INTERNATIONAL STANDARD

ISO 15927-3

First edition
2009-03-15

Hygrothermal performance of buildings — Calculation and presentation of climatic data —

Part 3:
Calculation of a driving rain index for vertical surfaces from hourly wind and rain data

Performance hygrothermique des bâtiments — Calcul et présentation des données climatiques —

Partie 3: Calcul d'un indice de pluie battante pour surfaces verticales à partir de données horaires de vent et de pluie

Reference number
ISO 15927-3:2009(E)

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Published in Switzerland

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Foreword

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ISO 15927-3 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components*, in collaboration with Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 15927 consists of the following parts, under the general title *Hygrothermal performance of buildings — Calculation and presentation of climatic data*:

— *Part 1: Monthly means of single meteorological elements*

— *Part 2: Hourly data for design cooling load*

— *Part 3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data*

— *Part 4: Hourly data for assessing the annual energy use for heating and cooling*

— *Part 5: Data for design heat load for space heating*

— *Part 6: Accumulated temperature differences (degree-days)*

Introduction

This part of ISO 15927 specifies two procedures for analysing data derived from hourly observations of wind and rainfall so as to provide an estimate in terms of both an annual average and short-term spells of the quantity of water likely to impact on a wall of any given orientation.

The first method, which uses hourly observations of wind and rainfall, is based closely on BS 8104 [1], which originated from a long series of measurements of driving rain on buildings in a wide range of locations within the UK. As such, the method applies to climates similar to those in the UK; in other regions, with very different climates, it is recommended that confirmation of its applicability be obtained by measurements of driving rain on representative buildings.

Where hourly observations of wind and rain are not available, the second procedure, based on the present weather code for rain and average wind speeds can be used.

In all cases, especially in mountainous areas, it is important that direct measurements of the rain impacting on building façades be made wherever possible.

Rain penetration around the edges of doors and windows or similar cracks in building façades depends on shorter periods of heavy rain and strong winds.

Hygrothermal performance of buildings — Calculation and presentation of climatic data —

Part 3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data

1 Scope

This part of ISO 15927 specifies two procedures for providing an estimate of the quantity of water likely to impact on a wall of any given orientation. It takes account of topography, local sheltering and the type of building and wall.

The first method, given in Clause 3 and based on coincident hourly rainfall and wind data, defines a means of calculating

— the annual average index, which influences the moisture content of an absorbent surface, such as masonry, and

— the spell index, which influences the likelihood of rain penetration through masonry and joints in other walling systems.

The second method, given in Clause 4 and based on average wind data and a qualitative recording of the presence and intensity of rain (the present weather code for rain), defines a means of calculating the spell length during which an absorbent material such as masonry is moistened, which has a 10 % probability of being exceeded in any year (commonly referred to as having a mean return period of 10 years).

A comparison between the two methods is given in informative Annex D.

Procedures are given to correct the results of both methods for topography, local sheltering and the type of building and wall.

The methods included in this part of ISO 15927 do not apply in

a) mountainous areas with sheer cliffs or deep gorges,

b) areas in which more than 25 % of the annual rainfall comes from severe convective storms,

c) areas and periods when a significant proportion of precipitation is made up of snow or hail.

2 Terms, definitions, symbols and units

For the purposes of this document, the following terms, definitions, symbols and units apply.

2.1 Definitions

2.1.1
spell
period, or sequence of periods, of wind-driven rain on a vertical surface of given orientation

NOTE Further information about spells is given in Annex B.

2.1.2
airfield hourly index
quantity of driving rain that would occur on a vertical wall of given orientation per square metre of wall during 1 h at a height of 10 m above ground level in the middle of an airfield, at the geographical location of the wall

2.1.3
airfield annual index
airfield index for a given wall orientation totalled over one year

2.1.4
airfield spell index
airfield index for a given wall orientation totalled over the worst spell likely to occur in any three-year period

2.1.5
wall annual index
quantity of wind-driven rain per square metre at a point on a wall of given orientation, based on the airfield annual index and corrections for roughness, topography, obstruction and wall factors

2.1.6
wall spell index
quantity of wind-driven rain per square metre at a point on a given wall, based on the airfield spell index and corrections for roughness, topography, obstruction and wall factors

2.1.7
line of sight
horizontal view away from the wall, over a sector spanning about 25° either side of the normal to the wall

2.1.8
terrain roughness category
classification of the surface roughness upwind in terms of the average height and spacing of obstructions such as buildings, trees or hedges

2.1.9
roughness coefficient
factor that allows for the modification of the wind speed by the roughness of the terrain upwind of a wall

2.1.10
topography coefficient
factor that allows for the effect of local topography on the wind speed

2.1.11
obstruction factor
factor that relates to shelter from the very local environment and allows for obstructions such as buildings, fences and trees close to, and upwind of, the wall

2.1.12
wall factor
ratio of the quantity of water hitting a wall to the quantity passing through an equivalent unobstructed space, allowing for the characteristics of the wall

2.1.13
wall orientation
angle between north and line normal to a wall

2.1.14
convective storm
heavy precipitation in the form of showers or thunderstorms generally lasting less than 1 h

2.1.15
reference spell
period during which a wall oriented in any given direction is moistened, having a 10 % probability of being exceeded in any year

2.1.16
present weather code
numerical code used by meteorological observers to assess the weather conditions at the time of an observation

NOTE Present weather codes are given in the WMO Guide [2].

