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Hygrothermal performance of buildings — Resistance to wind-driven rain of roof coverings with discontinuously laid small elements — Test methods

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Performance hygrothermique des bâtiments - Résistance à la pluie battante de couvertures en petits éléments posés en discontinu - Méthodes d'essai

Wärme- und feuchteschutztechnisches Verhalten von Gebäuden - Widerstand von Dacheindeckungen aus kleinformatigen, überlappend gedeckten Dachelementen gegen Schlagregen - Prüfverfahren

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Foreword

This document (CEN/TR 15601:2012) has been prepared by Technical Committee CEN/TC 89 “Thermal performance of buildings and building components”, the secretariat of which is held by SIS.

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Introduction

The extent to which roof coverings can resist water penetration from the combination of wind and rain, commonly referred to as wind driven rain, is important for the design of roofs. This CEN Technical Report describes a method of test to determine the performance of the roof covering against wind driven rain.

The combined action of wind and rain varies considerably with geographical location of a building and the associated differences in the rain and wind climate. Wind-rain climate zones are specified for: Northern Europe Coastal, Central Europe and Southern Europe. Each climate zone is divided into four wind-rain sub-tests (including a deluge condition).

This Technical Report does not contain information on the level of acceptable performance. The use of test results is given in Annex C.

In case of reference should be made to testing according to this document the word "shall" is used at the appropriate places.

1 Scope

This Techncial Report describes a method of test for determining the resistance of pitched roof coverings to wind-driven and deluge rain.

The test method is applicable to discontinuously laid unsealed small roof covering elements such as clay tiles, concrete tiles, slates, fibre cement slates and stones.

NOTE The test method may be adapted for fittings.

2 Normative References

This document contains no normative references.

3 Terms and definitions

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

3.1
test specimen
assembled array of elements for testing over which water leakage is to be observed or measured, excluding perimeter elements with sealed joints

3.2
set of tests
consisting of sub-tests B and D, (and optionally subtests A and C), for an appropriate climate zone, roof pitch and laying specification

Note 1 to entry: The sub-tests A, B, C and D are defined in Clause 8.

3.3
reference leakage rate
leakage rate of 10 g/m^2/5 min, 5-minutes being the duration of a single test step in the sub-test

4 Symbols and units

Symbol	Quantity	Unit
f	wind speed factor relating u and u_s	-
I_u	turbulence intensity	%
L	Simulated additional rafter length above the test specimen	m
R_h	rainfall rate on a horizontal plane	mm/h
R_{ro}	run-off rate	l/min
R_t	rainfall rate on the roof surface	mm/h
u	wind speed approaching the roof	m/s
u_t	terminal velocity of rain drops	m/s
σ_g	Standard deviation of the turbulent fluctuations in the wind speed	m/s
$\bar{u}$	Mean wind speed approaching the roof	m/s
u_s	wind speed over test specimen	m/s
W	the effective width of the test specimen	m
α	roof pitch	Degree°
θ	angle of incidence of rain	Degree°

5 Principle

A test specimen is fitted into the wind-driven rain apparatus, the external surface of the test specimen is exposed to wind and continuously sprayed with water, and run-off water is continuously applied at the top of the specimen. At the same time an air pressure difference between the upper and lower surfaces of the test specimen is increased or decreased in specific steps.

Water leakage through the test specimen, which can occur at certain air pressure differences, is observed and measured.

6 Test specimens

6.1 Test specimen samples

Samples for the test specimen shall comply, where relevant, with the appropriate product standard in respect of the appropriate sampling plan, or, in absence of a standard sampling plan, shall be selected at random from a representative population.

Discontinuously laid small elements for the test specimen shall be surface dry.

6.2 Dimensions of the test specimen

The dimensions of the test specimen shall be as large as necessary to be representative of the intended use.

The joints of elements in the test specimen shall be representative, e.g. the same length per square meter as designed for its intended use.

The test specimen shall comprise a minimum of 9 roof covering elements, a minimum length of 1,0 m and a minimum width of 1,0 m on a rectangular format.

6.3 Number of sets of tests

The number of sets of tests shall be at least one.

6.4 Preparation of test specimen

Construct the test specimen according to the roofing specification representative of its intended use (such as roof pitch, lap and the influence of fixing systems where appropriate).

The test specimen may be built in a surrounding frame to facilitate transport and fitting to the opening of the driving rain test apparatus. The joint between test specimen and surrounding frame shall be sealed to prevent water leakage during the test, without disturbance to joints between the discontinuously laid elements.

If a frame is used, it shall be able to resist the pressures applied during the test without deflecting to an extent that would influence the test results. The surround shall be prepared and installed so that any water penetration through the unsealed area of the test specimen is readily detectable.

The test specimen shall be conditioned to be surface dry before each test.

7 Apparatus

7.1 General

The test apparatus shall consist of:

— a suction chamber sealed to the underside of the test specimen and connected to a suction fan, as specified in 7.2;

— a fan system to create wind on the outside of the test specimen, as specified in 7.3;

— an installation capable of generating rain on the outside of the test specimen, as specified in 7.4;

— provisions for creating run-off water on the outside of the test specimen, as specified in 7.5; and

— facility for observation and measurement of leakage as specified in 7.6.

