps, etc. The two Scandinavian standards specify that all ventilation openings in the enveloping structure should be closed, including openings for mechanical ventilation. The Swedish standard also includes the requirement to ensure that plumbing installations connected to outside air are sealed, e.g. water traps must be filled with water. No specification of preparatory sealing is given in the USA standard (ASTM E779-81). In comparing the results of testing to these standards, it is most important to note the degree of sealing that has been applied.

All of the standards specify the presentation of the test results as a plot of air flow rate against pressure difference. The Swedish standard also recommends the inclusion in the test report of the value of air leakage (expressed in air changes per hour) at 50 Pa pressure differential. The mean of the leakage at +50 Pa and -50 Pa should be quoted. The Norwegian standard similarly requires the leakage at 50 Pa but the value to be quoted is the mean of the values measured at 45, 50 and 55 Pa in both positive and negative modes. The Canadian standard gives a method of calculating the equivalent leakage area and calls for it to be quoted in the test reports.

Summarised below are the comparative specifications of instrumentation precision, test pressure range and limits of the outdoor climate conditions under which tests may be conducted.

Although tracer gas methods have been used in research for many years, only one standard exists on the use of this technique to measure the air leakage of a building. ASTM E741-80 (USA) specifies a procedure in which tracer gas is introduced into the building, is thoroughly mixed with the air within the building, and then sampled over a period of time. Alternative methods for analysing the decay of tracer gas concentration are presented from which the air change rate is determined. Safety precautions are included and an appendix lists the common tracer gases, their main characteristics and the associated methods of detection.

Standard	Precision	Pressure range	Climatic limits
Canada (149-GP-10M)	Flow rate ± 5 % Pressure ± 2 Pa Temperature ± 1 °C	0 to - 50 Pa	Windspeed ⩽ 5.5 m/s
Norway (NS 8200)	Flow rate ± 6 % Pressure ± 2 Pa Overall ± 8 %	0 to ± 55 Pa	Windspeed ⩽ 6 m/s
Sweden (SS 02 15 51)	Flow rate ± 6 % Pressure ± 2.5 Pa Overall ⩽ ± 8 %	0 to ± 55 Pa	Windspeed ⩽ 10 m/s
USA (ASTM E779-81)	Flow rate ± 6 % Pressure ± 2.5 Pa Temperature ± 0.5°C Overall ⩽ ±10 %	0 to ± 75 Pa	Windspeed ⩽ 4.4 m/s Indoor-outdoor temperature difference ⩽ 11°C

3. TECHNIQUES FOR MEASURING AIR LEAKAGE - continued

3.2 Components

Europe:	*EN 42* *Methods of testing windows: air permeability* *European Committee for Standardisation*
International:	*ISO 6613* *Windows and door height windows - air permeability test* *International Organisation for Standardisation, 1980*
Belgium:	*STS 52.0* *External joinery - general principles* *INL Draft, 1983*
Denmark:	*DS/EN 42* *Methods of testing windows - air permeability test* *Danish Standard, 1976*
Netherlands:	*NEN 3660* *Windows. Air permeability, water tightness, rigidity and strength. Methods of test.* *Netherlands Standards Institute (NNI), 1975*
Norway:	*NS 3206* *Methods of testing windows. Air tightness.* *Norwegian Standards Institute (NBF), 1974*
New Zealand:	*NZS 4211:1979* *Specification for performance of windows (Appendix C9)* *Standards Association of New Zealand, 1979*
Sweden:	*SS 81 81 26* *Windows and doors - airtightness - testing.* *Swedish Standards Commission (SIS), 1983*

United Kingdom:	*BS 5368:Part 1:1976 (EN42)* *Methods of testing windows. Part 1: Air permeability test.* *British Standards Institution, 1976*
	BS 4315:Part 1:1968 *Methods of test for resistance to air and water penetration. Part 1: Windows and structural gasket-glazing systems.* *British Standards Institution, 1968*
United States of America:	*ASTM E283-73* *Standard test method for rate of air leakage through exterior windows, curtain walls and doors.* *American Society for Testing and Materials,1973*
	ASTM E783-81 *Standard method for field measurement of air leakage through installed exterior windows and doors.* *American Society for Testing and Materials,1981*

3.2.1 Windows

The two international standards EN 42 and ISO 6613 are virtually identical and as most of the European member countries have adopted these as the basis for their national standards, there is a substantially common approach to the air leakage testing of windows.

