DRAFT FOR DEVELOPMENT

RECOMMENDATIONS FOR THE GRADING OF WINDOWS

Resistance to wind loads, air infiltration and water penetration, and with notes on window security

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2 PARK STREET, LONDON W1A 2BS

Telex: 266933 Telephone: 01-629 9000

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This Draft for Development makes reference to the following British Standards:

BS 4315. Methods of test for resistance to air and water penetration.
Part 1. Windows and gasket glazing systems.
CP 3. Code of basic data for the design of buildings. Chapter V. Loading.
Part 2. Wind loads.
CP 152. Glazing and fixing of glass for buildings.

The following BSI references relate to the work on this Draft for Development:
Committee references BLCP/2 and BLCP/2/4

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CO-OPERATING ORGANIZATIONS

CODE DRAFTING COMMITTEE BLCP/2—WINDOWS, DOORS AND FRAMES

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Mr. R. Goodchild‡‡	*Department of the Environment—Forest Products Research Laboratory*
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The Drafting Sub-Committee BLCP/2/4, Windows, consists of the members of BLCP/2 Committee marked with an asterisk in the above list, under the Chairmanship of Mr. H. E. Beckett, with the following additional members:

Mr. J. E. Douglas	*Association of Builders' Hardware Manufacturers*
Mr. C. A. Brighton§§	*British Plastics Federation*
Mr. A. F. Pyne	
Mr. S. K. Finch	*British Woodwork Manufacturers' Association*
Mr. R. Slattery‖‖	
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Mr. J. F. R. White	
Mr. J. Jobson	*Department of the Environment*
Miss Margaret Law	*Department of the Environment—Joint Fire Research Organization*
Mr. S. Leith	*Scottish Development Department*

† Resigned December 1969.
‡ Replaced by Mr. G. H. Merrel May 1970.
§ Replaced by *Mr. D. R. Goodall December 1969.
‖ Replaced by *Mr. R. G. D. Brown October 1969.
¶ Resigned November 1969.
†† Replaced by *Mr. P. Whiteley May 1969.
‡‡ Replaced by *Mr. N. P. Skinner and *Mr. J. G. Sunley June 1970.
§§ Replaced by Dr. H. J. Sharp April 1970.
‖‖ Resigned December 1969.

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RECOMMENDATIONS FOR THE GRADING OF WINDOWS

Resistance to wind loads, air infiltration and water penetration, and with notes on window security

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature because of the lack of research data available. It is recommended that it should be applied on this provisional basis so that information and experience of its practical application may be obtained. Those who use it are urged to write to BSI giving their experience in applying this publication. Constructive proposals for improvement and more precise definition will be welcomed.

The intention is to issue a more permanent publication when sufficient knowledge and experience have accumulated.

The British Standards Institution requests that, because of the provisional nature of the publication, its reference number should not be marked on products.

FOREWORD

A comprehensive set of performance requirements for windows was circulated in November 1968 as a draft for comment, document 68/29449. Although this was designated a draft British Standard Code of Practice, it differed fundamentally from other Codes of Practice in that it was concerned only with the properties and performance to be provided by the manufacturer. The various properties were discussed without regard to the materials of which a window is made; wherever possible the appropriate methods of test were indicated; and an attempt was made to define the acceptance limits that were likely to be appropriate in various circumstances of use.

BSI is at present considering the need for national standards of performance requirements in building, and the possibility of embarking on a programme for the regrouping of much of the existing BSI documentation into more clearly defined categories, relating to performance requirements, product standards and codes of practice, for the design and construction processes. It is therefore not certain, at the time of issuing this Draft for Development, into which of these broad categories the final publication will fall, but it is intended that it will form part of future comprehensive documentation on performance requirements in building.