2.1.17
half day
twelve-hour period including the hours from 07:00 to 18:00 or from 19:00 to 06:00

2.2 Symbols and units

Symbol	Quantity	Unit
C_{R}	roughness coefficient	—
C_{T}	topography coefficient	—
D	hourly mean wind direction from north	°
H	effective height of feature	m
I_{A}	airfield annual index	$\mathrm{l/m^2}$
I_{S}	airfield spell index	$\mathrm{l/m^2}$
I_{WA}	wall annual index	$\mathrm{l/m^2}$
I_{WS}	wall spell index	$\mathrm{l/m^2}$
K_{R}	terrain factor	—
L	length	m
N	number of years of available data	—
O	obstruction factor	—
r	hourly rainfall total	mm
v	hourly mean wind speed	m/s
W	wall factor	—
x	horizontal distance	m
z	height above ground	m
z_0	roughness length	m
z_{min}	minimum height	m
Θ	wall orientation relative to north	°

3 Calculation of airfield indices from hourly wind and rain data

3.1 Sources of data

Data used for calculations according to this part of ISO 15927 shall have been measured by the methods specified by the World Meteorological Organization (see WMO Guide [2]).

3.2 Airfield annual index

For any location with at least 10 (and preferably 20 or 30) years of hourly values of wind speed, wind direction and rainfall, the annual index for wall orientation, Θ, is given by Equation (1).

$$I_{\mathrm{A}} = \frac{2}{9} \frac{\sum v r^{8/9} \cos(D - \Theta)}{N} \tag{1}$$

where the summation is taken over all hours for which $\cos(D - \Theta)$ is positive, i.e. all those occasions when the wind is blowing against the wall.

As the wind speed during rainfall is not generally the same as in dry weather, calculating the product of hourly averages of wind and rainfall is not strictly accurate, especially in showery weather. It has been shown, however, that the error is small and, in any case, several years of data for periods shorter than 1 h are available from very few places. Taking the product of the averages over days or months does lead to serious inaccuracies and should not be used for calculating driving rain indices.

3.3 Airfield spell index

For any location with at least 10 (and preferably 20 or 30) years of hourly values of wind speed, wind direction and rainfall, for each wall orientation, Θ, and for each spell of driving rain (see Annex B), calculate I'_{S} using Equation (2).

$$I'_{\mathrm{S}} = \frac{2}{9} \sum v r^{8/9} \cos\left(D - \Theta\right) \tag{2}$$

where the summation is taken over all hours in the spell for which $\cos(D - \Theta)$ is positive, i.e. all those occasions when the wind is blowing against the wall.

The 67 % percentile (i.e. the value for which 33 % of the I'_{S} values are higher) is found from the values of I'_{S} for all the spells within the period of available data.

The 67 % percentile defines the spell index, I_{S} (i.e. the maximum value of I'_{S} likely to occur once every three years).

4 Estimation of the effect of driving rain from average wind and present weather code for rain

The available data are divided into twelve-hour periods (07:00 – 18:00 and 19:00 – 06:00) called half days.

A half day is defined as “moistening” if all of the following conditions apply.

a) There is more than 4 mm of precipitation on a horizontal surface in the half day.

b) The present weather code reports some precipitation for at least three of the five three-hourly observations during the half day (i.e. at 06:00, 09:00, 12:00, 15:00 and 18:00 and at 18:00, 21:00, 00:00, 03:00 and 06:00).

NOTE Present weather codes of 50 or above indicate some form of precipitation.

c) The average wind speed during the half day is greater than 2 m/s.

d) The average wind direction during the half day is within ± 60° of the perpendicular to the wall, i.e. $|D - \Theta| \leqslant 60$.

Under these conditions, it is assumed that a wall surface will be wetted by driving rain, with subsequent water migration into the wall by capillarity.

A half day is defined as “drying” if all of the following conditions apply.

— The average atmospheric relative humidity during the half day is less than 70 %.

— The average wind speed during the half day is greater than 2 m/s.

— The average wind direction during the half day is within ± 60° of the perpendicular to the wall, i.e. $|D - \Theta| \leqslant 60$.

Under these conditions, it is assumed that the wind and atmospheric humidity allow the evaporation of water at the wall surface.

All other atmospheric conditions are considered neutral. A moistening half day is given the value “+1”, a drying half day “−1” and a neutral half day “0”.

The successive values are added to give a cumulative time series, with the constraint that the total does not fall below zero; a maximum value, equal to the length in half days of the longest moistening spell in the year, is deduced for each year and each wall orientation.

The cumulative distribution of annual maximum, established from N_Y years of meteorological data, is then fitted by a Gumbel function[1)]. This is used to obtain the reference spell, which is the maximum spell occurring once every 10 years for a given meteorological station and a given wall orientation.

5 Calculation of wall indices

5.1 General

The airfield indices calculated in Clause 3 are the amounts that would be collected by a free-standing driving-rain gauge in flat open country. They are converted into wall indices (i.e. the amounts of rain that would impact on a real wall) by multiplying by the terrain roughness coefficient, C_R, the topography coefficient, C_T, the obstruction factor, O, and the wall factor, W, as given in Equations (3) and (4).

$$I_{WA} = I_A C_R C_T O W \tag{3}$$

$$I_{WS} = I_S C_R C_T O W \tag{4}$$

These corrections can also be applied to the reference spell derived from the method defined in Clause 4.

