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Windows, doors and curtain walling — Impacted by windborne debris in windstorms — Test method and classification

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 162, *Doors, windows and curtain walling*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Windows, doors and curtain walling — Impacted by windborne debris in windstorms — Test method and classification

1 Scope

This document specifies a method to determine the windborne debris-resistance of windows (including skylights), doors or curtain walling to natural threats characterized by simulated destructive-windstorm events. The test method can also be used on windstorm protective systems for the missile impact tests.

The test method determines the performance of windows, doors or curtain walling, under conditions representative of events that occur in severe, destructive-windstorm environments using simulated missile impact(s) followed by the application of cyclic test load.

This document is applicable to the design of an entire window (including skylight), door or curtain walling, and also in case these systems are tested in combination with windstorm protective system assemblies and their installation.

This document is not applicable to:

— exterior garage doors and rolling doors are beyond the scope of this document and this document does not refer to:

  — bullet;

  — blast;

  — flood resistance.

— windstorm protective systems when tested alone, i.e. not tested in combination with windows, skylights, doors or curtain walling. When windows, skylights, doors or curtain walling are tested in combination with windstorm protective systems, pass and fail assessment criteria (see Clause 9), only refer to windows, skylights, doors or curtain walling themselves. This document does not define pass or fail criteria for windstorm protective systems.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
windstorm protective system
construction assemblies applied, attached, or locked over an exterior glazed opening system to protect that system from *windborne debris* (3.4) during *destructive windstorm* (3.2) events

Note 1 to entry: Windstorm protective systems include types that are fixed, operable, or removable.

3.2
destructive windstorm
severe weather event with high winds and turbulent gusts, such as a tropical cyclone, having a *reference wind speed* (3.3) capable of generating *windborne debris* (3.4)

3.3
reference wind speed
V_r
velocity of the wind used in calculation as determined by the ordering party

Note 1 to entry: The reference wind speed is intended to represent the 3-second gust wind speed design basis for a tropical cyclone such as used to describe a 50-year recurrence period or annual 0,02 probability of being exceeded ($V_r = V_{t=3\ s}$, see Annex C).

3.4
windborne debri
object carried by the wind in windstorms

3.5
air pressure differential
P
specified maximum air pressure differential in cyclic test load across the specimen, creating an inward or outward load

Note 1 to entry: The air pressure portion of the test shall use the *test loading sequence* (3.12). Select P_{pos} and P_{neg} for the maximum inward (positive) and maximum outward (negative) air pressure differential for which qualification is sought.

Note 2 to entry: *P* is determined depending on local building code or by the design professional.

Note 3 to entry: The air pressure differential is expressed in Pascal or its multiples.

3.6
windborne debris-resistance
performance of a window, a door or a curtain walling, [also in case these systems are tested in combination with a *windstorm protective system* (3.1)], to resist the impact of *windborne debris* (3.4) and *cyclic test load* (3.11) without occurrence of specified failure

3.7
test specimen
entire assembled unit submitted for test

3.8
missile
object that is propelled towards a *test specimen* (3.7), i.e. *lumber missile* (3.9) and *steel ball* (3.10) (3.11)

3.9
lumber missile
dressed piece of surface-dried, soft-wood, structural timber that impacts the glazing surface of the specimen.

3.10
steel ball
solid steel ball weighing 2 g ± 5 %, with an 8 mm nominal diameter

3.11
cyclic test load
beginning at a specified *air pressure differential* (3.5), the application of a positive (and negative) pressure to achieve another specified air pressure differential and returning to the initial air pressure differential

3.12
test-loading sequence
group of tests carried out in the following sequence:

a) missile impact test

b) air pressure cycling test

3.13
serviceability pressure
uniform, static air-pressure difference from wind, inward or outward, for which the test specimen is designed under service load conditions.

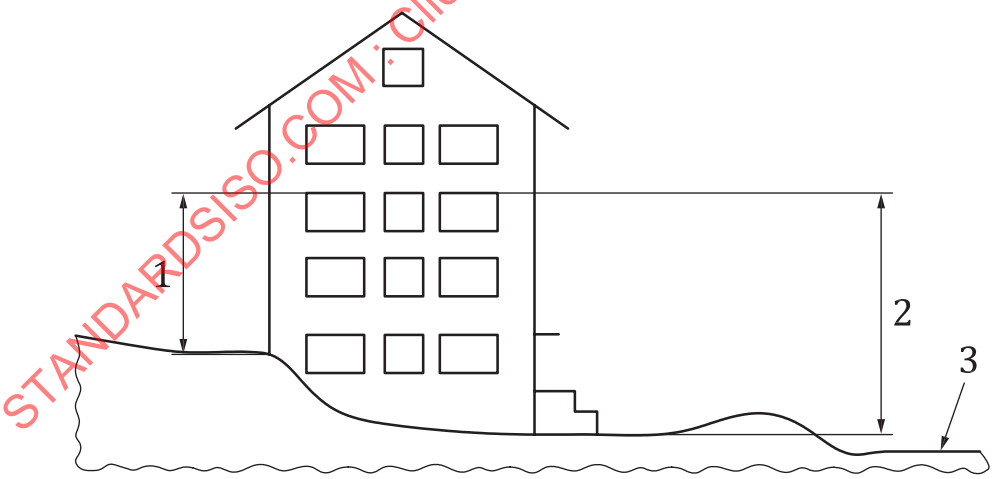
Note 1 to entry: Serviceability pressures are based on reference wind speed with a mean recurrence interval that relates to the importance level of the construction.

3.14
fenestration assembly
exterior windows (including skylights), doors, curtain walling, or a combination thereof, intended to be installed in a building

3.15
height above ground level of assembly
H_a
distance between the ground level and the head of the building component itself.

Note 1 to entry: In case of different ground level for a single front of a building (see key 1 and key 2 Figure 1), the ground level is the lower altitude line referred to each front of the building (see key 2 of Figure 1).

Note 2 to entry: for the definition of "head" of a window, see ISO 22496.



Key
1 height above (upper) ground level
2 height above ground level of assembly (H_a) for the front of the building
3 ground level not relevant for the fronts of the building

Figure 1 — Schematic examples of height above ground level of assembly depending on the different fronts of a building

3.16
external emergency exit doorset
panic exit doorset
external doorset in a construction work which separates the exterior climate from the interior of a building, that opens in an emergency situation with one single operation (without a key).

Note 1 to entry: An external emergency exit is usually fitted with panic exit devices (push bars) or emergency exit devices (push to open, lever handle or push pad).

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms apply:

DLO	Daylight opening – the width and the height of the visible glass (see Annex F)
G1I	Insulating glass type n°1 for test mock-up examples (see Annex F)
G2	Laminated glass type n°2 for test mock-up examples (see Annex F)
G2I	Insulating glass type n°2 for test mock-up examples (see Annex F)
H.S.	Heat strengthened glass
F.T.	Fully tempered glass
TH-1	Threshold type n°1 for test mock-up examples (see Annex F)
TH-2	Threshold type n°2 for test mock-up examples (see Annex F)
P	Air pressure differential
W	Width of the mock-up examples (see Annex F)
H_{mu}	Height of the mock-up examples (see Annex F)
V	reference wind speed
V_t	Velocity of the wind used in the test, as determined by the procedure of this document

5 Principle and significance

5.1 General

This test method shall be used to determine the windborne debris-resistance of windows, doors or curtain walling. Qualification under this document provides a basis to judge the ability of the fenestration assembly to remain without failure according to Clause 9 during extreme wind events, when they can be impacted by windborne debris. This minimizes the damaging effects of a destructive windstorm on the building interior and reduces the magnitude of internal pressurization and wind-driven rain infiltration.

This test method consists of mounting the test specimen and testing to an appropriate class, by impacting the test specimen with the missile(s) and then applying cyclic pressure differentials (i.e. a cyclic test load) across the test specimen in accordance with a specified test-loading sequence. The condition of the test specimen is observed and measured, and the results are reported.

A missile-propulsion device, an air pressure system and a test chamber are used to model representative conditions that can be representative of windborne debris and pressures in a windstorm event.

The performance determined by this test method relates to the ability of building envelope components to fulfil the pass criteria listed in Clause 9.

Classification is intended as a basis for judging the ability of the building envelope assembly to remain essentially without significant openings or holes as the result of a windstorm. Impact by missile(s) and subsequent cyclic static-pressure differentials simulate conditions representative of windborne debris and pressures in a destructive windstorm.

5.2 Significance and use

Structural design for the determination of windborne debris-resistance of windows, doors or curtain walling is based on positive and negative serviceability pressures (see 3.13). Impact resistance of building envelope components is generally performed according to test methods such as ISO 7892, to prove adequacy to different types of impacts, varying the mass of the body (impactor), its nature, drop height, impact location, and impact direction (acting from the outside or inside of the building). ISO 7892 is not developed to estimate the ability to withstand impacts from windborne debris followed by fluctuating pressures that simulate the windstorm environment.

Windstorm damage assessments demonstrated that windborne debris impact and the subsequent exposure to positive and negative pressure caused significant damage to building envelopes in extreme-wind events. The resistance of windows, doors or curtain walling to wind loading after impact depends upon product design, installation, load magnitude and duration.