In preparing the original draft for comment, account was taken wherever possible of the known performance of windows available in this country. Many of the properties included, however, have never been systematically explored and much more factual information will have to be assembled before the document can be finalized. Experimental work for this purpose is now going on in various places. In the meantime, window manufacturers and users are anxious that a start should be made in marketing windows of known performance and this initial document of limited scope has therefore been prepared. It proposes three grades of exposure, defined in terms of the maximum gust speeds, averaged over 3-second periods, which are to be expected and shows how, by appropriate adjustments of the maximum speeds, the grading system can be made to take account not only of the geographical location but also of the extent to which an area is built up and of the position of a window in a particular building. It then suggests performance limits for strength against wind loading, for air infiltration and for resistance to water penetration, which should be satisfied

under the three conditions of exposure. Finally, as a result of co-operation between the committee and the Home Office Crime Prevention Centre, it makes some recommendations in relation to the security of windows. This is a modest start and the document will be replaced by one of wider coverage as soon as possible. The present issue, however, should enable some useful progress to be made.

In preparing the present document the drafting Sub-Committee was greatly helped by being able to draw on the experience of the Building Research Station and the Forest Products Research Laboratory and on the research information made available through the representative of the Flat Glass Manufacturers' Association. Acknowledgement is also made of the work on the development of window testing being carried out at the BSI Hemel Hempstead Centre and at the Paisley College of Technology.

NOTE. As part of BSI's programme of metrication this Draft for Development is expressed in metric terms. The metric values are given in SI units and the N/m^2 is used as the basic unit for air pressures. As it is still usual for manometers to be calibrated in terms of mmH_2O (millimetres water gauge), approximate conversions in these terms are given for information.

For further information on SI units reference may be made to BS 3763, ' International System (SI) units ' and PD 5686, ' The use of SI units '.

RECOMMENDATIONS

1. SCOPE

1.1 For the purposes of this Draft for Development a window is taken to be any part of an external wall which consists predominantly of transparent or translucent sheet material contained within a surrounding frame, with any necessary intermediate frame members or coupling members. Windows are not normally designed to withstand loads imposed by the adjacent structures.

1.2 Because of the inadequacy of present knowledge these recommendations should not be applied to:

(1) windows in which any frame member is longer than 3 m;
(2) windows with multiple louvres;
(3) windows in which the opening lights are not fully framed;
(4) windows glazed with plastics sheets.

NOTE. The titles of the British Standards referred to in this Draft for Development are listed on page 2.

2. EXPOSURE CONDITIONS

2.1 Three grades of exposure should be recognized, defined in terms of the maximum 3-second gust speeds to be expected, as shown in Table 1.

TABLE 1. GRADES OF EXPOSURE

Exposure	Maximum 3-second gust speed*
	m/s
Sheltered	40
Moderate	45
Severe (*a*)	50
Severe (*b*)	(55)†

* The maximum speed averaged over a 3-second period, on a once in 50 years probability (see Appendix B of CP 3, Chapter V, Part 2).

† This figure is put in brackets as it is an assumed upper limit, unlikely to be exceeded in any permanently inhabited site in the UK.

Normally the upper limit for severe exposure should be taken at 50 m/s. Where the situation of the windows is known to be exceptionally windy and it seems likely that the speed of 50 m/s may be exceeded, the higher speed 55 m/s should be taken as the upper limit. This should only rarely be necessary.