1) The cumulative distribution of annual maximum is fitted by the Gumbel function

$$F(X) = \exp\left[-\exp\left(-\frac{X-a}{b}\right)\right]$$

where a is the mode and b the dispersion parameter. $F(X)$ is the probability of X not being exceeded during one year.

5.2 Roughness coefficient

The roughness coefficient accounts for the variability of mean wind velocity at the site due to

— the height above the ground,

— the roughness of the terrain in the direction from which the wind is coming.

The roughness coefficient at height z is given by Equations (5) and (6):

$$C_R(z) = K_R \ln(z/z_0) \qquad \text{for } z \geqslant z_{min} \tag{5}$$

$$C_R(z) = C_R(z_{min}) \qquad \text{for } z < z_{min} \tag{6}$$

These parameters depend on the terrain category as given in Table 1.

If there is a change of roughness within a kilometre upwind of a site, the smoothest terrain category in the upwind direction shall be used.

Table 1 — Terrain categories and related parameters

Terrain category	Description	K_R	z_0	z_{min}
I	Rough open sea; lake shore with at least 5 km open water upwind and smooth flat country without obstacles	0,17	0,01	2
II	Farm land with boundary hedges, occasional small farm structures, houses or trees	0,19	0,05	4
III	Suburban or industrial areas and permanent forests	0,22	0,3	8
IV	Urban areas in which at least 15 % of the surface is covered with buildings of average height exceeding 15 m	0,24	1	16

5.3 Topography coefficient

The topography coefficient accounts for the increase in mean wind speed over isolated hills and escarpments (not undulating and mountainous regions) and is related to the wind velocity upwind of the hill or escarpment. It shall be included for locations

— more than half-way up the slope of a hill,

— within 1,5 times the height of the cliff from the base of a cliff.

It is defined by Equations (7) to (9):

$$C_T = 1 \qquad \text{for } \Phi < 0{,}05 \tag{7}$$

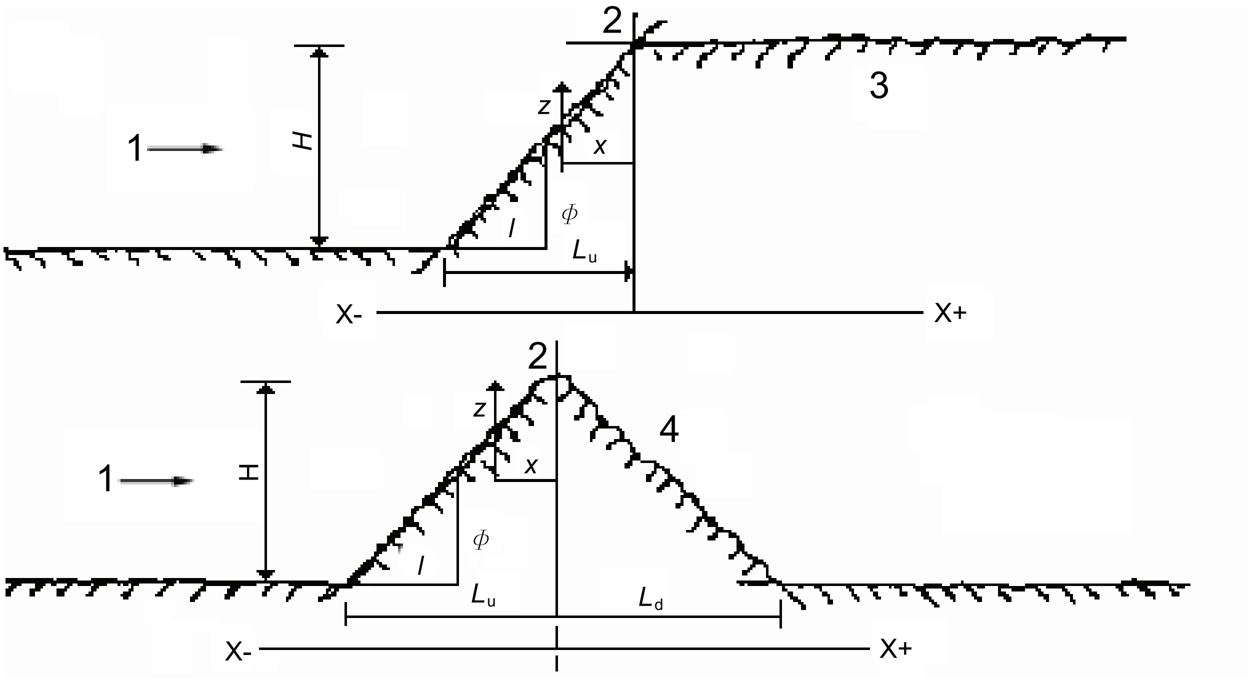
$$C_T = 1 + 2s\,\Phi \qquad \text{for } 0{,}05 \leqslant \Phi \leqslant 0{,}3 \tag{8}$$

$$C_T = 1 + 0{,}6s \qquad \text{for } \Phi > 0{,}3 \tag{9}$$

where

s is a factor obtained from Figures 2 and 3, scaled to the length of the upwind slope, L_u, or the downwind slope, L_d, in Figure 1;

Φ is the upwind slope, H/L_u, in the wind direction.