Specifically, the standards of Denmark (DS/EN42), Netherlands (NEN 3660), Norway (NS 3206), Sweden (SS 81 81 26), UK (BS 5368) and West Germany (DIN(EN42)) are either identical to or closely related to the international versions. The window under test is installed over the opening of a chamber by which controlled pressures are applied across the window assembly. Before the main testing commences, extraneous air leakage from the chamber is measured and preferably eliminated. In addition, three pressure pulses are applied - each of 3 seconds duration and up to at least 500 Pa. The window is then opened and closed five times and finally secured in the closed position. Pressure is applied in stages of 50, 100, 150, 200, 300 and at 100 Pa intervals thereafter up to the maximum test pressure difference. Then the pressure is reduced to the same levels in reverse order. Of these standards, the Swedish version is unique in also specifying tests with pressure differences in the opposite direction. The international and other national standards include the reversal of pressure as an option.

The remaining standards while not so clearly akin to the international standards, specify a very similar test procedure though without the initial pressure pulsations. The Belgian method specifies test pressures up to 500 Pa and in both the positive and negative directions. The New Zealand (NZS 4211), UK (BS 4315) and USA (ASTM E283-73) standards are specific in requiring the extraneous leakage from the test chamber to be subtracted from the leakage rate measured with the window in place.

The maximum test pressures specified range from 1000 Pa in BS 4315 (UK) to 75 Pa in ASTM Standard E283-73 (USA) if no other pressure difference is designated.

3.2.2 Doors

In general, doors do not seem to have had as much attention as windows although some of the test procedures are specifically applicable to both types of component, e.g. SS 81 81 26 (Sweden) and ASTM Standard E283-73 (USA).

3.2.3 Other building components and joints

The ASTM Standard E283-73 (USA) includes in its scope curtain walls as well as windows and doors.

The only standard specific to joints in buildings is ISO 6589-1981 which is based on the test method for measuring the air permeability of windows (ISO 6613). Laboratory tests are specified for the measurement of joint air leakage with nominal, minimum and maximum specified joint widths and with the joint varying from minimum to maximum width along its length. A method for determining leakage at junctions is also described. The application of pressure differences is similar to the window test and includes the three initial pressure pulses. Tests at both positive and negative pressure differences are specified and reference is made to the requirement for corrections to take account of extraneous air leakage from the test chamber.

3.2.4 On-site testing

The one standard specifically related to component air leakage testing on site is ASTM E783-81. It describes a procedure for determining the air leakage characteristics of exterior windows and doors but it is stated that the method may also be adapted for other leakage routes in the building structure. The test involves sealing a substantially airtight enclosure to cover the internal or external face of the window or door and maintaining a specified pressure difference across the component by supplying air to, or exhausting air from, the enclosure. The required air flow rate is measured and recorded as the leakage through the component. The measurement and correction for extraneous leakage through the test enclosure is also detailed.

4. MINIMUM VENTILATION REQUIREMENTS

Canada:	*Residential Standards, Canada* *Associate Committee on the National Building Code* *National Research Council of Canada, 1977* *The National Building Code of Canada* *Associate Committee on the National Building Code* *National Research Council of Canada, 1980*
Denmark:	*The Danish Building Regulations* *Ministry of Housing, 1982*
Finland:	*D2* *Ventilation in Buildings* *National Building Code of Finland* *Ministry of the Interior, 1978*
Netherlands:	*NEN 1087* *Ventilation in dwellings. Requirements.* *Netherlands Standards Institute (NNI), 1981* *NPR 1088* *Ventilation in dwellings. Indications and examples of constructional performance of ventilation supplies.* *Netherlands Standards Institute (NNI), 1975*
New Zealand:	*NZS 1900* *Model building by-laws. Part 4: Residential buildings* *Standards Association of New Zealand, 1964*
Norway:	*Chapter 47. Ventilation and installation.* *Building Regulations of 1st August 1969* *Royal Ministry of Local Government and Labour*
Sweden:	*Chapter 36. SBN 1980. Air Quality.* *Swedish Building Code with Comments* *National Swedish Board of Physical Planning and Building (1981)*
Switzerland:	*SIA 384/2* *Thermal load of buildings for the design of heating plants* *Swiss Engineering and Architectural Association 1982.*

United Kingdom:	*Building Regulations (Second Amendment)* *Her Majesty's Stationery Office (HMSO), 1981*
	The Building Standards (Scotland) *Her Majesty's Stationery Office (HMSO) 1981*
United States of America:	*ASHRAE Standard 62-81* *Ventilation for acceptable indoor air quality* *The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. 1981*
West Germany:	*DIN 1946 Part 2* *Air conditioning. Health requirements.* *German Standards Institute (DIN), 1983*

Considerable attention is currently being paid to the specification of the rates of ventilation required in occupied buildings. Pressures to avoid excessive energy consumption have resulted in a tendency to reduce ventilation rates while increasing concern over indoor air pollution is producing a reverse trend. As a result of these two opposing influences the minimum ventilation rate requirement often becomes the maximum as well.