5.3 Options

This test method can be used:

— either to test the windows (incl. skylights), doors or curtain walling for classification according to 10.3

— or to test the windows (incl. skylights), doors or curtain walling to other conditions without classification as requested by the ordering party, in which case the required information, in accordance with Annex A, shall be provided for the test procedure.

6 Test apparatus

Any equipment capable of performing the test procedure within the allowable tolerances may be used.

6.1 Mounting frame, supporting the outer specimen test frame(s) in a vertical position during testing. The mounting frame shall be either integral with the test chamber or capable of being installed into the test chamber prior to or following missile impact(s). The mounting frame shall be anchored so it does not move when the specimen is impacted. The specifications for the inner and the outer specimen-support frame shall be specified in the testing report.

6.2 Air-pressure cycling test chamber, consisting of an enclosure or box with an opening against which the test specimen is installed. It shall be capable of withstanding the specified cyclic static-pressure differential. The chamber shall be deep enough to avoid contact with the test specimen during pressure cycling. Pressure taps shall be provided to facilitate measurement of the cyclic pressure differential. They shall be located such that the measurements are unaffected by the air supplied to or evacuated from the test chamber or by any other air movements.

6.3 Air-pressure system, consisting of a controllable blower, a compressed-air supply/vacuum system or other suitable system capable of providing the required maximum air-pressure differential (inward and outward acting) across the test specimen. Specified pressure differentials across the test specimen shall be imposed and controlled through any system that subjects the test specimen to the prescribed test-loading program. Examples of suitable control systems include manually operated valves, electrically operated valves or computer-controlled servo-operated valves.

6.4 Air-pressure-measuring apparatus. Pressure differentials across the test specimen shall be measured by an air-pressure-measuring apparatus with an accuracy of ±2 % of its maximum rated capacity, or ±100 Pa, whichever is the lowest, and with a response time of less than 50 ms.

EXAMPLE Mechanical pressure gages and electronic pressure transducers are acceptable.

6.5 Missile-propulsion device(s), capable of propelling a missile at a specified speed and orientation towards a specified impact location; see Annex B. The missile shall not be accelerating upon impact due to the force of gravity along a line normal to the specimen.

6.6 Speed-measuring system, capable of measuring missile speeds within the tolerances defined in 8.3.2.

6.7 Missiles

6.7.1 General

Missiles shall be one or more of the following, as appropriate to classification, see 10.2. Any other representative missiles shall have mass, size, shape and impact speed determined by engineering analysis (see Annex G) considering the reference wind speed.

6.7.2 Small-ball missile

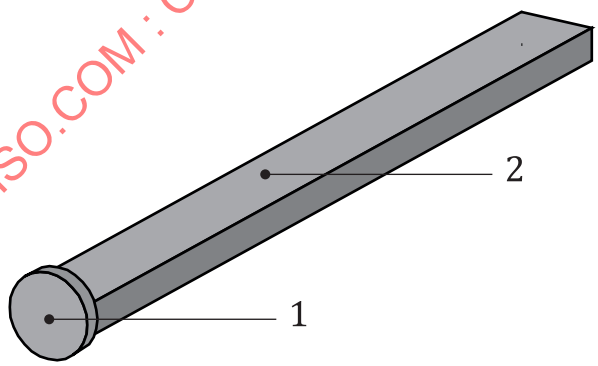
A solid steel ball weighing 2 g ±5 %, with an 8 mm nominal diameter, and an impact speed according to Table 1.

6.7.3 Lumber missile

The lumber missile shall be made of pine or fir with a moisture content of 15 % ±4 %, and a cross section of 50 mm x 100 mm with no defects, including knots, splits, checks, shakes, or wane within 30 cm of the impact end, which shall be trimmed (cut in 90° angle).

The lumber missile shall have a mass of between 910 g ± 100 g and 4 100 g ± 100 g and a length between 525 mm ± 100 mm and 4,0 m ± 100 mm and an impact speed according to Table 1.

If required for propulsion, a circular sabot (i.e. circular base plate as represented in Figure 2) having a mass of no more than 200 g may be applied to the trailing edge of the lumber missile. The mass and length of the lumber missile includes the mass and length of the sabot.



Key

1 (optional) circular sabot (base plate)

2 lumber missile

Figure 2 — Schematic diagram of lumber missile

6.7.4 Other missile

Any other representative missile with mass, size, shape, and impact speed as a function of reference wind speed determined by engineering analysis (see Annex G).

6.8 Speed-measuring system. The speed-measuring system shall be calibrated. Calibration shall be performed at the speed-measuring system manufacturer's recommended frequency. The speed measuring system shall be calibrated by at least one of the following methods:

— photographically, using a stroboscope and a still camera;

— photographically, using a high-speed motion-picture or video camera with a frame rate exceeding 500 frames per second capable of producing a clear image and a device that allows single-frame viewing;

— using gravity to accelerate a free-falling object having negligible air drag through the timing system and comparing measured and theoretical elapsed times.

6.9 Pressure transducers. Electronic pressure transducers shall be calibrated at six-month intervals using a standardized calibrating system or a manometer readable to 10 Pa (1 mm of water).

6.10 Manometers. The calibration of manometers is normally not required, provided that the instruments are used at a temperature near their design temperature.

7 Test specimens

7.1 General

The test specimens shall consist of the entire fenestration assembly and contain all devices used to resist wind and windborne debris (e.g. windstorm protective systems tested in combination with the specimen).

All parts of the test specimen shall be full size, as specified for actual use, using the identical materials, details, and methods of construction. Mullions shall be tested as part of the test sample and true glazing bars shall be tested as part of the test samples.

7.2 Test specimen size

The test specimen to be tested shall have nominal dimensions representative of the commercial production.

The size of the test specimen shall be determined by the ordering party. All components of each test specimen shall be full size.

Where it is impractical to test the entire fenestration assembly such as curtain walling and heavy commercial assemblies, test the largest size of each type of panel as required by the ordering party, to qualify the entire assembly. When the smaller panels exceed a 50 % reduction in their individual length size (e.g. height or width) with reference to the panel that has been tested for certification purposes, a second test should be conducted. The second test shall check that the higher stiffness of these smaller building components is not influencing their impact performances when it comes to wind-borne debris simulation.

7.3 Test specimen

Individual windows (including skylights), doors or curtain walling, should be tested separately (see Figure 4 and Figure 6).

Windows (including skylights), doors or curtain walling intended to be installed combined together shall be tested by joining at least three lites into one mounting frame, separated only by the mullions (see Figure 5 and Figure 7). These mullions should be representative of the mullions of the building envelope to be tested.

Openable elements (and windstorm protective devices affecting their operation) shall be opened and closed twice before testing.

When windstorm protective systems are intended to be installed combined with windows (including skylights), doors or curtain walling, the deflection after the impact testing shall be verified. This parameter is used to establish the minimum design installation distance of these building components from the

internal building envelope to be protected. External windstorm protective systems maximum deflection should guarantee a minimum distance of these building components from the internal building envelope.

If windows (including skylights), doors or curtain walling are intended to be installed combined with windstorm protective systems, the assembly shall be tested by joining at least three lites into one mounting frame, separated only by the mullions.

7.4 Order of testing

Test specimens passing the acceptance criteria of the lumber-missile or small-ball-missile impact test shall be submitted for the air-pressure-cycle test.

8 Test procedure

8.1 General

The test procedure shall follow Annex D.

Test specimen shall be tested to a class appropriate to its use. The following test information shall be provided:

a) missile type;

b) maximum specified air-pressure differential (see 8.4.3).

If the test specimen is tested at other conditions, then the relevant information shall be provided in accordance with Annex A.

8.2 Preparation

8.2.1 General

Remove from the test specimen any sealing or construction material that is not intended to be used when the unit is installed in or on a building. The test specimen shall not be removed from the mounting frame at any time during the test sequence.

8.2.2 Installation

Support and secure the test specimen into the mounting frame in a vertical position using the same number and type of anchors normally used for product installation as defined by the manufacturer or as required for a specific project. If this is impractical, install the test specimen with the same number of equivalent fasteners located in the same manner as the intended installation. This test shall not be used to evaluate anchorage of curtain walling and heavy commercial assemblies. In those cases, the specimen shall be securely anchored to facilitate testing.

8.2.3 Conditioning

Condition the specimens separately for at least 4 h within a temperature range of 15 °C to 35 °C. For specimens tested in different temperature conditions, those conditions shall be agreed by the ordering party.

8.2.4 Missile impact

Take the following steps to prepare the specimen for missile impact.

— Secure the specimen and mounting frame such that the missile (lumber missile or small-ball missile) impacts the exterior side of the specimen as installed.

— Locate the end of the propulsion device from which the missile exits at least 1,5 times the length of the missile from the specimen. This distance shall be no less than 1,80 m.

— Set up appropriate signal/warning devices to prevent test and/or other personnel from coming between the propulsion device and the test specimen during testing.

— Weight each missile prior to starting the test.

— Load the missile into the propulsion device.

— Reset the speed-measuring system.

— Align the missile-propulsion device such that the specified missile impacts the test specimen at the specified location.

8.3 Missile impact test

8.3.1 Projectile descriptions

Propel the missile at the specified impact speed specified in Table 1.