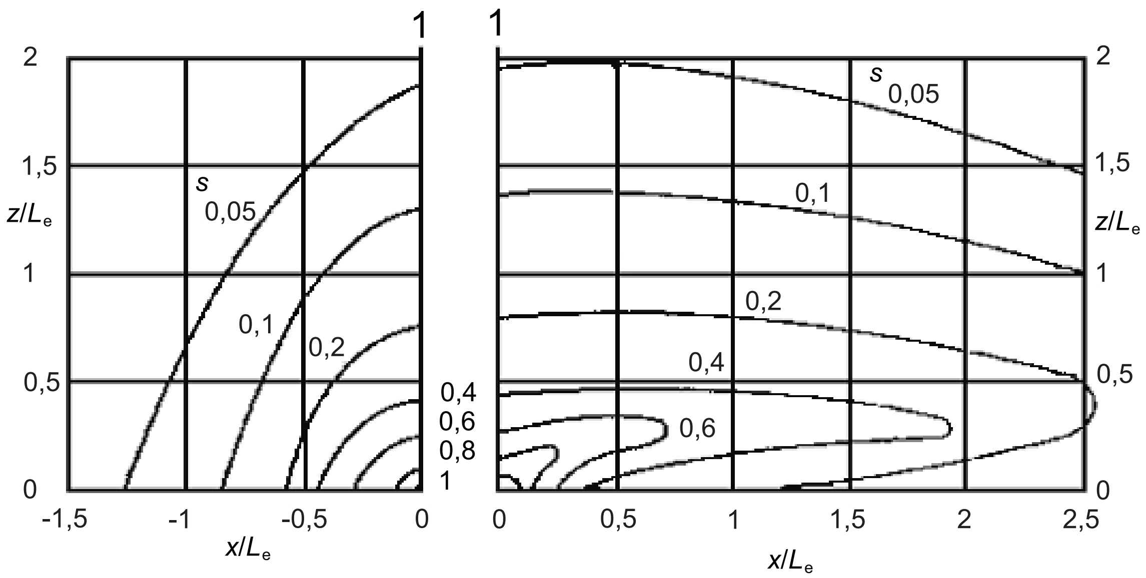
Key

1 wind
2 crest
3 downwind slope < 0,05
4 downwind slope > 0,05
L_u is the actual length of the upwind slope in the wind direction
L_d is the actual length of the downwind slope
L_e is the effective length of the upwind slope defined in Table 2
H is the effective height of the feature
x is the horizontal distance of the site from the top of the crest
z is the vertical distance from the ground level of the site

Figure 1 — Definition of factors determining topography coefficient

Table 2 — Effective length, L_e

Upwind slope Φ ($= H/L_u$)	
Shallow ($0,05 \leqslant \Phi \leqslant 0,3$)	Steep ($\Phi > 0,3$)
$L_e = L_u$	$L_e = H/0,3$

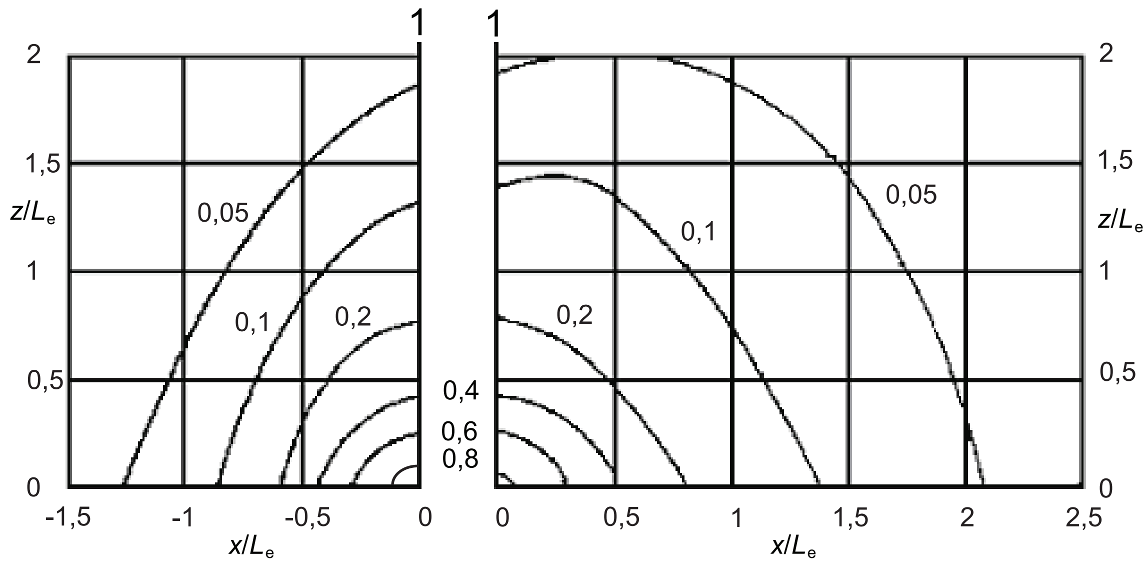


a) Upwind **b) Downwind**

Key

1 crest

Figure 2 — Factor *s* for cliffs and escarpments



a) Upwind **b) Downwind**

Key

1 crest

Figure 3 — Factor *s* for hills and ridges

5.4 Obstruction factor

The exposure of the wall should be assessed by determining the horizontal distance to the nearest obstacle that is at least as high as the wall, along the line of sight from the wall. When the obstructions are being assessed, account should be taken of possible changes such as the felling of trees in the development of a housing estate.

Select the obstruction factor for the appropriate distance from Table 3.