Examples of wind-driven rain apparatus are illustrated in Annex A.

NOTE Apparatus of different design is likely to produce different wind driven rain test results, but can produce consistent comparisons of performance between different roof covering elements.

7.2 Suction chamber

The suction fan connected to the suction chamber shall be capable of creating a stable pressure difference, maintained for 5 minutes ± 10 seconds, across the test specimen. The pressure difference shall be measured to a maximum inaccuracy of 1 % or 2,5 Pa, whichever is greater. The height and shape of the suction chamber shall be sufficient to ensure uniform pressure conditions.

It shall be possible, when required, to seal the connection between the suction chamber and the suction fan (e.g. by providing a valve, which can be closed or opened).

A water collector shall be provided, connected to the suction chamber, capable of recording the amount of leakage water during any pressure step in the test, to a maximum inaccuracy of 2 % or 1 g, whichever is greater. The surfaces of the suction chamber shall allow leakage water to flow freely into the water collector.

7.3 Fan system

The fan system shall be capable of generating wind in the direction of the eaves to the ridge. The wind flow shall be horizontal or parallel to the surface of the inclined test specimen.

Calibrate the fan system for spatial variation of the wind speed, by taking measurements at not less than 9 positions uniformly distributed, at a height of 200 ± 10 mm over a flat boarded area which replaces the test specimen for the purposes of the calibration, at the relevant roof pitch. The calibration wind speed shall be (10 ± 0,5) m/s at the centre of the test specimen.

The spatial variation of the wind speed shall be not more than ±15 % over the test specimen.

Wind speed shall be measured to a maximum inaccuracy of 0,5 m/s.

The turbulence intensity I_u in the oncoming wind shall be less than 10 % at each position. The turbulence intensity I_u (%) is expressed as $I_u = 100\sigma_g / \bar{u}$, where σ_g and $\bar{u}$ are the standard deviation of the turbulent fluctuations in the wind speed and mean wind speeds respectively, measured over a duration of not less than 5 minutes for this purpose.

Mean wind speed

$$\bar{u} = \frac{\sum_{i=1}^{n} u_i}{n} \tag{1}$$

Standard deviation

$$\sigma_g = \sqrt{\frac{\sum_{i=1}^{n} (u_i - \bar{u})^2}{n-1}} \tag{2}$$

where

u_i are individual wind speed measurements;

n is the number of wind speed

7.4 Rain generating installation

The installation shall be capable of supplying a stable rain rate (± 5%) as given in Table 2 for the roof pitch under test. The spatial variation shall be not more than ± 35 % over the area of the test specimen during a period of 5 minutes ± 10 seconds.

The rain droplet size shall be representative of natural rain, predominantly in the range of 0,6 mm to 2,5 mm diameter.

NOTE 1 Water droplets introduced into a high velocity air stream tend to break up over distance. Accordingly, it is recommended that the droplets are introduced far enough above the test specimen for this process to be completed and for the droplets to achieve the required velocity prior to impact with the test specimen.

NOTE 2 A variation of ± 35 % in wind driven rain distribution when combined with run-off water (see 7.5) results in a combined variation of not more than 10 %.

To calibrate the rain falling directly on the test specimen, replace the test specimen with a flat board which incorporates rainfall measuring devices in its upper surface. The measuring devices shall each be between 0,10 m^2 and 0,20 m^2 in plan area and arranged so that they do not collect any run-off water during calibration. The rain shall be measured to a maximum inaccuracy of 3 % or 0,2 mm/h, whichever is larger.

Calibrate the uniformity of rain distribution for each roof pitch and each test A, B, C and D (see Clause 8) as appropriate.

7.5 Run-off water

Run-off water to simulate the rafter length of the roof above the position of the test specimen, shall be evenly distributed across the top of the test specimen with a maximum deviation of not more than 10 % over the width of the test specimen. The quantity of run-off water shall be measured to a maximum inaccuracy of 3 %.

Precautions should be taken to avoid unrepresentative distribution of run-off water on the uppermost course of roof covering elements which, for example, could cause premature leakage through their sidelaps.

NOTE As a precaution, the sidelaps in the uppermost course of roofing elements may be sealed.

7.6 Observation and measurement of leakage

The suction chamber shall be provided with:

a) a transparent under-surface for clear visual observation of the nature and position of leakages which may appear on the underside of the test specimen during the test;

b) an apparatus to continuously collect and measure the amount (by weight or by volume) of leakage water which may fall from the test specimen into the suction chamber during the test.

To minimize surface tension, absorption and retention of water on the internal surfaces of the suction chamber, the surfaces shall be smooth, non-absorbent and inclined at a vertical angle of not less than 15° from the horizontal towards the lower collecting apparatus during testing.

8 Test procedure

8.1 General

Carry out the test in an environment with a temperature of between 5 °C and 35 °C with the test specimen installed in the apparatus at the specified roof pitch.