Table 1 — Applicable missiles

Missile type	Missile	Impact speed (m/s)
A	(2 ± 0,1) g (small steel ball)	40
B	(910 ± 100) g (small lumber)	15
C	(2 050 ± 100) g (small lumber)	12
D	(4 100 ± 100) g (medium lumber)	15
E	(4 100 ± 100) g (medium lumber)	24
NOTE 1 Impact speed is given here to two significant figures (see ISO 16932:2020, Table 1).		
NOTE 2 Missile weight is given to one significant figure (with possible uncertainty given to one significant figure) (see ISO 16932:2020, Table 1).		

8.3.2 Impact-speed tolerance

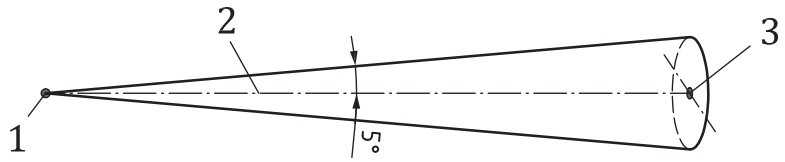
The measured missile speed shall be within the following respective tolerances at the chosen measuring point after the missile leaves the propulsion device:

a) ±2 % specified speed for lumber missile impact test;

b) ±1 % specified speed for small-ball missile impact test.

8.3.3 Impact angle

For missiles having a longitudinal axis, on impact the longitudinal axis of the missile shall be within ±5° of a line normal to the specimen at the specified impact point. For each missile, the allowable deviation of launching angle is shown in Figure 3.



Key

1 starting point of the missile
2 normal line of the testing face
3 objective/ striking point

Figure 3 — Allowable launching angle deviation

8.3.4 Impact location

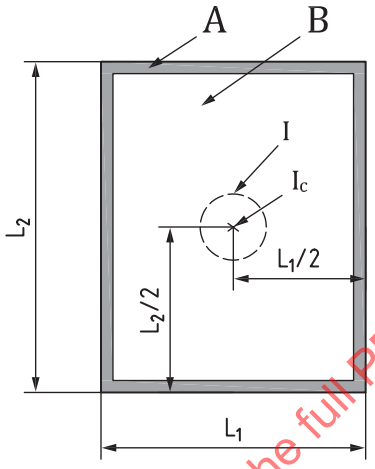
8.3.4.1 Lumber-missile test

Impact each test specimen once (in Figure 4, key I), as shown in Figure 4.

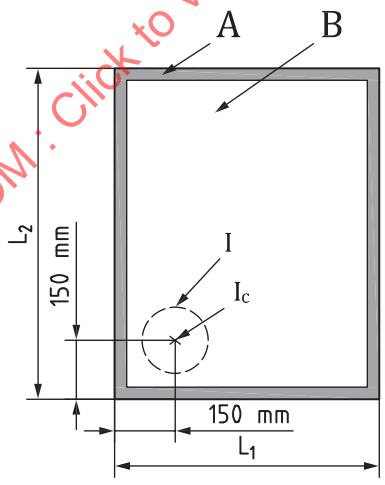
a) Impact one specimen with the missile within a 65 mm radius circle at the centre of specimen.

b) Impact a different specimen with the missile within a 65 mm radius circle with the centre located 150 mm from supporting members at a corner.

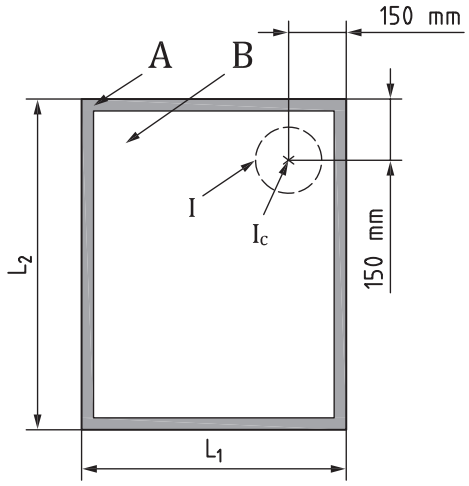
c) Impact the remaining specimen with the missile within a 65 mm radius circle having its centre located 150 mm from supporting members at a diagonally opposite corner.



a) Specimen 1: impact area of wood lumber missile impact test for individual windows (incl. skylights), doors or curtain walling tested separately



b) Specimen 2: impact area of wood lumber missile impact test for individual windows (incl. skylights), doors or curtain walling tested separately

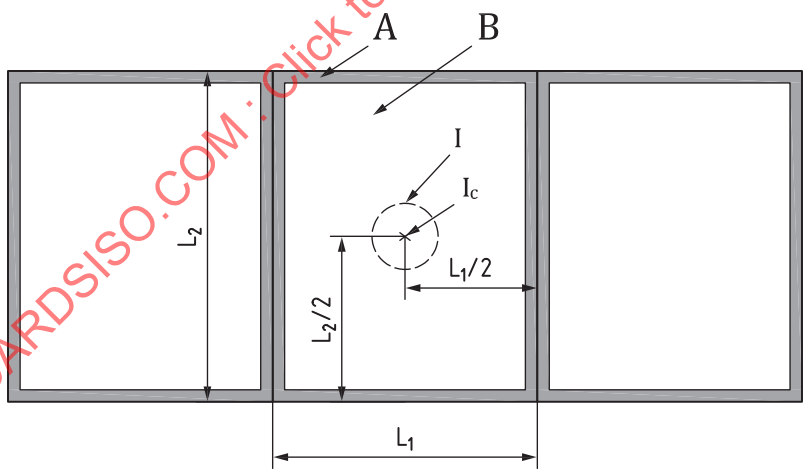


c) Specimen 3: impact area of wood lumber missile impact test for individual windows (incl. skylights), doors or curtain walling tested separately

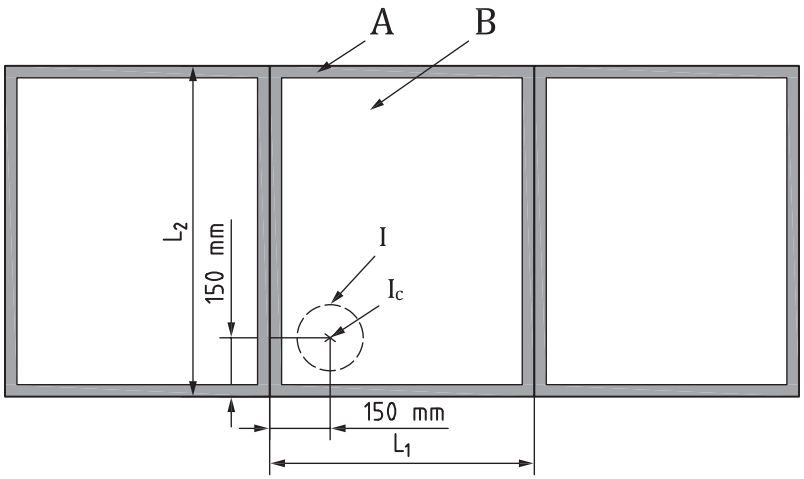
Key

I impact area of each specimen
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen

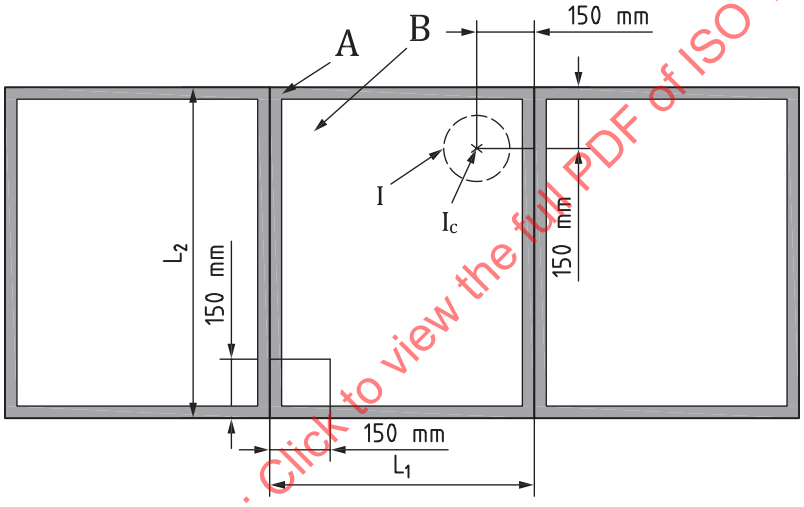
Figure 4 — Impact area of wood lumber missile impact test for individual windows (incl. skylights), doors or curtain walling tested separately



a) Specimen 1: impact area of wood lumber missile impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame



b) Specimen 2: impact area of wood lumber missile impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame



c) Specimen 3: impact area of wood lumber missile impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame

Key

I impact area of each specimen
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen

Figure 5 — Impact area of wood lumber missile impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame

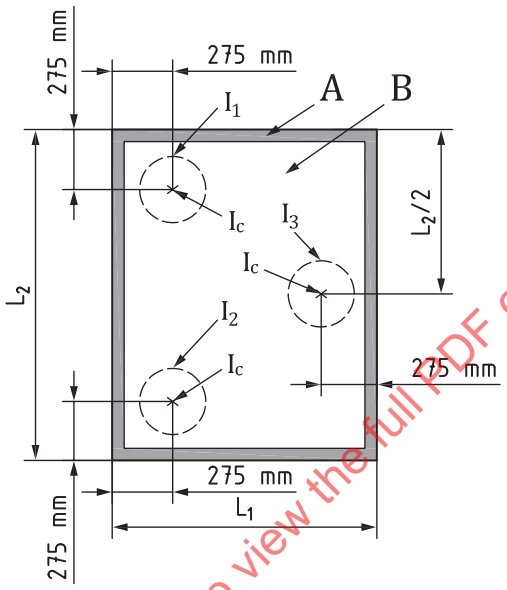
8.3.4.2 Small-ball-missile test

Impact each test specimen three times (in Figure 6: I1, I2 and I3) with 10 steel balls each as shown in Figure 6. Each specimen shall receive a total of 30 impacts from steel balls.