If the layout of an estate is likely to funnel winds towards a wall, the obstruction factor should be taken as 1,0 even if obstructions are present.

NOTE The obstruction can vary significantly at different points along a long wall.

Table 3 — Obstruction factor

Distance of obstruction from wall m	**Obstruction factor** O
from 4 to 8	0,2
over 8 to 15	0,3
over 15 to 25	0,4
over 25 to 40	0,5
over 40 to 60	0,6
over 60 to 80	0,7
over 80 to 100	0,8
over 100 to 120	0,9
over 120	1,0

5.5 The wall factor

The amount of rain incident on a wall depends on the type of wall, its height and other factors such as overhangs or the orientation of bricks, etc., within the structure. In addition, the amount of incident rain varies significantly over the surface of a wall due to the flow of air around corners, over the roof, etc.

The wall factor, W, for the appropriate position on the wall shall be obtained from Table 4.

Table 4 — Wall factor, W

Description of wall	Average value	Distribution
Two-storey gable	0,4	0,5 0,4 0,3 0,3 0,3 0,2
Three-storey gable	0,3	0,5 0,4 0,3 0,3 0,3 0,3 0,3 0,3 0,2
Multi-storey building with flat roof (pitch < 20°)	0,2 for a ten-storey building, for example, but with a higher intensity at top	0,5 for top 2,5 m 0,2 for remainder
Two-storey wall with eaves	0,3	Pitched roof (≥20°) typical overhang: 350 mm 0,3 0,3 0,3
Three-storey wall with eaves	0,4	Pitched roof typical overhang: 350 mm 0,4 0,4 0,4
Two-storey building with flat roof (pitch < 20°)	0,4	0,5 0,4 0,2

Annex A
(informative)

Limits to the validity of the calculated indices

The procedures specified in Clauses 3 and 4 allow the calculation of the two driving-rain indices on a wall of any orientation at or near a meteorological station from which sufficient rainfall and wind data are available, taking the local topography into account. There are, however, in any country, relatively few stations from which sufficient data are available to allow the calculation of the indices. It is, therefore, necessary to decide how representative the indices calculated at a meteorological station are of a building at a distant location.

There are currently no defined rules for the validity of the data; however, it is possible to give the following guidelines.

— Indices calculated from inland stations are not representative of buildings in coastal locations (i.e. situated at less than 8 km from the sea).

— In mountainous terrain calculated indices apply only to the immediate neighbourhood of the station.

— In predominantly flat regions (i.e. with variations in altitude less than 100 m), the calculated indices are valid up to 100 km from the measurement station. In hilly regions, the limits to validity are much less.

— If equivalent annual or monthly mean data are available from a closer location, comparison of these with the means from the station at which the indices were calculated can provide more specific guidance.

If sufficient stations are available, maps of the driving-rain index can be produced to provide information on exposure ratings over a whole country or region. A method of generating driving-rain maps is given in Annex C.

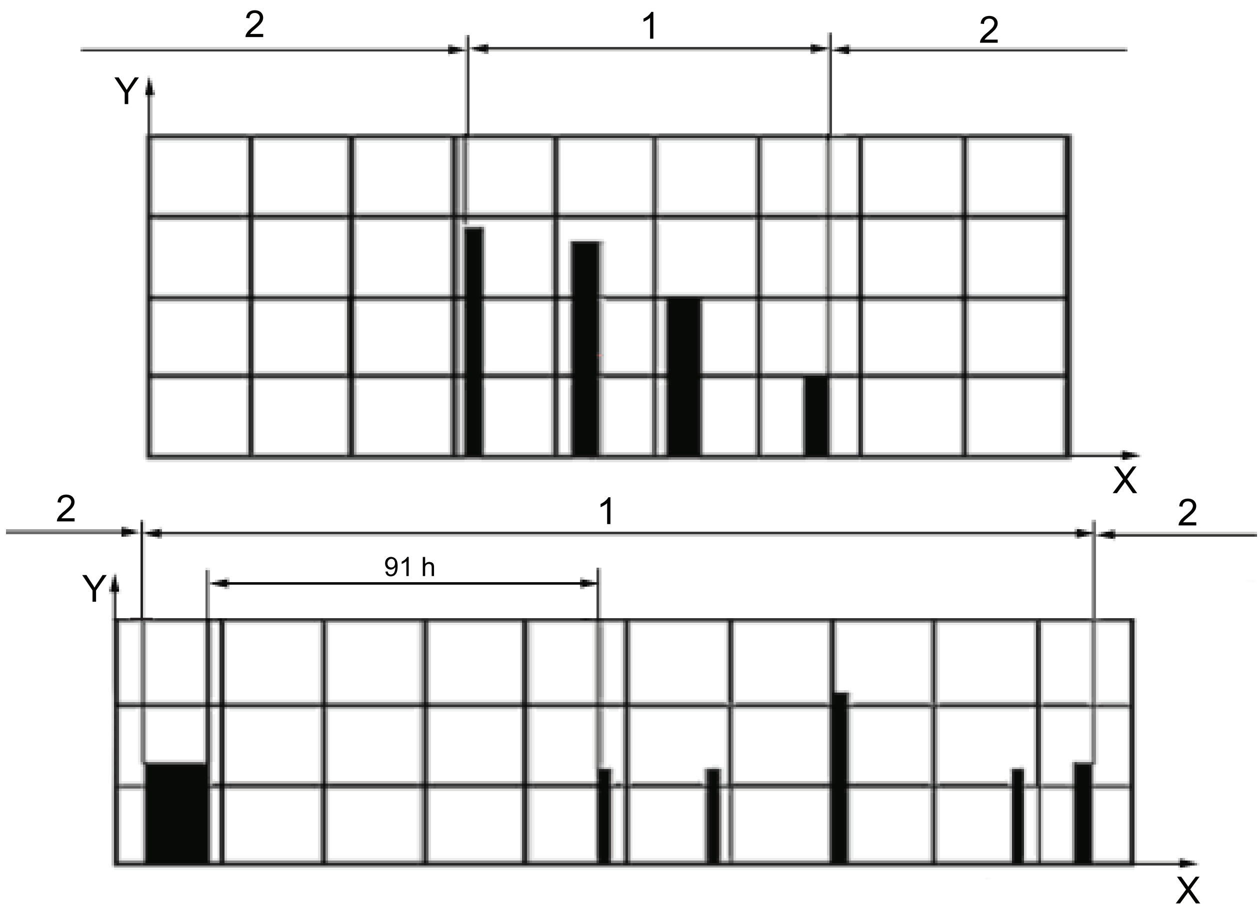
Annex B
(informative)