Seal the edges of the test specimen to prevent leakage of water or air into or out of the suction chamber. Such seals shall not affect the headlaps and sidelaps of the unsealed areas of the test specimen.

Select and continuously apply the relevant wind speed, rain-fall rate, and amount of run-off water according to the conditions specified in 8.2. The test specimen shall be surface dry before testing.

In the wind-driven rain sub-tests (A, B and C), measure initially the pressure difference with the suction chamber closed and adopt this pressure difference as the reference datum for subsequent pressure changes during the sub-test. Then reduce the pressure in the box in steps of from 5 Pa to 10 Pa and maintain each pressure step for 5 minutes ± 10 seconds. Measure the amount of leakage water (if any) at each pressure step, or continuously, up to the reference leakage rate.

NOTE 1 The test can be continued to greater pressure differences to observe additional leakage rates.

In the deluge sub-test (D), apply the rainfall and run-off without wind (suction fan turned off) and with the suction chamber open to the atmosphere, for 2 minutes ± 10 seconds. Observe any leakage and measure the amount of leakage water.

Fine spray can enter through joints in certain types of discontinuously laid elements, producing small amounts of water on the test specimen or on the surface of the suction chamber. Its occurrence shall be recorded

NOTE 2 Such fine spray may or may not be regarded as leakage depending on the performance requirements.

Precautions shall be taken to prevent water leakage travelling down the underside of the test specimen and from draining out at lower courses of the roof covering, by, for example, applying a grease line across the underside of all the discontinuously laid elements in the test specimen above the head of the tile or slate below.

8.2 Test conditions

8.2.1 General

A set of tests shall consist of sub-tests B and D (and optionally sub-tests A and C), carried out with the following wind-rain combinations as defined in Table 2 for appropriate climate zones:

— Sub-test A: Low wind speed with severe rainfall rate;

— Sub-test B: High wind speed with high rainfall rate:

— Sub-test C: Severe wind speed with low rainfall rate;

— Sub-test D: Maximum rainfall rate with no wind (deluge).

Other wind-rain conditions may be used, based on appropriate data derived from:

— extreme values of a specified return period 5 minute averaging times of combined wind-rain for sub-tests A, B and C;

— extreme values of specified return period 2 minute averaging times for sub-test D.

8.2.2 Wind speed modification for roof pitch

For apparatus where the test specimen is laid parallel to the air-stream, a modification to the wind speed shall be applied to allow for the effect of roof pitch, by $u_S = u_f$. Values of f are given in Table 1.

Where the test specimen is laid at a pitch to the horizontal wind, $f = 1{,}0$.

Table 1 — Wind speed modification factor

Roof pitch (Degrees)	***f***
15,0	0,85
17,5	0,81
20,0	0,80
25,0	0,76
30,0	0,71
35,0	0,67
40,0	0,60
45,0	0,54
f values for other intermediate roof pitches are obtained by interpolation	

8.2.3 Run-off water

The run-off rate R_{ro} (l/min) shall be calculated by the formula:

$$R_{ro} = R_t.W.L/60 \quad (3)$$

where

R_t is the rainfall on the roof surface, in mm/h;

W is the effective width of the test specimen, in m;

L is the simulated additional rafter length above the test specimen, in m.

Unless otherwise specified, L shall be not less than 5 m.

Table 2 — Wind-conditions test conditions

Climate zone	Sub-test	Test conditions			
		wind speed u m/s	**rainfall** R_h mm/h	**roof pitch** $\alpha°$	**rainfall on roof surface** R_t mm/h
Northern Europe, coastal	A	5	110	15,0	124
				17,5	126
				20,0	127
				25,0	129
				30,0	130
				35,0	129
				40,0	128
				45,0	126
	B	13	60	15,0	85
				17,5	89
				20,0	92
				25,0	99
				30,0	104
				35,0	109
				40,0	113
				45,0	116
	C	25	6	15,0	13
				17,5	14
				20,0	15
				25,0	17
				30,0	19
				35,0	20
				40,0	22
				45,0	23
	D	0	225	15,0	217
				17,5	215
				20,0	211
				25,0	204
				30,0	195
				35,0	184
				40,0	172
				45,0	159

Climate zone	Sub-test	Test conditions			
		wind speed u m/s	**rainfall** R_h mm/h	**roof pitch** $\alpha°$	**rainfall on roof surface** R_t mm/h
Central Europe	A	4	200	15,0	217
				17,5	219
				20,0	220
				25,0	220
				30,0	219
				35,0	217
				40,0	213
				45,0	207
	B	10	130	15,0	167
				17,5	172
				20,0	176
				25,0	185
				30,0	192
				35,0	197
				40,0	202
				45,0	204
	C	15	8	15,0	13
				17,5	14
				20,0	15
				25,0	16
				30,0	17
				35,0	18
				40,0	19
				45,0	20
	D	0	300	15,0	290
				17,5	286
				20,0	282
				25,0	272
				30,0	260
				35,0	246
				40,0	230
				45,0	212