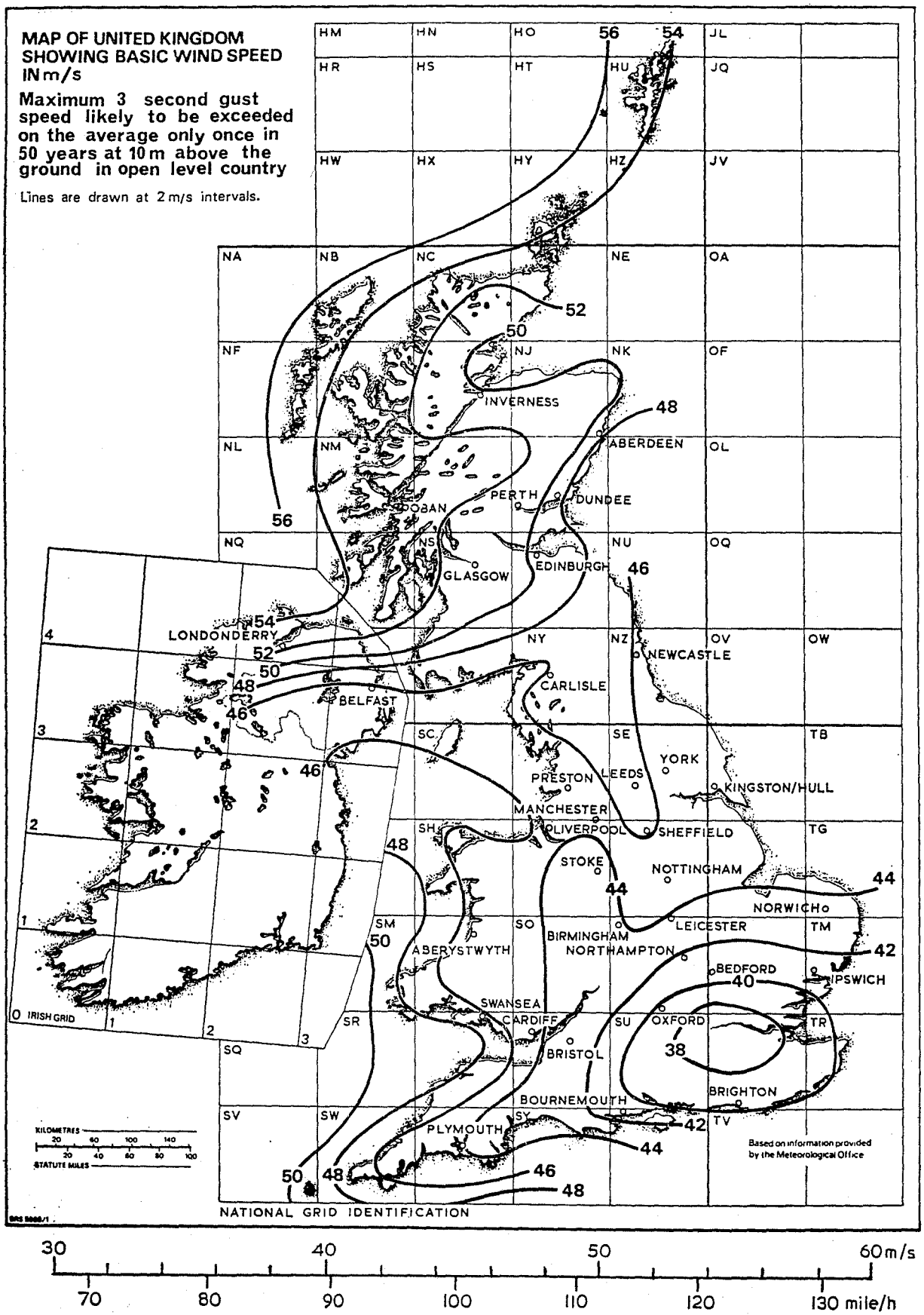

Fig. 1. Distribution of basic wind speed over the UK

2.2 The 3-second gust speed is the figure normally provided by the standard meteorological wind-measuring instrument, and for ordinary meteorological purposes its maximum value is usually stated at a standard height of 10 m above ground level. The maximum speed will, however, vary not only on a geographical basis but also in relation to height and position on a building and the extent to which an area is built up. All these factors have to be taken into account in a final assessment of the grade of exposure in any set of circumstances. The procedure to be followed should be that described in CP 3, Chapter V, Part 2.