The nature of a "spell" of driving rain

A "spell" is considered to be a period of driving rain during which the risk of penetration through masonry increases, i.e. a period in which the input of water due to the driving rain exceeds the loss due to evaporation. Generally, spells are periods of 1 h to 2 h during a shower or 8 h to 12 h during the passage of a depression. Occasionally, however, there are long spells when successive depressions cause repeated periods of rain with little or no net evaporation in between. There can be periods of as long as 96 consecutive hours with no driving rain within the spell before evaporative loss exceeds gain from the rain; see Figure B.1. A gap between two spells is, therefore, defined by a period of at least 96 h when $v \cdot r^{8/9} \cdot \cos(D - \Theta) \leqslant 0$.

It is important to note that a spell is defined here in terms of rain penetration through masonry, which requires a prolonged input of water. Rain penetration through doors, windows and other similar gaps in the façade depends on shorter-term inputs of heavy rain under high pressure differences.

Figure B.1 shows two typical spells.



Key

X time, expressed as days (each tic represents a half day)

Y input of water, l/(m²·h)

1 spell

2 96 h or more to next spell

Figure B.1 — Periods of driving rain against a wall used to define two typical spells of rain

Annex C
(informative)

The procedure for generating the driving-rain maps[2)]

C.1 Hourly wind and rain data were available from 20 main meteorological stations for 1959 to 1982. Hourly wind data, three hourly records of the weather type and daily rainfall totals were available from these stations and 32 subsidiary ones. A procedure was developed to estimate the hourly rainfalls from the data available at the subsidiary stations; it was possible to calibrate this procedure at the main stations.

C.2 For all 52 stations, airfield annual and spell indices were calculated on walls of 12 different orientations, i.e. at 30° intervals. For convenience of plotting, these were converted to "map indices" on a log scale with the annual indices, m_A, and the spell indices, m_S , calculated as given in Equations (C.1) and (C.2), respectively:

$$m_A = 6 + 19{,}93 \log_{10}(I_A/200) \quad \text{(C.1)}$$

$$m_S = 10 + 19{,}93 \log_{10}(I_S/20) \quad \text{(C.2)}$$

C.3 A much more detailed rainfall map of the UK, based on data from 6 500 stations, and the wind-flow map were then used to guide interpolation among the 52 stations with driving-rain data, so as to estimate the map indices at any point. As shown on Figure C.1, these are displayed as