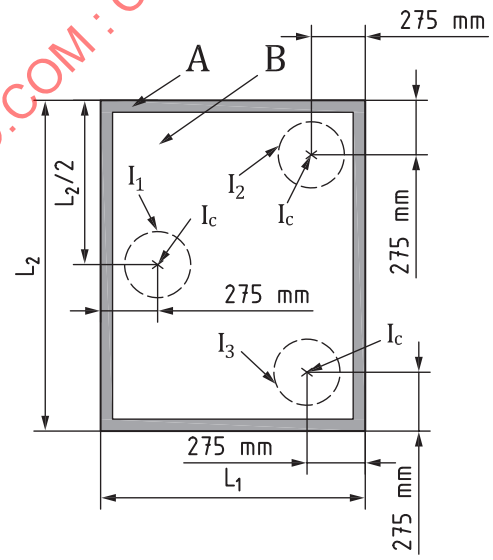
a) The corner-impact locations shall be entirely within a 250 mm radius circle having its centre located 275 mm from the corner edges.

b) The edge-impact locations shall be entirely within a 250 mm radius circle having its centre located at 275 mm from the edges and located at the centre line between two corners.

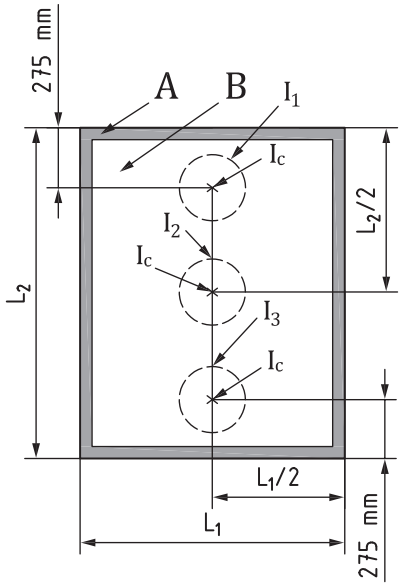
c) The centre-impact location shall be entirely within a 250 mm radius circle having its centre located at the horizontal and vertical centre line of the specimen.



a) Specimen 1: impact area of steel ball impact test for individual windows (incl. skylights), doors or curtain walling tested separately



b) Specimen 2: impact area of steel ball impact test for individual windows (incl. skylights), doors or curtain walling tested separately

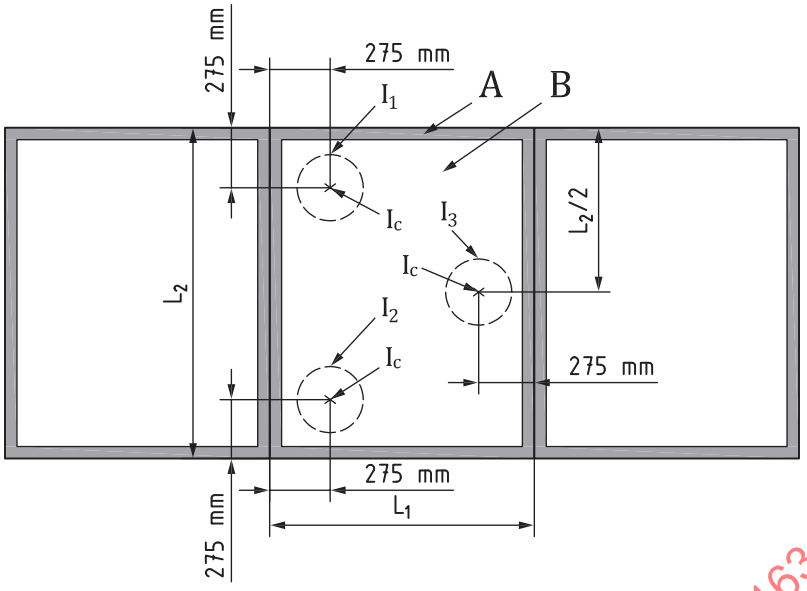


c) Specimen 3: impact area of steel ball impact test for individual windows (incl. skylights), doors or curtain walling tested separately

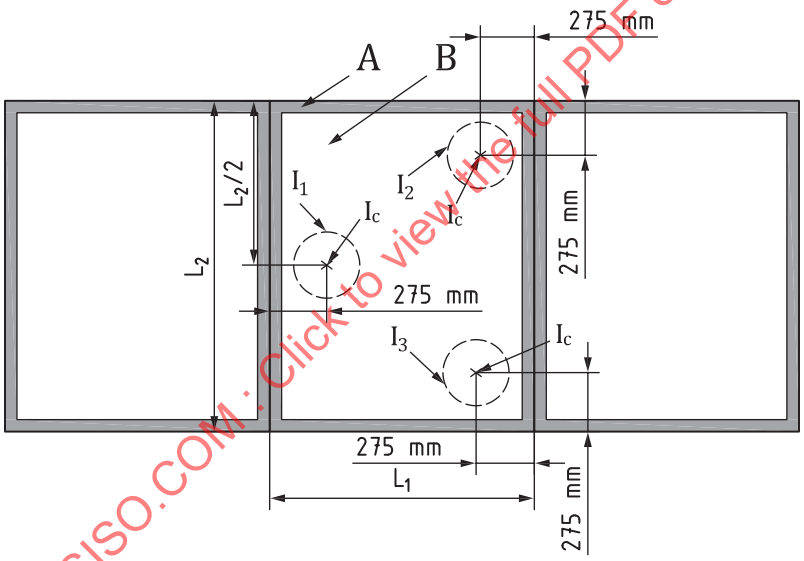
Key

I_1 impact area n°1 of each specimen
I_2 impact area n°2 of each specimen
I_3 impact area n°3 of each specimen
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen

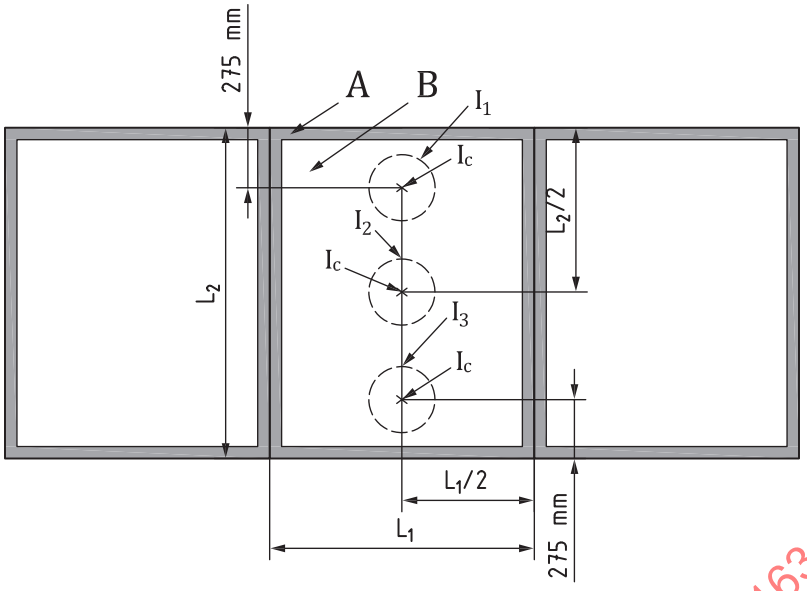
Figure 6 — Impact area of steel ball impact test for individual windows (incl. skylights), doors or curtain walling tested separately



a) Specimen 1: impact area of steel ball impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame



b) Specimen 2: impact area of steel ball impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame



c) Specimen 3: impact area of steel ball impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame

Key

I_1 impact area n°1 of each specimen
I_2 impact area n°2 of each specimen
I_3 impact area n°3 of each specimen
I_c centre of the impact area
I_1 impact area n°1 of each specimen
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen

Figure 7 — Impact area of steel ball impact test for windows (incl. skylights), doors or curtain walling intended to be installed combined together and tested by joining at least three lites into one mounting frame

8.4 Air pressure cycling test

8.4.1 General

Specimens passing the acceptance criteria for the lumber- or small-ball-missile impact test shall be subjected to the air-pressure-cycle test. If the mounting frame is not integral within the test chamber, attach the mounting frame to the test chamber such that the exterior side of the test specimen faces outward from the chamber.