2.3 The maximum 3-second gust speed should first be ascertained for the geographical location, at the standard 10 m height, either from Fig. 1, or its associated tabulation of figures for cities and towns in Table 2, which are taken from CP 3, Chapter V, Part 2; or directly from the Meteorological Office*. It should then be multiplied by the appropriate factor from Table 3, in accordance with the nature of the terrain and the height of the window in the building. Finally, if the site is an elevated one in hilly country, an additional topographical factor of 1·1 should be applied. The resultant corrected speed will then determine the exposure grading for the particular set of conditions. On a tall building, different exposure gradings are likely to apply at different heights on the building.

TABLE 2. BASIC 3-SECOND GUST SPEEDS IN METRES PER SECOND FOR SOME CITIES AND TOWNS IN THE UK

Aberdeen	49	Leeds	46
Bedford	40	Leicester	44
Belfast	45	Liverpool	46
Birkenhead	47	London	38
Birmingham	43	Londonderry	52
Blackpool	46	Luton	40
Bournemouth	42	Manchester	45
Bradford	47	Middlesbrough	45
Brighton	40	Newcastle-upon-Tyne	45
Bristol	43	Northampton	42
Cambridge	41	Norwich	43
Cardiff	45	Nottingham	45
Carlisle	46	Oxford	40
Coventry	44	Perth	50
Dumfries	47	Plymouth	44
Dundee	50	Portsmouth	40
Edinburgh	50	Preston	45
Exeter	43	Sheffield	46
Glasgow	51	Southampton	40
Great Yarmouth	43	Stoke	43
Huddersfield	46	Swansea	48
Inverness	49	Wolverhampton	43
Ipswich	41	York	45
Kingston-upon-Hull	45		

These values apply to the cities and towns only and not necessarily to the surrounding areas.

* Meteorological Office Met O 3(b), London Road, Bracknell, Berkshire RG12 2SZ.
Meteorological Office, 26 Palmerston Place, Edinburgh EH12 5AN.
Meteorological Office, Tyrone House, Ormeau Avenue, Belfast BT2 8HH.

TABLE 3. SPEED CORRECTION FACTORS FOR GROUND ROUGHNESS AND HEIGHT ABOVE GROUND LEVEL

Ground roughness*	Category 1	Category 2	Category 3	Category 4
Height above ground level	Correction factors			
m				
3 or less	0·83	0·72	0·64	0·56
5	0·88	0·79	0·70	0·60
10	1·00	0·93	0·78	0·67
15	1·03	1·00	0·88	0·74
20	1·06	1·03	0·95	0·79
30	1·09	1·07	1·01	0·90
40	1·12	1·10	1·05	0·97
50	1·14	1·12	1·08	1·02
60	1·15	1·14	1·10	1·05
80	1·18	1·17	1·13	1·10
100	1·20	1·19	1·16	1·13
120	1·22	1·21	1·18	1·15
140	1·24	1·22	1·20	1·17
160	1·25	1·24	1·21	1·19
180	1·26	1·25	1·23	1·20
200	1·27	1·26	1·24	1·22

* *Ground roughness categories*

Category 1. Open country with no obstructions.
Category 2. Open country with scattered windbreaks.
Category 3. Country with many windbreaks; small towns; outskirts of large cities.
Category 4. Surface with large and frequent obstructions, e.g. city centres.

3. WIND LOADING

3.1 To determine the maximum wind loadings against which windows should be tested, for the three grades of exposure, the dynamic pressure q is first computed from the maximum 3-second gust speed for each grade, using an expression of the form $q = kV^2$, where k is a constant the value of which depends on the units being used. It is then necessary to apply an appropriate pressure coefficient. This may be positive, indicating pressure, or negative, indicating suction, and its value will depend on the position on the particular building and on the building's shape. For windows in most positions in buildings it is proposed that design loadings should be taken which are 1·5 times the dynamic pressure. This is in line with the existing glazing code, CP 152. The 1·5 factor embraces possible dangerous combinational effects where pressure or suction on the outer face of a window may be supplemented by suction or pressure on the inner face as the result of an opening in the building envelope. The critical values of wind loadings which result from this process are shown in Table 4.