Climate zone	Sub-test	Test conditions			
		wind speed u m/s	**rainfall** R_h mm/h	**roof pitch** $\alpha°$	**rainfall on roof surface** R_t mm/h
Southern Europe	A	2	248	15,0	254
				17,5	253
				20,0	252
				25,0	248
				30,0	243
				35,0	235
				40,0	226
				45,0	215
	B	8	166	15,0	201
				17,5	206
				20,0	210
				25,0	217
				30,0	222
				35,0	226
				40,0	228
				45,0	229
	C	20	6	15,0	11
				17,5	12
				20,0	13
				25,0	14
				30,0	16
				35,0	17
				40,0	18
				45,0	19
	D	0	415	15,0	401
				17,5	396
				20,0	390
				25,0	376
				30,0	359
				35,0	340
				40,0	318
				45,0	293

Values of R_t in Table 2 are calculated by formula 4:

$$R_t = R_h(\cos\alpha + \tan\theta.\sin\alpha) \quad (4)$$

where α is the roof pitch

(based on the derivation in Annex B) with θ according to formula 5:

$$\theta = \tan^{-1}\left\{u/\left(4{,}505R_h^{\,0.123}\right)\right\} \quad (5)$$

Values of R_t for intermediate roof pitches are obtained by interpolation.

9 Evaluation and expression of test results

During the test, leakage of the test specimen shall be continuously observed from the underside of the test specimen, recording at the relevant pressure any fine spray, wetting on the underside, and leakage.

The amount of leakage water and the corresponding pressure difference at each pressure step shall be calculated.

NOTE 1 The underside applied pressure should be referenced to the initial pressure difference measured with the connection sealed between the chamber and the suction fan (the zero pressure datum).

NOTE 2 Description of leakage may be supplemented with diagrams and photographs.

10 Test report

The test report shall contain the following:

a) Reference to this CEN Technical Report;

b) Identification of the roof covering:

   1) Name, manufacturer or supplier of elements;

   2) Type of elements;

   3) Production code number or similar identifier;

   4) Date and form in which the elements arrived at the laboratory, including fixing devices, if any;

   5) Handling, storage and conditioning of the elements before testing.

c) Test procedure:

   1) Turbulence intensity of the apparatus;

   2) Calibration of the fan system, rain generating and run-off water devices;

   3) Method of preparation of the test specimen, including dimensions, laying of the element and sealing of the edges;

   4) Sub-test conditions B and D (and optionally A and C) and the climate zone or appropriately derived wind-rain conditions;

5) Roof pitch;

6) Any deviation from this Technical Report and any incidents which may have influenced the results;

7) Date of test;

8) Name and signature of technician responsible for the test.

d) Results:

1) Description of the continuous visual observation and the pressures applied to the underside of the test specimens for the wind-rain sub-tests A, B and C as appropriate;

2) The initial pressure measured with the suction pressure chamber closed;

3) The suction pressure applied to the underside of the test specimen at which the reference leakage rate occurs;

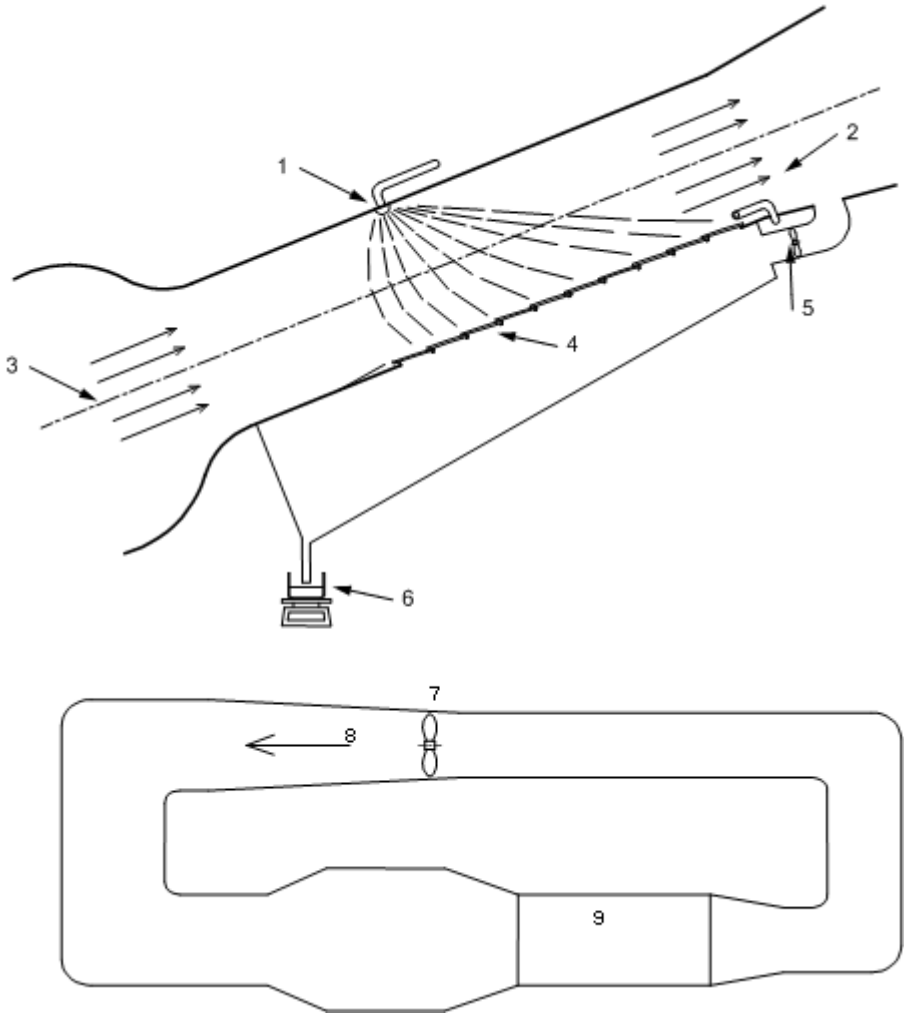
4) Increments of underside pressure and the corresponding leakage rate.