8.4.2 Leakage

If at any time during testing the specified maximum pressure differential cannot be achieved in either direction due to excessive air leakage, cover all cracks and joints through which leakage occurs with tape or film in such manner as to stop the leakage. Tape shall not be used when there is a probability that it will restrict significantly differential movement between adjoining segments of the specimen, in which case cover both sides of the test specimen with a single thickness of polyethylene or other plastic film no thicker than 0,050 mm.

The tape should be applied in a manner that allows the full load to be transferred to the test specimen and that does not prevent movement or failure of the test specimen.

Apply the film loosely with extra folds of material at each corner and at all offsets and recesses. When the load is applied there shall be no fillet caused by tightness of the plastic film.

8.4.3 Air-pressure differential

The maximum air-pressure differential, *P*, is specified by the ordering party, or it is equal to the serviceability pressure assigned for worst exposure.

Note 1 *P* is determined depending on local building code or by the design professional.

Note 2 Pressure differentials used in the air pressure cycling test can be determined as the serviceability pressure differentials for the building and the other structure in accordance with codes and/or standards of each country and region. In this case, the pressure differentials can have positive and negative values, $P_{positive}$ and $P_{negative}$, respectively.

8.4.4 Cyclic test loading

If the mounting frame is not integral within the test chamber, attach the mounting frame to the test chamber such that the exterior side of the test specimen faces outward from the chamber.

If at any time during testing the specified maximum pressure differential cannot be achieved in either direction due to excessive air leakage, cover all cracks and joints through which leakage occurs with tape or film in such manner as to stop the leakage. Tape shall not be used when there is a probability that it will restrict significantly differential movement between adjoining segments of the specimen, in which case cover both sides of the test specimen with a single thickness of polyethylene or other plastic film no thicker than 0,050 mm. The technique of application is important in order that the full load is permitted to be transferred to the test specimen and that the film does not prevent movement or failure of the test specimen. Apply the film loosely with extra folds of material at each corner and at all offsets and recesses. When the load is applied there shall be no fillet caused by tightness of the plastic film.

Unless otherwise specified, apply the cyclic static pressure differential loading in accordance with Table 2 in which *P* denotes the maximum inward (positive) and outward (negative) air pressure differentials.

Unless otherwise specified, the duration of each air pressure cycle shall not be less than 1 s and not more than 5 s. The time between successive cycles shall be no more than 1 s.

Interruptions for equipment maintenance and repair shall be permitted.

If necessary due to the limitations of the test laboratory, it is permitted for the test specimen to be removed, reversed and reinstalled in the test chamber between the positive and negative pressure cycles.

The test specimen shall not contact any portion of the test chamber in the out of plane direction at any time during the application of the cyclic static pressure differential loading.

Table 2 — Cyclic static air pressure differentials - test sequence

Step	Pressure direction	Pressure difference	Cycles
1	Inward	0,2 *P* to 0,5 *P*	3 500
2	Inward	0,0 *P* to 0,6 *P*	300
3	Inward	0,5 *P* to 0,8 *P*	600
4	Inward	0,3 *P* to 1,0 *P*	100
5	Outward	0,3 *P* to 1,0 *P*	50
6	Outward	0,5 *P* to 0,8 *P*	1 050
7	Outward	0,0 *P* to 0,6 *P*	50
8	Outward	0,2 *P* to 0,5 *P*	3 350

9 Pass and fail assessment criteria

9.1 General

The following pass and fail criteria shall be fulfilled both after impact and pressure-cycle test.

If the missile from the impact test penetrates the sample(s), the test is considered a failure.

If there is a failure during the impact test, the pressure-cycle test does not need to be performed.

9.2 Glass infill(s)

After completion of the impact test and after completion of the cycling test, all the following criteria shall be fulfilled:

a) the glass pane shall not have openings through which a 76 mm diameter solid sphere can pass;

b) no tears longer than 130 mm and larger than 1 mm shall be formed through which air can pass;

c) if the glass pane(s) pulls out or releases from the edge of the test specimen(s) frame, the test is considered a failure.

9.3 Panel(s)

For panels made from materials other than glass, no penetrable openings shall exist on the panel through which a 76 mm diameter solid sphere can pass.

Profiles, hardware and attachments shall remain safely attached to the specimen(s).

If the panel(s) pulls out or releases from the edge of the test specimen(s) frame, the test is considered a failure.

9.4 External emergency exit doorset (panic exit doorset)

External emergency exit doorset (panic exit doorset) in external walls should be functioning (openable) after the test, to allow entering or leaving the building.

9.5 Edge releases

If the glazing pulls out or tear longer than 130 mm and larger than 1 mm is formed at the edge of the test specimen frame as a result of impact or pressure cycling tests, terminate the test and do not classify the glazing: the test is considered a failure.

9.6 Windstorm protective systems

If windows (incl. skylights), doors or curtain walling are tested combined with windstorm protective systems, the maximum windstorm protective system deflection should guarantee a minimum distance of these building components from the building envelope.

10 Product qualification

10.1 Requirements

Product qualification of test specimens shall be accepted according to the designated building level of protection, wind zone, and assembly elevation. Test specimen satisfying criteria in Clause 9 shall be classified as providing acceptable protection for a windstorm in terms of the number of missile impacts, the

mass/size of the missile, the missile velocity and the maximum pressure differential, P (see 8.4.3). Various levels of performance (Table 3) differ in testing requirements for:

— missile type and impact speed;

— air pressure differential P.

10.2 Applicable missile for impact test

The applicable missile from Table 1 shall be chosen using Table 3, depending on the levels of protection (see 10.3) and on the reference wind-speed zones (see 10.4).

Table 3 — Description Levels

Level of protection	Level 1		Level 2		Level 3		Level 4	
H_a (m)	> 10	≤ 10	> 10	≤ 10	> 10	≤ 10	> 10	≤ 10
Wind zone 1	N	N	A	C	B	D	D	D
Wind zone 2	N	N	A	C	B	D	D	D
Wind zone 3	N	N	A	D	B	D	D	E
Wind zone 4	N	N	A	D	B	D	D	E
NOTE A, B, C, D and E refer to applicable missile types, as defined in Table 1. "N" means that testing is not required.								

10.3 Levels of protection

There are four levels of potential hazard to human life as defined in this document based on building type and use. The protection level required are specified by the ordering party or as directed by the test client. Levels are numbered 1 to 4.

The following are examples of buildings requiring levels of designated protection.

— Level 1: is advised for unprotected buildings and other structures, which are expected to have low hazard to human life in cyclones and other severe storms. Buildings in this level may include, but are not restricted to, agricultural houses, temporary facilities and storage facilities.

— Level 2: is advised for protection of buildings and other structures which are expected to have moderate hazard to human life in cyclones and other severe storms. Buildings in this level may include, but are not restricted to, houses, commercial and industrial buildings.

— Level 3: is advised for protection of buildings and other structures which are expected to have a substantial hazard to human life in cyclones and other severe storms. Buildings in this level may include, but are not limited to, major office buildings, schools, shopping centres, hotels and other buildings and structures where a significant number of people congregate in one area.

— Level 4: is advised for enhanced protection of essential facilities. Buildings in this level may include, but are not limited to, hospitals and other health care facilities, fire, rescue, ambulance, and police stations, and buildings and other structures having critical national defence functions or designated as storm shelters during a severe storm.

10.4 Reference wind-speed zones

There shall be four reference wind speed zones:

— wind zone 1: reference wind speed equal to or greater than 50 m/s and less than 55 m/s, i.e.:

$$(50\ \text{m/s} \leq V < 55\ \text{m/s});$$

— wind zone 2: reference wind speed equal to or greater than 55 m/s and less than 60 m/s, i.e.:

($55\ m/s \leq V < 60\ m/s$);

— wind zone 3: reference wind speed equal to or greater than 60 m/s and less than 65 m/s, i.e.:

($60\ m/s \leq V < 65\ m/s$);

— wind zone 4: reference wind speed equal to or greater than 65 m/s, i.e.:

($V \geq 65\ m/s$).

NOTE The value of reference wind speed in this subclause is indicated as gust wind speed. In case other wind speeds are used, such as 10-minute wind speed, refer to Annex D.

Annex A
(normative)

Required information and test report

A.1 Testing specimen in different conditions: required information

If it is not the intent to classify the specimen in accordance with Clause 10 but to test it at other conditions, the following test information shall be provided by the test client:

a) number of test specimens;

b) conditioning temperature of specimens and minimum cure, if appropriate;

c) pass/fail criteria, if different from test requirement of Clause 9;

d) reference wind speed;

e) maximum air-pressure differential and its relationship to the serviceability pressure;

f) missile, and relationship to the classification defined in Clause 10, such as:

   a. description of the missile, including dimensions, mass and tolerances;

   b. missile speed at impact, or the equation relating missile speed to reference wind speed, and missile orientation at impact;

   c. number of impacts;

   d. location of impacts on the test specimens and tolerances;

g) test-loading program, and relationship to classification defined in Clause 10, such as:

   a. positive and negative cyclic test loads;

   b. number of cycles of cyclic test load sequence to be applied;

   c. minimum and maximum duration for each cycle;

h) whether or not certification of the calibration is required.