TABLE 4. CRITICAL VALUES OF WIND LOADING

Exposure	Maximum 3-second gust speed	Probable maximum wind loading	
	m/s	N/m²†	mmH₂O†
Sheltered	40	1500	150
Moderate	45	1900	190
Severe (*a*)	50	2300	230
Severe (*b*)	(55)	(2800)	(280)

† These values have been rounded.

3.2 These proposed design wind loadings will be adequate for most positions on a building. They may, however, be a little low for the exceptional circumstances which can occur near the corners of high buildings. Where windows are to be inserted within 3 m of an exposed corner, a grade of exposure one higher than would normally be assumed should be taken. If the exposure is already graded as Severe (*a*), this would be an occasion for bringing the exceptional grade Severe (*b*) into use.

3.3 The grading of wind loading described in 3.1 and 3.2 has been devised to enable manufacturers to meet the demands of a wide range of exposure conditions without having to make windows in an uneconomic multiplicity of strengths. Nevertheless, there may be circumstances, particularly at low heights in built-up areas inland, where the use of the proposed grades must result in the windows being appreciably over-designed in relation to the actual maximum wind loads to be expected. This is an inevitable consequence of any grading system with a small number of grades. For those who prefer to use more flexible arrangements it is equally acceptable, in any particular application, to design to meet the expected maximum wind load rather than that of the nearest grade above. This is a direct application of CP 3, Chapter V, Part 2. Much of the procedure outlined in Section 2 above, and the use of the 1·5 factor as described in 3.1 to cover all circumstances other than those near the corners of high buildings, will still apply. The windows need then be tested only up to the actual design load. In all circumstances the thickness of glass in the test should be in accordance with CP 152.

3.4 The testing of windows against wind loading can best be done in an apparatus in which the window is fitted into a surround to form one wall of a box which can be pressurized, and it is generally convenient to use the same box as for the air infiltration and water penetration tests. Ideally, the maximum pressure should be built up quickly, in simulation of a 3-second gust, from a much lower steady pressure representing the mean value maintained in a wind storm. Such a test is at present being developed at the Hemel Hempstead Testing Centre of BSI, but experience needs to be gained before the test can be generally recommended. Meanwhile, a slower form of test will have to be used, though the time occupied in the test should be kept as short as possible. Arrangements should be made to observe deflections at selected points on the window frame likely to show maximum movement, and the maximum pressure difference should be imposed as quickly as the equipment will permit, with pauses of not longer than 1 minute for the reading of deflections at one half and three quarters of the maximum. At the maximum pressure difference the pressure should be held for not longer than 1 minute and then suddenly released and the full pressure re-imposed in as short a time as possible, to simulate wind buffeting. The release and re-imposition of pressure should be done three times in all. Subsequently the pressure should be allowed to return to zero and a check should be made that there is no permanent residual deflection.

3.5 Because in a building a window may be subjected to either pressure or suction, it should be tested in both directions. If it has opening lights, they should be closed firmly and secured by the ordinary window catches. In the event of there being too much air leakage to permit the necessary build up of pressure, the opening joints can be taped, though some care may be necessary to ensure that this does not affect the deflections. The sequence of pressure tests should normally be:

Pressure on outer face of window

Test to 1500 N/m^2	(150 mmH_2O)	(Sheltered)
Test to 1900 N/m^2	(190 mmH_2O)	(Moderate)
Test to 2300 N/m^2	(230 mmH_2O)	(Severe (*a*))
Test to 2800 N/m^2	(280 mmH_2O)	(Severe (*b*), if required)

Pressure on inner face of window

Repeat above sequence

For windows which are designed only for Sheltered, or for Sheltered and Moderate exposures, the testing can be stopped at the appropriate points. Alternatively, the windows can be tested for the expected actual wind loading, in accordance with 3.3. All testing should be done at normal laboratory temperature.