5) Amount of leakage water measured in the deluge rain for sub-test D;

6) Where appropriate, the comparison of the performance of the product in the test specimen with the performance of a reference product in another test specimen using the same apparatus.

Annex A
(Informative)

Examples of wind-driven rain apparatus



Key

1	direct rain nozzle	6	balance for leakage water
2	un off water	7	fan
3	approach wind	8	air flow
4	test specimen	9	test cell
5	suction fan and valve		

Figure A.1 — Closed wind tunnel with approach wind parallel to test specimen (section and plan view)

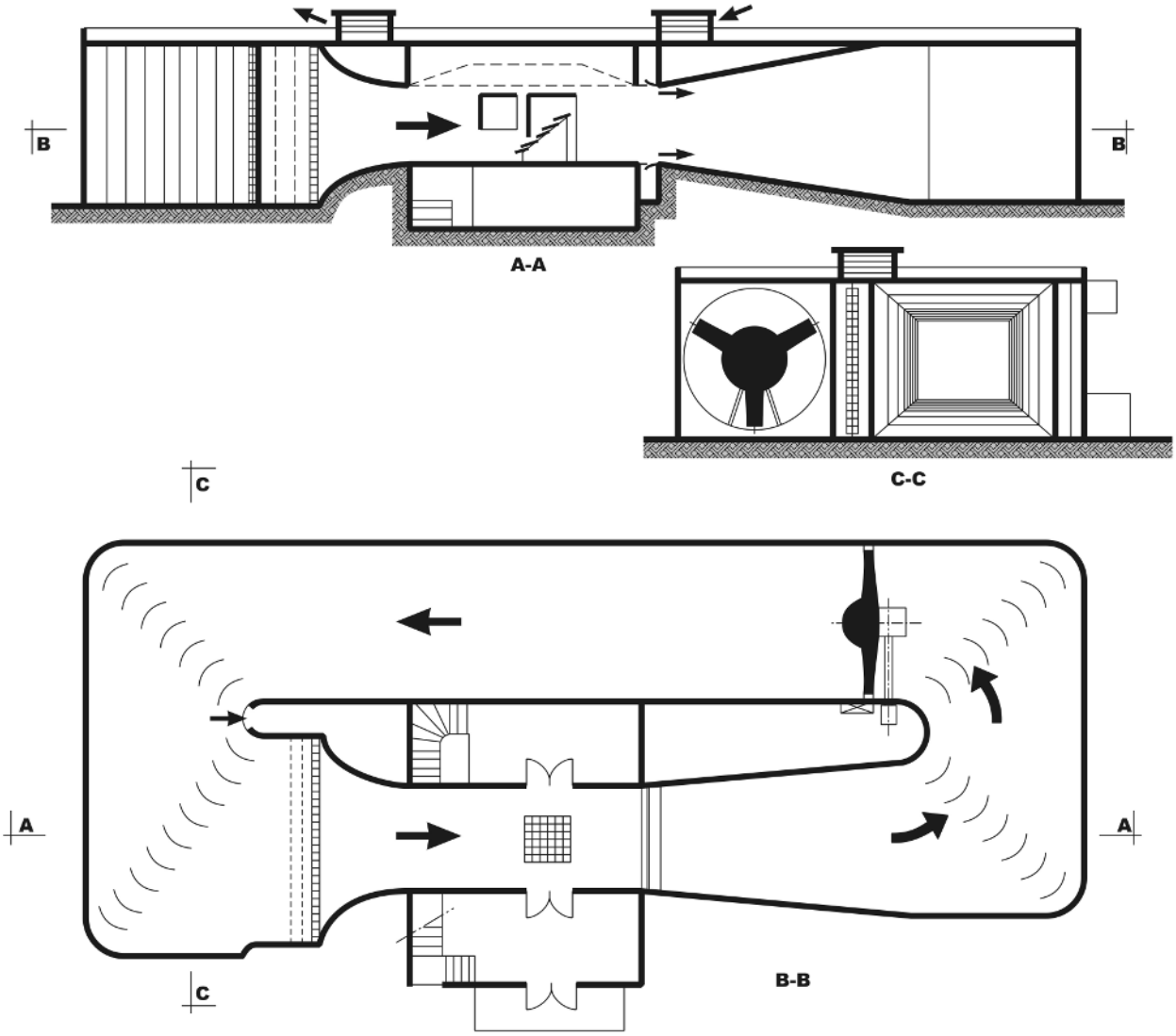
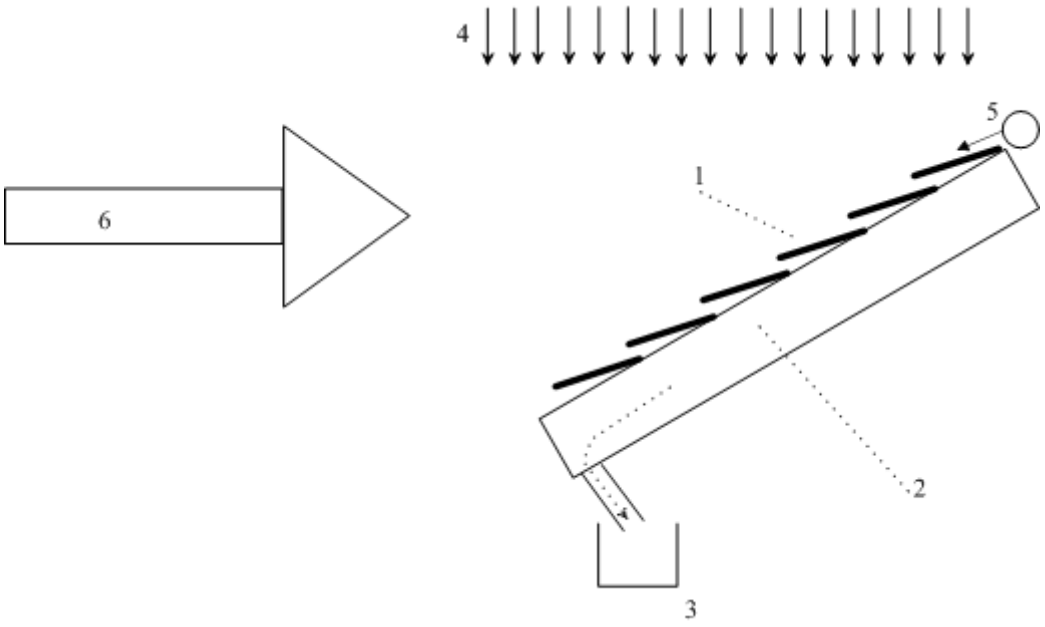