A.2 Test report

A.2.1 General information

The test report shall contain the following general information:

a) a reference to this document, i.e. ISO 16316:2024;

b) name(s) and address(es) of the testing agency, including the identification of the organization performing the measurement;

c) the name(s) of individual(s) conducting the test and the author of the report;

d) signatures of persons responsible for supervision of the tests;

e) date of test and report;

f) all details necessary to identify the test specimen:

   1) manufacturer's model number;

   2) description of the test specimen;

   3) the number of specimens tested;

   4) specifications such as the name, type, width, height, thickness, material, colour, and other elements of the frame, glazing, shading device, opaque panel, or other components;

   5) any additional data or information on the test specimen, when relevant for the test results, shall be given in the test report, for example description of anchors (type, quantity, layout), description of test substrate, detailed description of glazing (including bite, interlayer type and thickness, tempering of glass lites, method of glazing or type of silicone used, daylight opening size, nominal size, etc.), description of hardware used (if applicable), description of internal fixing screws, amount of shimming;

   6) the technical drawings (elevations, sections), photographs, and others of the test specimen;

   7) any deviation from the drawings or any modifications made to the test specimen to obtain the reported values;

g) type(s) of test performed;

h) any deviations from the procedure.

A.2.2 Missile impact test

The impact test report shall contain the following information:

a) location of impact(s) on each test specimen;

b) exact description of the missile including materials, dimensions and mass (weight);

c) missile speed and orientation at impact;

   NOTE orientation refers to the impact orientation of the missile to the glass, i.e. perpendicular, head on.

d) conditioning temperature of the specimens.

A.2.3 Air pressure cycling test

The air pressure cycling test report shall contain the following information:

a) cyclic static-pressure loading differential(s) and sequence;

b) maximum air pressure differential (P) and its relationship to the serviceability pressure;

c) a statement as to whether or not tape or film, or both, were used to seal against air leakage and whether, in the judgment of the test engineer, the tape or film influenced the results of the test.

A.2.4 Results

The test results report shall contain the following information:

a) results (pass or fail) for each test specimen, expressed as a statement of whether, upon completion of testing, the test specimens pass or fail in accordance with any specified criteria;

b) a description of the condition of the test specimens after completion of each portion of testing, including details of damage and any other pertinent observations, including any disengagement of specimen and fasteners;

c) identification or description of any special specification or criteria when the tests are made to check conformity of the test specimen to that particular specification or pass/fail criteria;

d) a description of the condition of the test specimens after completion of each portion of testing, including details of damage and any other pertinent observations, including any disengagement of specimen and fasteners;

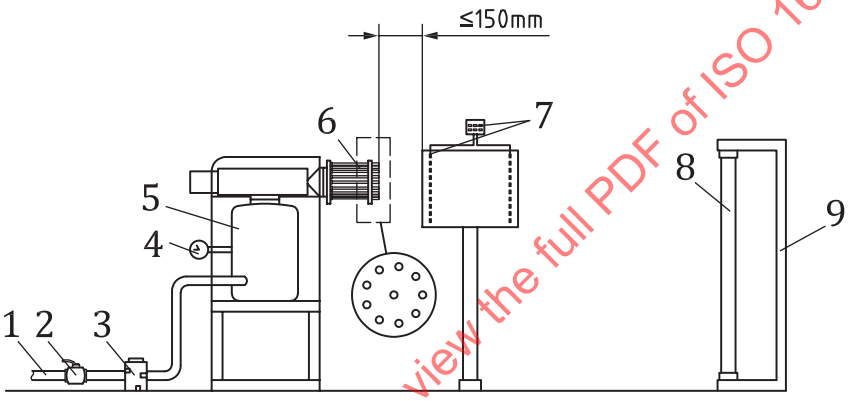
e) statement of any additional data or information considered to be useful to a better understanding of the test results, conclusions or recommendations.

Annex B
(informative)

Recommended missile-propulsion devices

B.1 Steel ball testing apparatus

A compressed-air cannon that is capable of propelling small missiles of the size and to the speed defined in this document shall be used. The cannon assembly shall be comprised of a compressed-air supply, a remote firing device, a barrel and a timing system. The small-missile cannon shall be mounted on a frame designed to permit movement of the cannon so that it can propel missiles to impact the test specimen at specified locations. The photoelectric sensors shall be positioned to measure missile speed within 150 cm of the impact point on the test specimen. For a schematic steel ball testing apparatus configuration, see Figure B.1.



Key

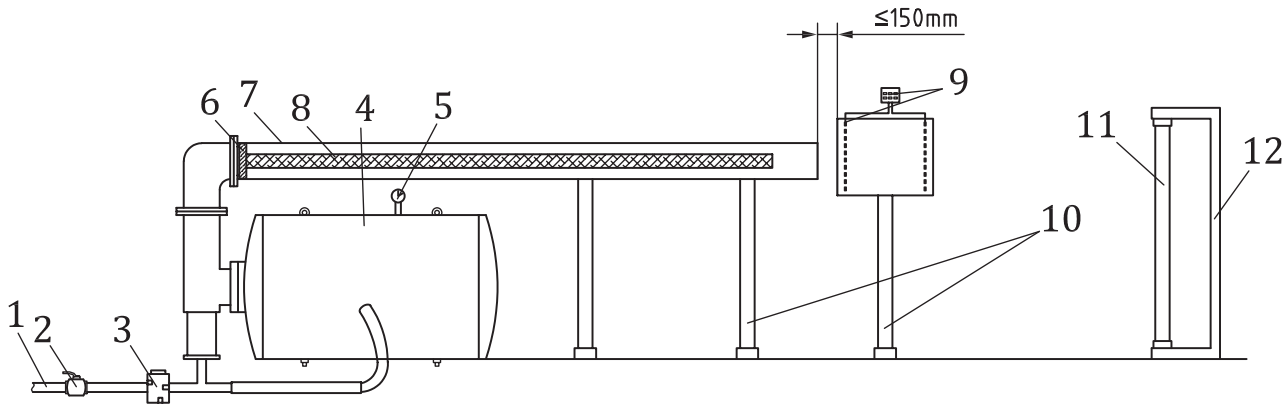
1 air pipe
2 valve
3 solenoid valve
4 pressure gage
5 pressure vessel
6 launching tube
7 velometer
8 specimen
9 pressure chamber

Figure B.1 — Schematic steel ball testing apparatus configuration

B.2 Wood lumber testing apparatus

The large missile air cannon shall use compressed air to propel the large missile. The cannon shall be capable of producing missile impact at the speeds defined in this document. The large missile cannon shall consist of four major components: a compressed-air supply, a pressure-release valve, a barrel and support frame and a speed-measuring system for determining missile speed. For a schematic diagram of wood lumber test apparatus, see Figure B.2.

The end of the missile that impacts the target is denoted as the missile's impact end. The end of the missile opposite to the impact end is denoted as the missile's trailing edge. A sabot shall be used at the trailing edge of the missile to facilitate launching.



Key

1 air pipe
2 valve
3 solenoid valve
4 pressure gage
5 pressure vessel
6 circular base of missile
7 launching tube
8 wood lumber
9 velometer
10 support
11 specimen
12 pressure chamber

Figure B.2 — Schematic diagram of wood lumber test apparatus

Annex C
(informative)

Reference wind speed

The reference wind speed V_r in this document indicates the 3-second gust wind speed. In the case other gust (3-second) wind speeds are used in the design, such as the mean wind speed averaged over 10 min or 1 h, the following conversion formulae can be used referring to ISO 4354[1]:

$$V_{t=10\ \text{min}} = 0{,}69 \times V_{t=3\ \text{s}} \quad \text{(C.1)}$$

$$V_{t=1\ \text{h}} = 0{,}65 \times V_{t=3\ \text{s}} \quad \text{(C.2)}$$

where

$V_{t=3\ \text{s}}$ is the 3-second gust wind speed;

$V_{t=10\ \text{min}}$ is the 10-minute mean wind speed;

$V_{t=1\ \text{h}}$ is the 1-hour mean wind speed.

Note $V_r = V_{t=3\ \text{s}}$

Annex D
(normative)

Flow chart of test procedure

The flow chart in Figure D.1 explains the test procedure according to this document.