3.6 Where the window is to be putty-glazed it is unlikely that the putty will set hard enough in any reasonable time to permit the pressure testing without serious risk of displacement of the glazing material. To overcome this difficulty a proprietary crack stopper based on methyl ethyl cellulose with chalk as filler may be used in place of the putty, but following the normal technique for puttying. The glazing joints should be painted after 24 hours.

3.7 The criterion of success in this testing against wind loading is that, after being tested to the appropriate maximum pressure, the window should show no permanent deformation or any other damage, and that there should be no failure of the window fastenings. At the maximum pressure the maximum recoverable deflection of any member of the main frame should not exceed 1/125 of the clear span of the member, in single glazed windows, or 1/175 of the clear span of the window member in windows glazed with sealed double units.

NOTE. These deflection limits do not apply to frame members longer than 3 m, which are excluded from the scope of this Draft for Development.

3.8 Although the above form of test has been speeded up as far as is practicable, there may still, on a few occasions, be breakage of glass which according to CP 152 would be judged of adequate thickness for the required maximum pressure. Where this happens it can almost certainly be ascribed to the fact that glass is strongest under impulsive loading and considerably weaker under sustained loading; which is part of the argument for the development of a short-period gust test. If such a situation arises, and the window is fully framed (and therefore within the scope of this document), it should be assumed that the glass breakage is due to the sustained loading effect, and the window should not be deemed to have failed because of the breakage. Provided the window frame has not been damaged, it should be reglazed and retested. It is hoped that in the fairly near future it will be possible to minimize this difficulty by using a 3-second gust test.

4. AIR INFILTRATION

4.1 Windows should be tested for air infiltration by the method described in BS 4315, Part 1. Normally the test should be made only for inward air flow, i.e. with the pressure applied to the outer face of the window. For the three grades of exposure defined in Section 2 the air infiltration rates at the stated pressure differences should not exceed the values as summarized in Table 5.

TABLE 5. AIR INFILTRATION LIMITS

Exposure	Maximum air infiltration rate	Pressure difference	
	m^3/h per metre length of opening joint	N/m^2	(mmH_2O)
Sheltered	12	100	10
Moderate	12	150	15
Severe	12	200	20

In choosing these values account has been taken of the variations in performance likely to be found between nominally identical windows due to variations in manufacture. All production windows should comply with these minimum requirements.

4.2 The testing of the window for air infiltration should be done after the window has been subjected to the wind loading test at the required pressure. In this case it is not possible, in the present state of knowledge, to extend the flexibility permitted with wind loading, and the testing for air infiltration should be done at the appropriate grade or grades.

5. WATER PENETRATION

5.1 The resistance to water penetration should also be tested by the method described in BS 4315, Part 1. After 15 minutes with the water applied but at zero pressure difference, the pressure is raised in steps of 50 N/m^2 (5 mmH_2O) every 5 minutes until ' gross leakage ' through the window occurs. The pressure difference limits for the three grades of exposure are given in Table 6.

5.2 It should be clearly understood that these pressure differences have no direct relation to the actual pressure differences to be expected during rain storms. They represent test conditions which have been found to correlate satisfactorily, in this method, with the actual performance of windows in buildings.

TABLE 6. PRESSURE DIFFERENCE LIMITS FOR RESISTANCE TO WATER PENETRATION

Exposure	Pressure difference up to which ' gross leakage ' should not occur	
	N/m^2	(mmH_2O)
Sheltered	50	5
Moderate	150	15
Severe	300	30

5.3 The testing of the window for water penetration should be done after the window has been tested for resistance to wind pressure and for air infiltration. As in testing for air infiltration, this water penetration test should be done at the appropriate grade or grades.

5.4 In the water test of BS 4315, Part 1, the window is mounted flush with its surround and the figures in Table 6 apply to this condition. In practice a better performance in respect of water penetration can usually be obtained by setting a window back from the outer face of a wall and it is recommended that this should be done wherever possible.