A summary of the required ventilation rates specified in the various countries is presented in Table 1. The rates are variously expressed in terms of flow rate per person, per room and per unit floor area so comprehensive comparison is impossible. Some variations between countries and between types of rooms are evident.

For dwellings, Denmark, Finland and Sweden have a general requirement which corresponds to 0.5 air changes/hour in rooms of normal height, whereas double that requirement is specified in Canada for mechanical ventilation.

Comparing the requirements for offices reveals that the minimum ventilation rate now specified in the USA (ASHRAE Standard 62-1981) is 2.5 dm^3/s per person whereas the West German equivalent is over three times higher at 8.3 dm^3/s (DIN 1946 Part 2 1983), It is also interesting to compare the increase in the ventilation rates required when smoking is allowed. In West Germany, ventilation has to be increased by a factor of 1.7, in Finland by a factor of 2 and in the USA by a factor of 4.

In most countries, mechanical ventilation is not mandatory in dwellings and so ventilation requirements are also specified in terms of the minimum area of ventilation opening, at least for the more critical rooms. Table 2 shows considerable variation between countries.

The latest version of ASHRAE Standard 62 (1981) reveals an interesting development. It contains two procedural options.

One is a prescriptive method in which, as in most other relevant standards, minimum ventilation rates for a number of building types and usage are specified. The alternative approach is based on specifications of limits of concentration of the most common contaminants but it does not prescribe the method for maintaining the concentrations below the specified levels. Both objective measurement and subjective evaluation of the resulting environment are incorporated though not clearly prescribed. While this approach allows the innovation of alternative methods of contaminant control, it is recognised that insufficient or incompatible data exists on the acceptable limits of concentration of many contaminants and that objective measurement techniques for some of the contaminants are either non-existent or expensive.