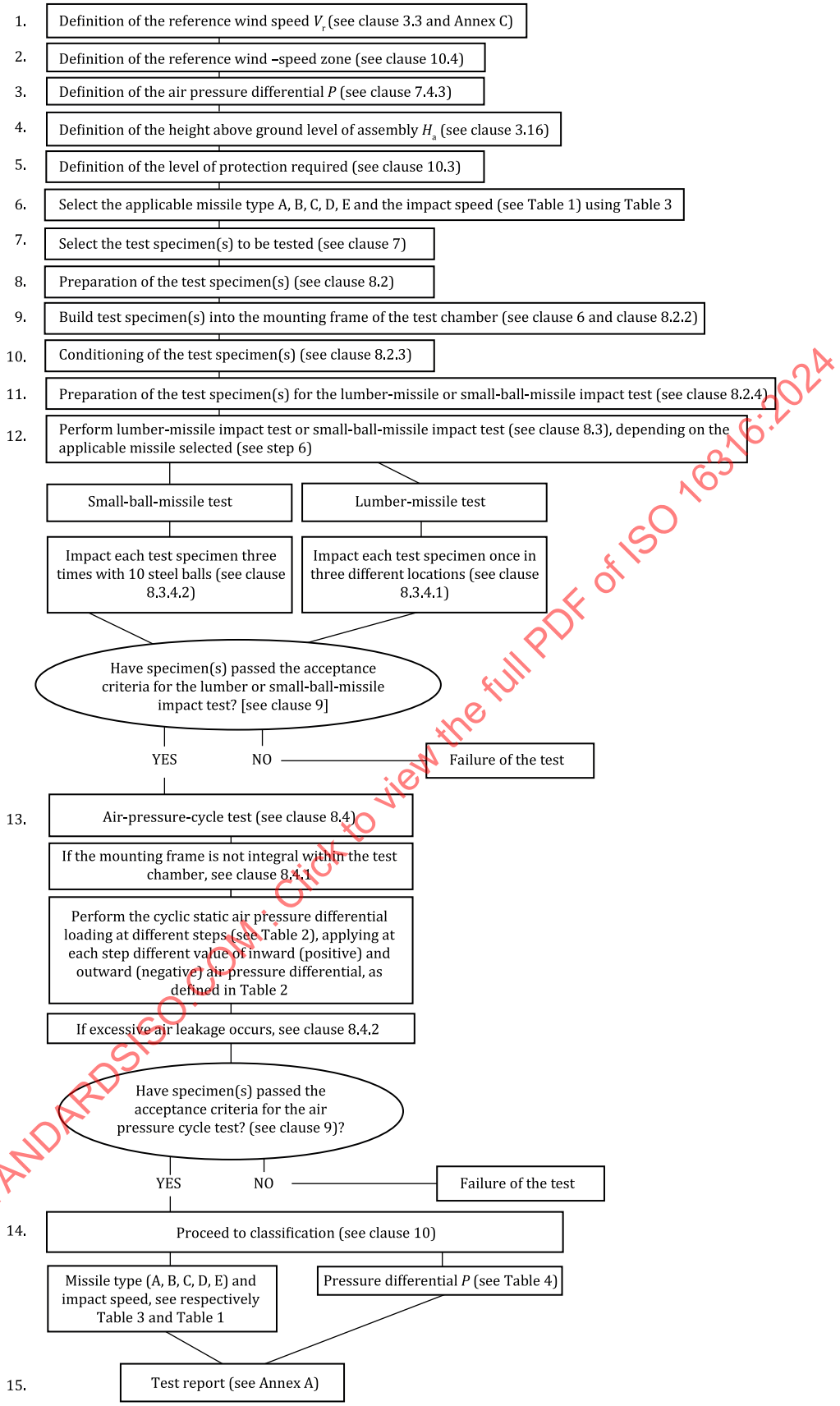


Figure D.1 — Flow chart of test procedure

Annex E
(informative)

Guidance on substitution criteria for fenestration assemblies qualified under this document

E.1 Introduction

Substitution allowances are presented in the following text. There are three types of substitutions for fenestration assemblies qualified under this document:

a) substitutions of infill elements;

b) substitutions of anchorage;

c) substitutions of all other elements.

The substitution criteria in Annex E are related to impact and cycling performance only as found in this document and does not qualify systems for other performance attributes.

The substitution language applies to the following fenestration assemblies (for representative diagrams of these fenestration assemblies see ISO 22496 and ISO 22497):

— sliding windows;

— sliding doors;

— storefront framing;

— fixed windows;

— mullions;

— projected or hinged windows

— dual action windows and doors;

— hinged doors;

— curtain wall;

— skylights and roof windows.

Specialty windows and greenhouse windows are not covered in these substitution allowances.

E.2 Substitution categories

a) Allowed automatically: no additional testing or analysis necessary.

b) Engineering analysis: demonstrated or documented performance through a review of materials that predicates a minimum of equivalent performance.

c) Single specimen: one specimen, identical to the original specimens qualified with the only difference being the elements to be substituted.

d) Not allowed: not qualified by testing of a single specimen.

E.3 General premises for substitution

E.3.1 General

Substitutions are only allowed to assemblies that have passed all the prescribed performance requirements of this document.

E.3.1.1 Fenestration assemblies other than curtain walling and storefront

For fenestration assemblies other than curtain walling and storefront, any substitution of an assembly of the same type as the three glass initial specimens shall be allowed automatically, provided the substitution is:

a) equal to or smaller in overall area, up to a 50 % reduction in their individual length size (e.g. height or width) with reference to the panel that has been tested (if the panel size reduction exceeds 50 % in the individual length size, for certification purposes, a second test should be conducted);

b) contains the same or a fewer number of equal dimension or smaller dimension sash, panels, or lites;

c) is rated at equal or lower design pressures.

Assemblies are allowed automatically to be stretched in one dimension only, provided:

— the overall area of the substitution assembly does not exceed the overall area of the originally tested element;

— the infill elements are equal to or smaller in overall area [up to a 50 % reduction in their individual length size (e.g. height or width), with reference to the panel that has been tested];

— the rating is at equal or lower design pressures.

Engineering analysis or testing of additional specimen sizes can be conducted to override these limitations.

E.3.1.2 Curtain walling and storefront

For curtain walling and storefront, any substitution of an assembly of the same type as the three initial glass specimens shall be allowed automatically, provided:

— the overall area of the substitution assembly does not exceed the overall area of the originally tested element;

— the infill elements are equal to or smaller in overall area [up to a 50 % reduction in their individual length size (e.g. height or width), with reference to the panel that has been tested];

— the rating is at equal or lower design pressures.

Curtain walling and storefront are allowed automatically to be stretched in one dimension only, provided:

a) the overall area of the substitution assembly does not exceed the overall area of the originally tested element;

b) the infill elements are equal to or smaller in overall area [up to a 50 % reduction in their individual length size (e.g. height or width), with reference to the panel that has been tested];

c) the deflection and stress limits of any structural member or component is not exceeded;

d) the rating of the originally tested specimens is not exceeded.

Testing of additional specimen sizes can be conducted to override these limitations.

For window and curtain walling types included in this annex, see ISO 22496 and ISO 22497.

E.3.2 Products qualified under small missile test

For products qualified under small missile test, substitutions of all elements that are not infill elements, anchorage or hardware shall be allowed automatically.

E.3.3 Products qualified under large missile test

For products qualified under large missile test (and for those elements not allowed automatically for small missile test), substitutions of all elements that are not infill elements or anchorage shall be allowed according to the following criteria.

— Any substitution testing shall be qualified at a pressure equal to or less than the design pressure at which the three initial glass specimens were qualified. The originally achieved qualified design pressure shall be maintained for the original samples. The substituted element can have a lower design rating.

— Any substitution of an element shall not be allowed if a failure occurs for any reason during a single specimen test of that substitution.

— Substituted elements according to the methods explained in E.3.1 shall be allowed to be combined into a system.

— Multiple substituted elements that are individually qualified by a single specimen test shall be allowed to be combined into a system when supported by engineering analysis.

E.3.4 Anchorage

— Each method of anchoring shall be qualified by testing a single specimen in the condition that produces the greatest load on the anchoring method, or qualified by engineering analysis.

— Any substitution of the fastener within an anchoring method, supported by engineering analysis to be equal to or stronger than the initial qualified fastener, shall be allowed automatically provided the original spacing is not exceeded.

— Insect screens: if the initial specimens were tested without screens the addition of screens shall be allowed automatically. If the initial specimens were tested with insect screens, substitution or elimination of the insect screen shall require single specimen testing.

E.4 Premises for substitution — Glazed products

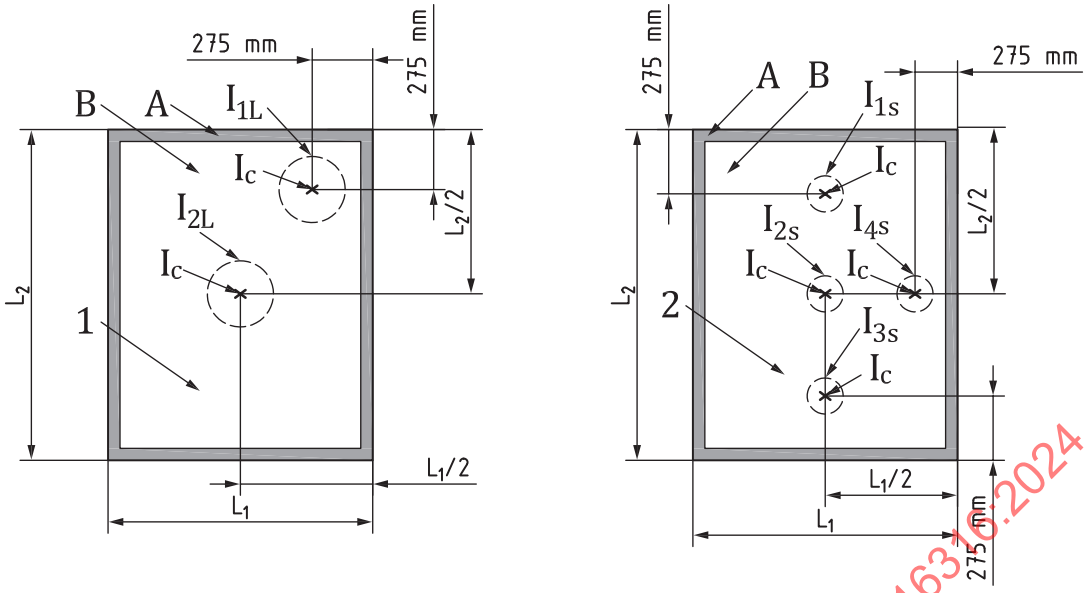
E.4.1 General

When substituting an element on the basis of a single specimen test refer to Figure E.1 and select the worst case for impact locations for large missile or small missile. Order of impact is immaterial.