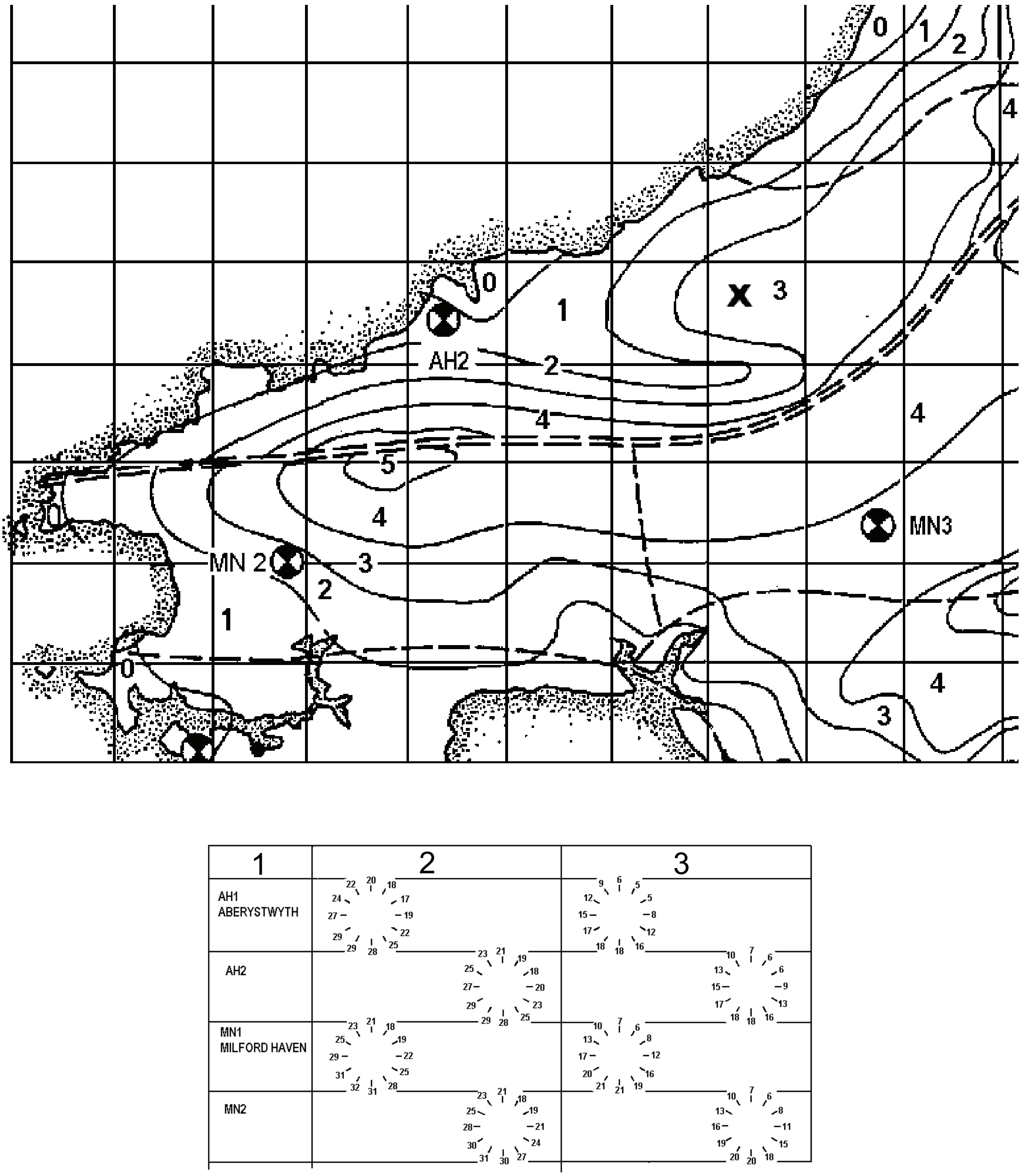
a) contours of "geographical increment", i, which show the local variation of the indices within each region;

b) roses of 12 annual and spell "rose values", r, covering subregions.

The map annual and spell indices, which refer to specific locations, are derived by adding the geographical indices to the rose values for the specific wall orientation.

C.4 In practice, therefore, to assess a west-facing wall built at location X in subregion AH2 shown in Figure C.1, the geographical increment is 3, the spell rose value is 27 and the annual rose value is 15. The map spell index of 30 can, therefore, be converted to the airfield spell index using the inverse of Equation (C.2) and the map annual index of 18 can be converted to the airfield annual index with the inverse of Equation (C.1). The corrections specified in Clause 5 for topography, obstruction and wall type are then applied to give the wall indices.

2) Taken from BS 8104 [1].



Key

1 subregion

2 spell rose values, r_s

3 annual rose values, r_A

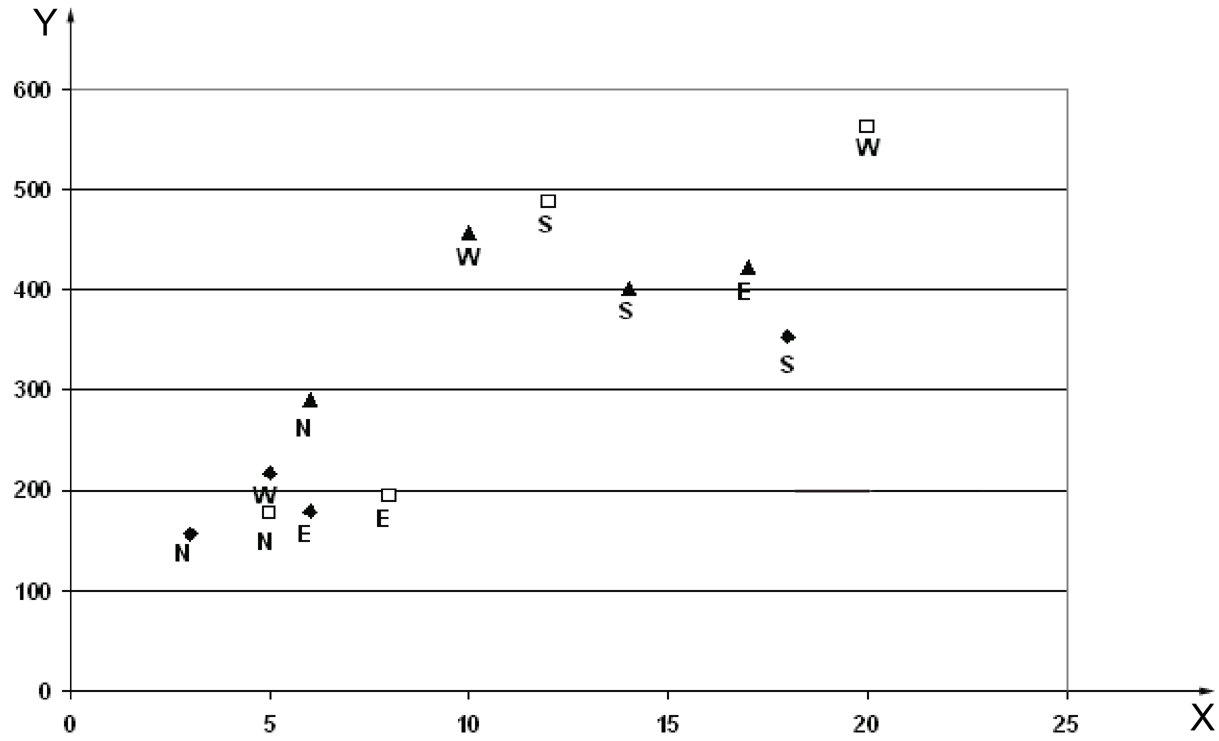
Figure C.1 — Example of driving-rain map and roses (illustrative values)