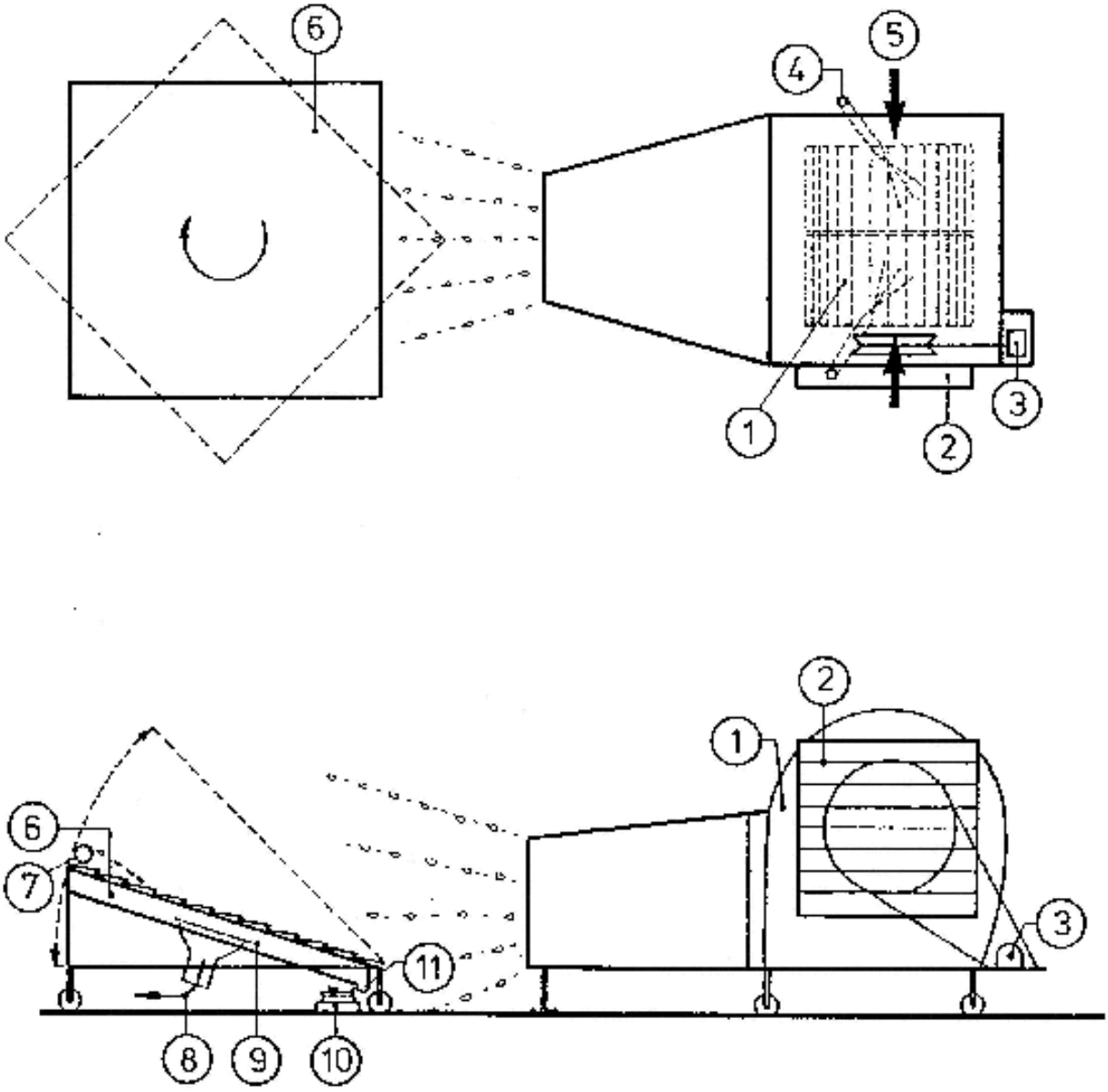
Figure A.2 — Closed wind tunnel with horizontal wind