FIGURE 1: Window air leakage rates - per m joint length

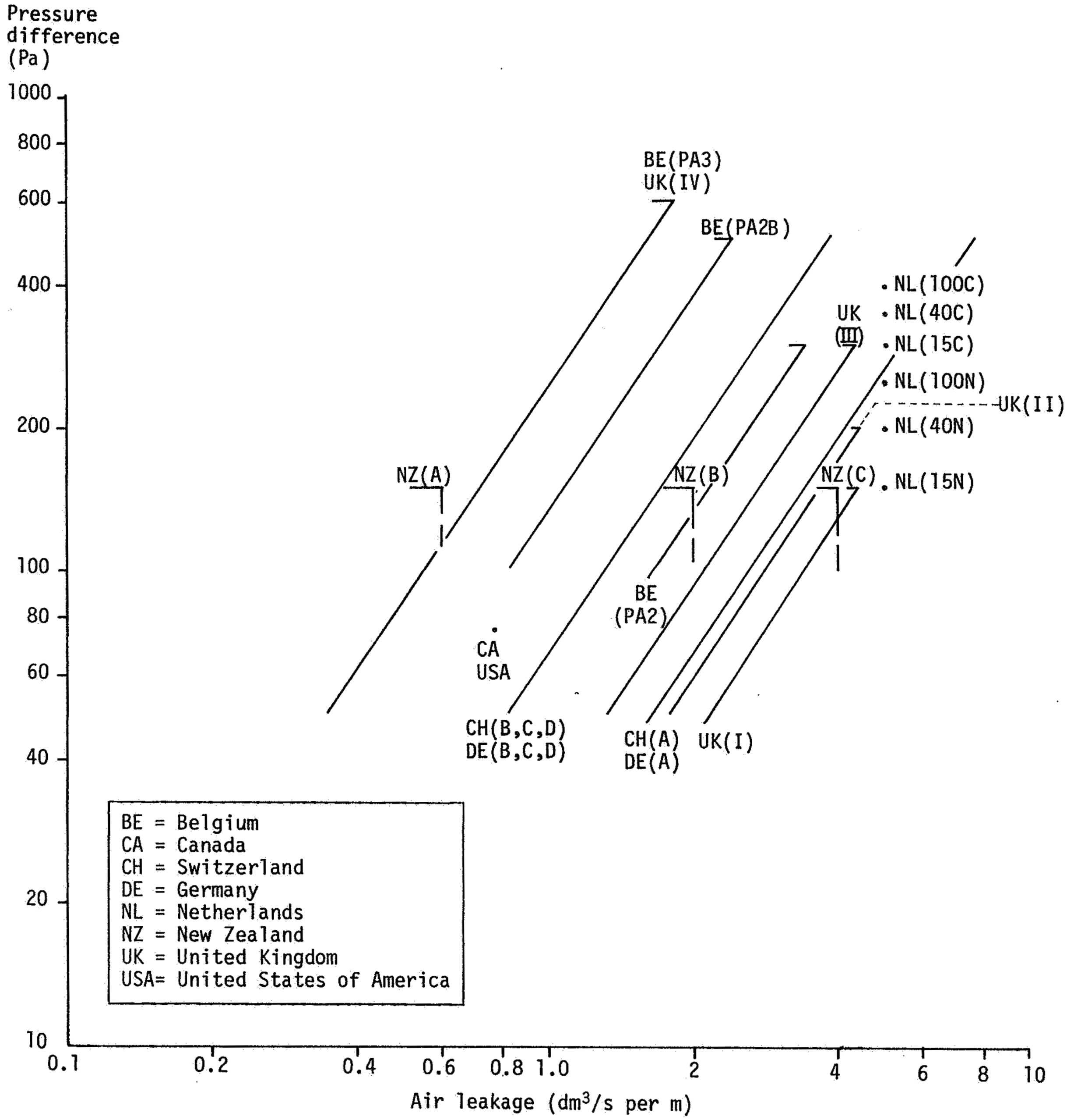

FIGURE 2: Window air leakage rates - per m^2 window area

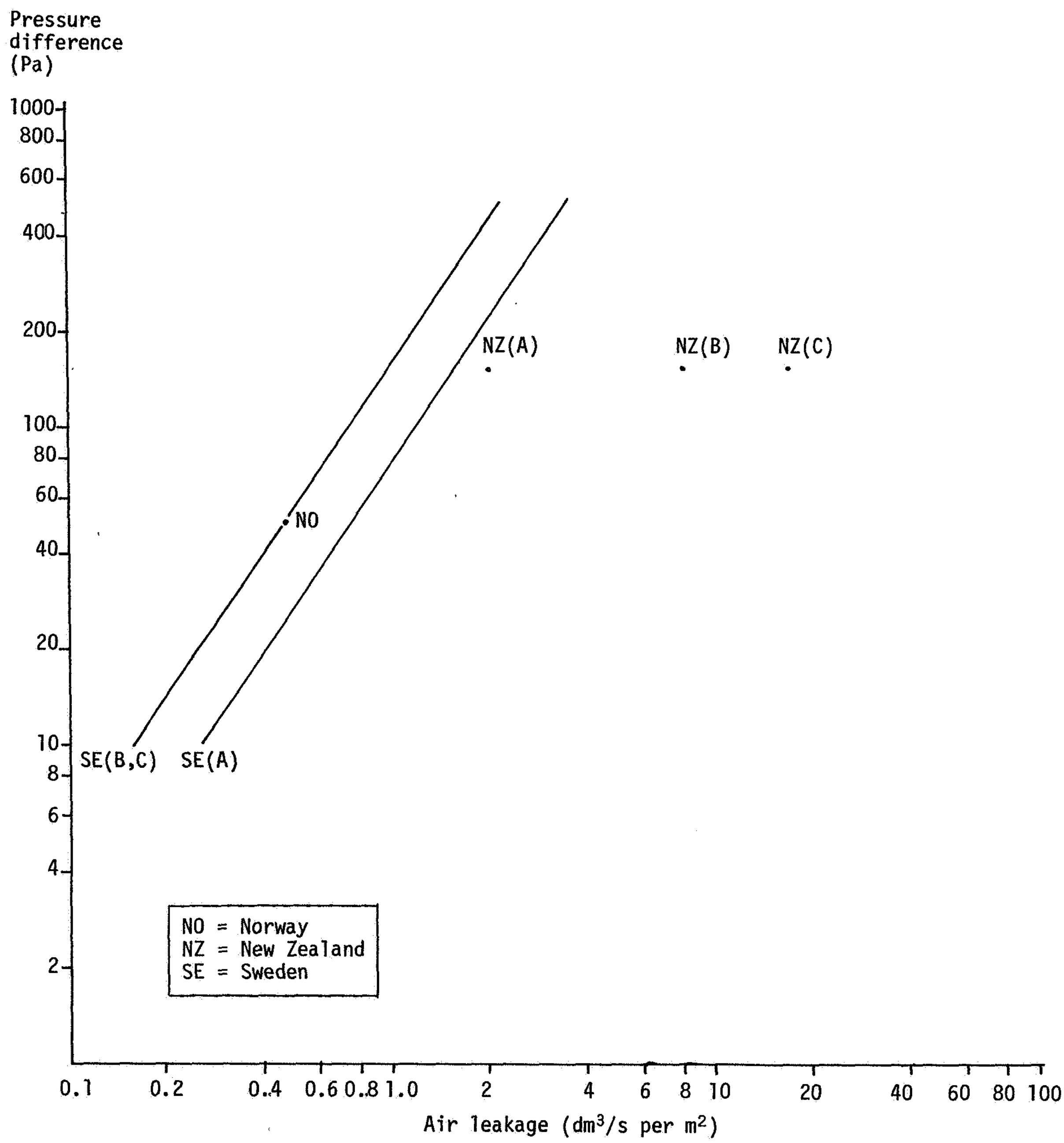

TABLE 1: Minimum ventilation rates

		Canada	Denmark	Finland	Netherlands	Norway	Sweden	Switzerland	UK	USA	W. Germany
Residential	Whole dwelling	1 ac/h [3]	0.5 ac/h	0.35 $dm^3/s\ m^2$ [2]			0.35 $dm^3/s\ m^2$ ≡ 0.5 ac/h				
Residential	Living room				21 - 42 $dm^3/s\ m^2$				3 - 8 dm^3/s pers. [4]	5 dm^3/s	1 - 1.5 ac/h
Residential	Bedroom				1 $dm^3/s\ m^2$				3 - 8 dm^3/s pers. [4]	5 dm^3/s	1 - 1.5 ac/h
Residential	Kitchen		15 - 20 dm^3/s [3]	8.8 dm^3/s	21 - 28 $dm^3/s\ m^2$	22 dm^3/s [3]	10 dm^3/s	22 - 33 dm^3/s	6 ac/h [1,4]	50 dm^3/s [1]	33 dm^3/s
Residential	Bathroom/WC		15 dm^3/s [3]	6.4 dm^3/s	14 $dm^3/s\ m^2$	17 dm^3/s [3]	10 dm^3/s	17 dm^3/s	3 ac/h [1,4]	25 dm^3/s [1]	17 dm^3/s
Offices	No smoking	refers to ASHRAE Standards		0.8 $dm^3/s\ m^2$		1.4 $dm^3/s\ m^2$				2.5 dm^3/s pers.	8.3 dm^3/s pers.