Annex D
(informative)

Comparison of methods specified in Clauses 3 and 4

A comparison was made between the results of the two methods specified in Clauses 3 and 4, which adopt a significantly different approach to calculating the driving-rain impact on a wall. A data set of 20 years of hourly values from three UK stations, which contained all the parameters needed to implement both methods, was analysed.

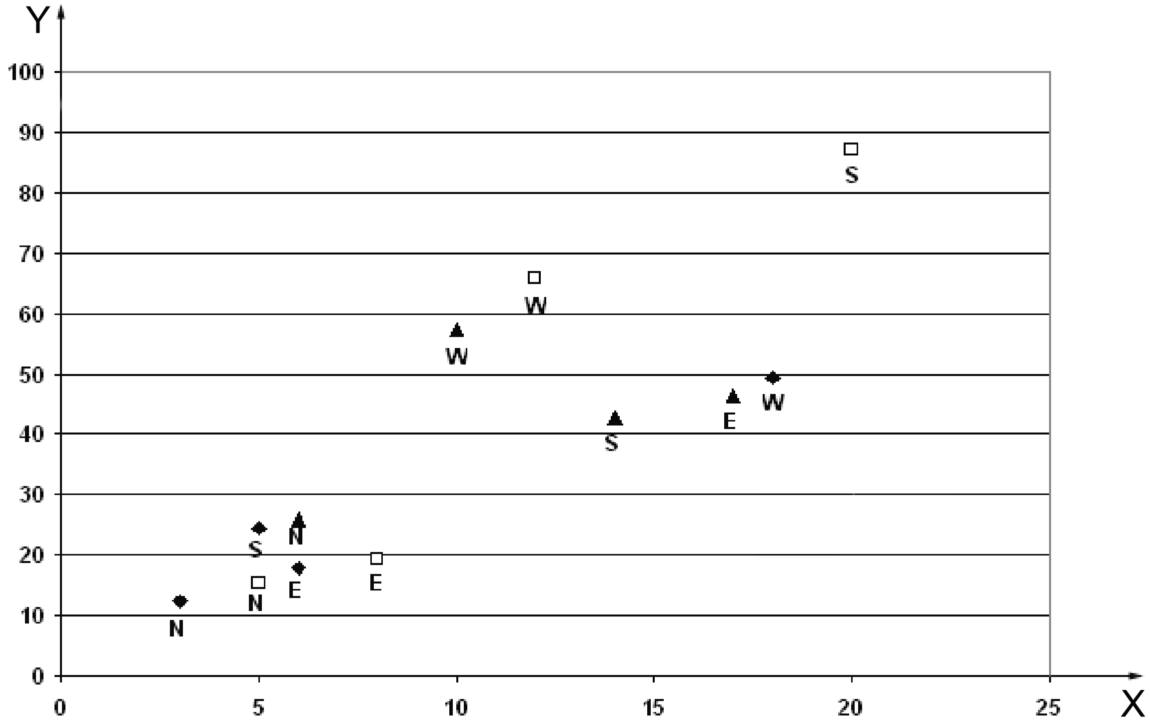
Figures D.1 and D.2 show there is a reasonable level of agreement between the two methods, when both the annual totals (Figure D.1) and the spell totals (Figure D.2) are considered.



Key

X	$90P_5$, the 90 percentile value of the annual longest moistening period, half days (see Clause 4)
Y	$90P_4$, the 90 percentile of the annual driving rain (see Clause 3)
N, E, S, W	north-, east- south- and west-facing walls, respectively
♦	London
□	Manchester
▲	Edinburgh

Figure D.1 — Comparison of the 90 percentile values from the Clause 3 method of annual total and the Clause 4 method of annual longest moistening period for three UK locations



Key

X 90P_5, the 90 percentile value of the annual longest moistening period, half days (see Clause 4)

Y 93P_4, the 93 percentile of the annual driving rain (see Clause 3)

N, E, S, W north-, east-, south- and west-facing walls, respectively

♦ London

□ Manchester

▲ Edinburgh

Figure D.2 — Comparison of the 93 percentile values from the Clause 3 method of spell total and the 90 percentile values from the Clause 4 method of annual longest moistening period for three UK locations

Bibliography

[1] BS 8104:1992, *Code of practice for assessing exposure of walls to wind-driven rain*

[2] *WMO Guide to Meteorological Instruments and Methods of Observation*, WMO No. 8; World Meteorological Organisation, 1996

[3] VDI 3786 Blatt 2, *Meteorologische Messungen für Fragen der Luftreinhaltung — Wind* (Meteorological measurement concerning questions of air pollution — Wind)

[4] VDI 3786 Blatt 7, *Meteorologische Messungen für Fragen der Luftreinhaltung — Niederschlag* (Meteorological measurement concerning questions of air pollution — Precipitation)

ICS 07.060; 91.120.10

Price based on 17 pages