Key

1 test specimen
2 suction chamber
3 water collector and balance
4 rain
5 run-off water
6 wind

Figure A.3 — Open apparatus with horizontal wind



Key

1	drum motor	7	run-off water
2	gust fan	8	suction fan
3	electric motor	9	transparent pessure chamber
4	water supply	10	balance for leakage water
5	air intake	11	water collecting gutter
6	test specimen		

Figure A.4 — Open apparatus with horizontal wind

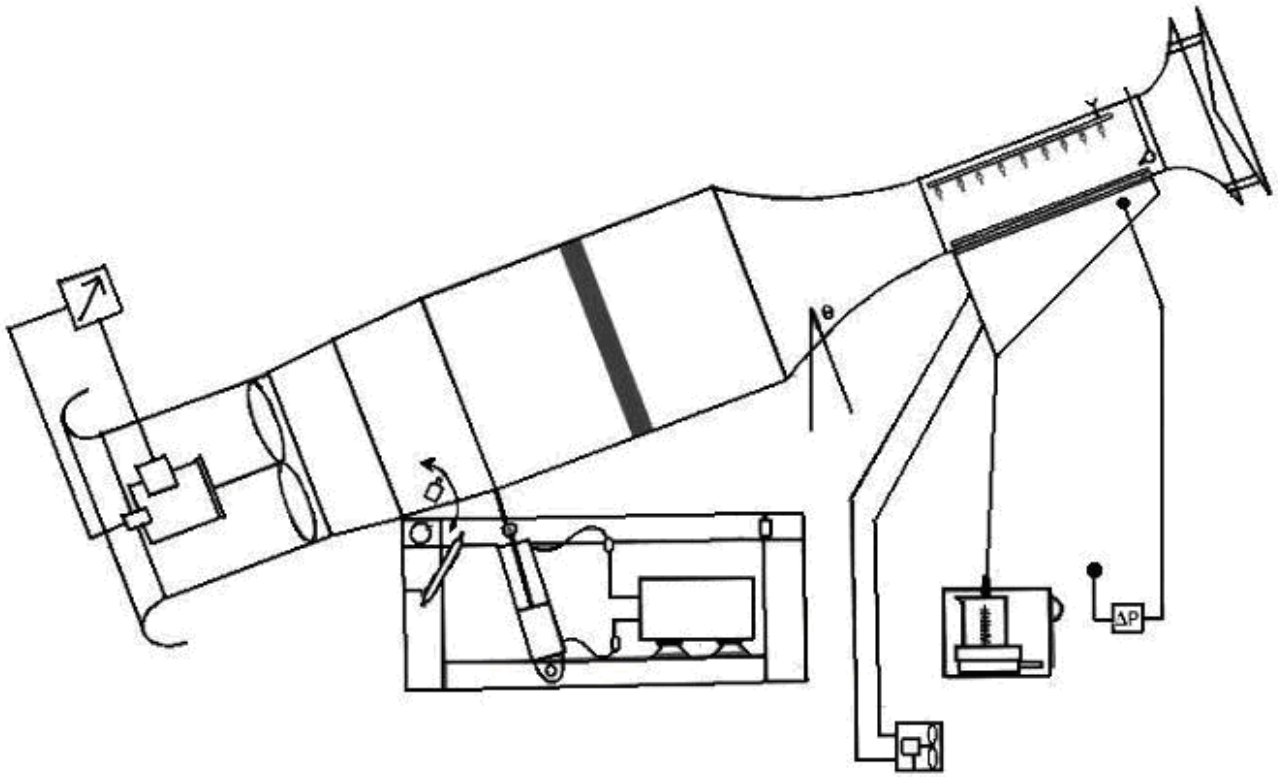


Figure A.5 — Open apparatus with wind parallel to test specimen

Annex B
(Informative)