6. SECURITY

6.1 The achievement of full security with windows, in so far as this can be done, involves the use of special fittings and special glazing materials, and is expensive. No attempt is made to cover the requirements for full security in this document.

6.2 With ordinary windows, the value of security measures is to some extent limited by the fact that a burglar may gain entry by breaking the glass. If, however, the panes are large and therefore likely to be noisy when broken, or are in public view, he will try other means of entry first and will break the glass only as a final resort.

6.3 In these circumstances it is worth considering the features of window design which make breaking in more difficult. The following points should be kept in mind:

(1) Fasteners, bolts and hinges should be strong enough to resist forcing, and fasteners should be designed so that they cannot be released by the insertion of a thin blade.

(2) No opening light should be openable from the outside, when it is fastened in the closed position, except by the use of special tools or by breaking a part of the window.

(3) Large opening lights which may need to be left open by small amounts for ventilation should have fittings enabling this to be done without loss of security.

(4) Small ventilating lights which can give access to the fasteners of larger opening lights are often a serious security risk. If used they should open in such a way, or be in such positions, that access to other fasteners is impossible. In the upper parts of windows bottom-hung ventilating lights will in general be more

secure than top-hung lights. As an alternative to small ventilating lights, special window ventilators may be used and will often give greater security. The long slotted types should not normally allow any entry. Those which are mounted in holes cut in the glass should not be capable of being dismantled from the outside, as the holes are usually large enough to admit an arm.

(5) With bead glazing systems, inside glazing is more secure than outside glazing, in that the panes cannot then be taken out without breakage, simply by the removal of the glazing compound and/or beads. With putty glazing the same comment applies during the first few months of the putty's life, but it is difficult to remove the putty once it has set hard.

(6) Louvre windows may present a special risk, and care should be taken to ensure that individual glass slats cannot be slid or sprung out of their end seatings.

(7) Double glazing, and especially the use of double windows, is likely to act as a deterrent to entry by the breakage of glass.

6.4 Security risks will vary greatly according to the positions of windows. They will be greatest where there is easy external access at ground level or from balconies, particularly where the windows are in a secluded position. In such places there could with advantage be a greater use of simple window locks.

6.5 Where more particular advice on window security is needed, the crime prevention department of the local police should be consulted.

7. SUMMARY OF RECOMMENDED REQUIREMENTS

The test conditions and recommended requirements for wind loading, air infiltration and water penetration are summarized in Table 7. The wind loading tests are done in duplicate, with the pressure applied first on the outer face of the window and then on the inner face. The air and water tests are done with the pressure on the outer face only.

TABLE 7. SUMMARY OF REQUIREMENTS

Test	Exposure	Test pressure		Requirement
		N/m^2	(mmH_2O)	
Wind loading*	Sheltered	1500	150	No permanent distortion or other damage. For single glazed windows deflections not greater than 1/125 and for double glazed windows deflections not greater than 1/175 of the span under consideration.
	Moderate	1900	190	
	Severe (*a*)	2300	230	
	Severe (*b*)	2800	280	
Air infiltration	Sheltered	100	10	Infiltration not greater than 12 m^3/h per metre length of opening joint at test pressure.
	Moderate	150	15	
	Severe	200	20	
Water penetration	Sheltered	50	5	No gross leakage up to the test pressure.
	Moderate	150	15	
	Severe	300	30	

* Where windows are being designed for the actual expected wind load instead of for one of the grades, in accordance with 3.3, the test pressure should be the expected maximum load.

NOTE. For certain conditions of exposure, the proposed requirements for air and water penetration are easier than those required by the Government departments, some of which were directly represented on this committee. Details of the Government requirements, with explanation of the underlying principles, have been published (see Technical Note No. 1—' Performance requirements for windows ', Interdepartmental Sub-Committee for Component Co-ordination, April 1970.)