Offices	Smoking			1.6 $dm^3/s\ m^2$						10 dm^3/s pers.	13.9 dm^3/s pers.

Notes:
[1] Installed capacity for intermittent use
[2] Values also given per person related to occupancy density for smoking and non-smoking
[3] If mechanical ventilation is used, otherwise ventilation openings are specified (see Table 2)
[4] Scotland only, for England and Wales see Table 2 . Separate regulations apply to Inner London.

TABLE 2: Minimum ventilation openings

		Canada	Denmark	Netherlands	New Zealand	Norway	Sweden	UK
Residential	Living room	0.28 m^2		0.02 to 0.04 m^2	5% [3]			5% [1,3]
	Bedroom	0.28 m^2		0.02 to 0.04 m^2	5% [3]			5% [1,3]
	Kitchen	0.28 m^2	0.015 to 0.02 m^2	0.02 to 0.03 m^2	5% [3]	0.02 m^2 [2]	0.02 m^2	5% [1,3]
	Bathroom/WC	0.09 m^2	0.015 m^2	0.01 m^2	5% [3]	0.015 m^2 [2]	0.015 m^2	5% [1,3]

Notes:

[1] England and Wales only. Different specifications apply to Inner London and Scotland.

[2] Requirements for exhaust air, additional requirements are specified for supply air.

[3] % of floor area.