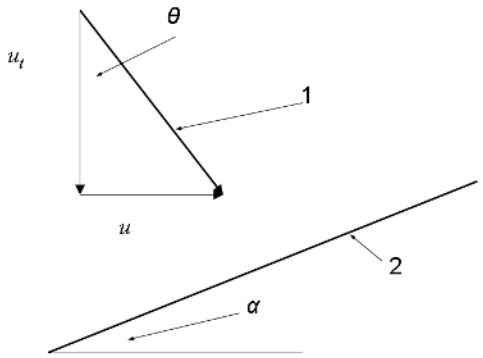
Derivation of the rainfall rate on a pitched roof

The quantity of rain falling on a pitched roof (R_t in mm/h) is a function of the rainfall rate falling on a horizontal plane (R_h in mm/h), the trajectory of the raindrops and the pitch of the roof slope. The trajectory of the raindrops is, in turn, determined by the terminal velocity (u_t in m/s) of the raindrops and the speed of the wind (u in m/s). The relationship between u_t and R_h was established by Lacey [1] by formula B.1:

$$u_t = 4{,}505 R_h^{0{,}123} \tag{B.1}$$

The derivation of this formula is based on data given by Laws and Parsons [2] of the median raindrop size as a function of R_h and on the relationship between raindrop diameter and u_t established by Best [3].

When wind is blowing the raindrops are carried along horizontally at approximately the speed of the wind. The trajectory of the raindrops can therefore be calculated from the vector addition of u_t and u (Figure B.1):



Key

1 raindrop trajectory

2 roof slope

Figure B.1

The incident angle of the raindrops to the vertical is given by formula B.2:

$$\theta = \tan^{-1}\left(u / u_t\right) \tag{B.2}$$

For a roof pitch of α degrees to the horizontal, the quantity of water falling onto each square meter of roof, R_t, may be found by trigonometry (formula 8):

$$R_t = R_h\left(\cos\alpha + \tan\theta.\sin\alpha\right) \tag{B.3}$$

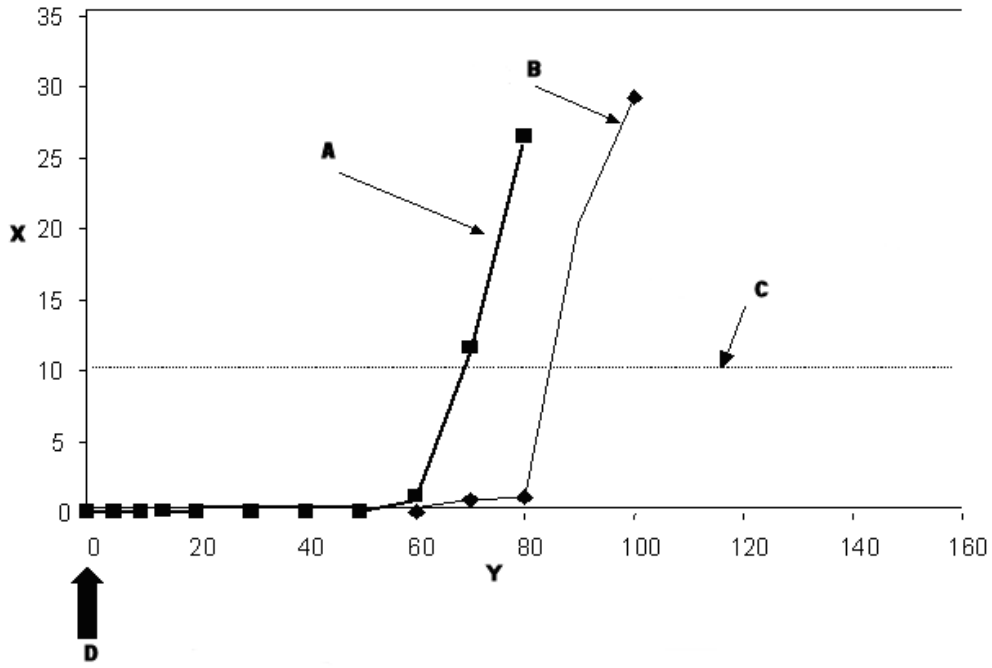
Annex C
(Normative)

Use of test results

Compare the performance of the product in the test specimen with the performance of a reference product in another test specimen. The reference product shall have known satisfactory performance under the same wind-rain conditions.

For satisfactory performance of the product, the applied suction required to cause leakage of 10g/m^2 per 5-minute step in the test specimen shall be not less than the applied suction value of the reference product test specimen at the same leakage rate and wind-rain conditions. The comparative tests shall be carried out using the same apparatus.

NOTE Figure C.1 illustrates the results of a typical comparative test.



Key

X Leakage (g/m^2/5 minutes)
Y Applied suction pressure (Pa)
A Reference product
B Test product
C Reference leakage rate 10g/m^2/5 minutes step
D Zero pressure datum

The applied suction pressure is shown relative to the pressure at the start of the sub-test with the suction chamber closed (zero pressure datum).

Figure C.1 — Example of sub-test B comparative test

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