E.4.2 Glazing sealants, adhesives, and backbedding

Substitution of glazing sealants, insulating glass primary or secondary sealants, adhesives, or backbedding shall require the testing of a single specimen.

Substitution with no additional testing shall be permitted when the change is limited to the colour of glazing sealants, insulating glass primary or secondary sealants, adhesives, or backbedding. In this case, documentation is provided to report that the nominal specific gravity of the substituted material is within +/-0,06 from that used in the certified specimens or historic documentation is provided showing that different colours perform to the same performance properties.



Key

I_{1L} impact area n°1 of each specimen for large missile test
I_{2L} impact area n°2 of each specimen for large missile test
I_{1s} impact area n°1 of each specimen for small missile
I_{2s} impact area n°2 of each specimen for small missile
I_{3s} impact area n°3 of each specimen for small missile
I_{4s} impact area n°4 of each specimen for small missile
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen
1 large missile test specimen
2 small missile test specimen

Figure E.1 — Single specimen impact locations

Any substitution within the fenestration glazing sealant, insulating glass primary or secondary sealants, adhesives or backbedding demonstrated to be equal to or stronger in ultimate tensile strength than the initial three qualified glass specimens shall require a single specimen test. Substitution of a sealant, adhesive or backbedding material with a lower movement capability shall not be allowed.

The glazing sealant characteristics should be tested according to the same standard used to classify the material installed on the original specimen, when comparing its performances.

E.4.3 Glazing tapes

Substitution of glazing tape colour shall require a single specimen test, or shall be supported by engineering analysis provided the only change from the initial three qualified glass specimens is a change in the tape colour, as follows.

For preformed tapes, documentation is provided that the nominal specific gravity of the substituted material is within ±0,06 from that used in the initial three glass specimens, or historic data/documentation is provided showing that different colours perform to the same performance properties that are either within or outside the allowable specific gravity range.

For foam tapes, documentation is provided that the specific gravity, as determined by applicable test methods, does not differ by more than ±20 % from that used in the initial three glass specimens.

Any substitution within the fenestration glazing tapes demonstrated by an applicable reference standard to be equal to or stronger than the initial three qualified glass specimens shall require a single specimen test.

E.4.4 Glass plies

Glass colour change shall be allowed automatically.

Substitution or adding of glass coating (reflective, coated, low-e, frit, and so forth) shall be allowed when supported by engineering analysis of the durability and compatibility of the treatment with glazing infill, interlayer, and sealant, adhesives or back-bedding materials.

For any non-sacrificial lite, individual glass ply thickness increase shall require the testing of a single specimen. A substitution with a decrease in glass ply thickness shall not be allowed.

For any non-sacrificial lite, any of the following glass type changes shall require a single specimen test (see E.4.5.1 d), E.4.5.2 b), E.4.5.2 c), E.4.5.2 d) for sacrificial lites):

a) annealed to heat-strengthened;

b) annealed to chemically-strengthened;

c) annealed to fully tempered;

d) heat-strengthened to fully tempered;

e) chemically-strengthened to fully tempered;

Glass type change from heat-strengthened to annealed or heat-strengthened to chemically-strengthened shall not be allowed.

Glass type change from fully tempered to heat-strengthened, chemically-strengthened, or annealed shall not be allowed.

Glass decorative surface (sandblasted, acid etched, and so forth) substitution shall require a single specimen test.

E.4.5 Insulating glass units

E.4.5.1 Preconditions for insulating glass unit substitutions

a) The impact resisting lite (monolithic or laminated) of an insulating glass unit shall be composed of the same glass type and treatment with equal thickness or thicknesses of glass, and thicker or equal interlayer of the same manufacturer and type as originally tested and approved.

b) The glazing detail (glazing sealants, adhesives, stops, etc.) shall be unchanged other than to accommodate any variations in overall glazing thickness.

c) Substitutions for insulating glass shall only be made for systems with the impact resistant glazing structurally adhered to the frame or sash glazing leg or bed in the same manner and position as originally tested and approved.

d) In an insulating glass unit, typically one lite provides the impact resistance (usually a laminated lite) and the other lite is considered to be “sacrificial.” This sacrificial lite can fracture without detriment to the impact resistant lite which is providing the actual building envelope protection.

e) Glazing systems typically have a stationary glazing stop that is a permanent part of the frame or sash, or a removable glazing stop (also referred to as a glazing bead), or both. If a removable stop is used, a system can be tested with this stop removed, if it considered to be non-structural and unnecessary to pass the required test.

E.4.5.2 Systems tested with a removable glazing stop or bead in place

a) Any substitution to an insulating glass unit from a single glazing (monolithic or laminated glass) shall require the testing of one additional specimen provided the system meets all the preconditions in E.4.5.1.

b) Substitutions in glass treatment, specifically and only from annealed to tempered, or annealed to heat-strengthened, or heat-strengthened to tempered shall be allowed automatically to sacrificial lites (see E.4.5.1 a)) of insulating glass units, provided the system meets all the preconditions in E.4.5.1.

c) Increase in glass thickness shall be allowed automatically to sacrificial lites, providing the system meets all the preconditions in E.4.5.1.

d) Reductions in glass thickness in sacrificial lites of insulating glass units shall require a single specimen test, provided the system meets all the preconditions in E.4.5.1.

e) Substitutions of a monolithic sacrificial lite with a laminated sacrificial lite shall be allowed automatically in insulating glass units, provided the system meets all the preconditions in E.4.5.1.

f) Substitution of a laminated sacrificial lite with a monolithic sacrificial lite shall not be allowed to the sacrificial lite.

E.4.5.3 Systems tested without a removable glazing stop or bead in place

a) Any substitution to an insulating glass unit from a single glazing (monolithic or laminated glass) shall be allowed automatically provided the system meets all the preconditions of E.4.5.1. Spacers, setting blocks, primary seals and secondary seals that do not alter any other performance criteria of the assembly shall be allowed to be used in this substitution.

b) Substitutions in glass thickness and type shall be allowed automatically to sacrificial lites (see E.4.5.1 d)) of insulating glass units, provided the system meets all the preconditions in E.4.5.1.

Substitutions from a system approved with an insulating glass unit to a monolithic or single laminated unit shall not be allowed.

E.4.6 Insulating glass unit spacers

When the approved system was tested with an insulating glass unit a change in spacer type, shape or dimension shall require a single specimen test.

If the conditions in E.4.5.1 c) are met, a change in spacer type, shape, or dimension is allowed automatically.

E.4.7 Asymmetrical insulating glass unit orientation

A change in the orientation (order of lites from outboard to inboard) of an asymmetrical insulating glass unit from the approved orientation shall not be allowed.

E.4.8 Interlayer type or brand

Any substitution of interlayer colour from the same manufacturer and type as was originally qualified shall be allowed automatically.

Any substitution of interlayer decorative treatment from the same manufacturer and type as was originally qualified shall be allowed automatically provided the decorative treatment does not contact the glass or plastic glazing.

Any increase of the interlayer thickness by any amount, provided it is the same manufacturer and type as was originally qualified shall be allowed automatically.

Any substitution of interlayer type shall not be allowed. Provided the interlayer type and thickness remain the same (see the following two paragraphs of this clause), any substitution of interlayer manufacturer shall require a single specimen test.

A decrease of the nominal interlayer thicknesses up to 10 % for the same type or brand interlayer as was originally qualified shall require a single specimen test.

Decrease of the nominal interlayer thickness of more than 10 % for the same type interlayer as was originally qualified shall not be allowed.

E.5 Premises for substitution — Framing materials

E.5.1 General

For all wind zones, any substitution of framing materials on the basis of a single specimen test shall require infill impacts as shown in Figure E.1.

The substitution profile section moduli and moments of inertia shall be greater than or equal to the original profile tested, evaluated by engineering analysis.

Any substitution within the material of the framing, sash, panel, or door leaf shall maintain the same glazing design, detail, and glass bite as originally tested.

E.5.2 Sliding-projected-dual action windows, sliding doors and hinged doors consisting of sliding door and window panels, fixed panels of door or window assemblies, window sash, window vents, and hinged door leaves

E.5.2.1 General

Any substitution within the operable window or operable door assembly shall meet the requirements of E.5.1 and E.2 2nd bullet point, or require a single specimen test.

Any substitution of a stronger substrate for a weaker substrate shall be allowed with engineering analysis to confirm the anchor type and strength required for the stronger substrate.

E.5.2.2 Rolling, sliding, and hinging hardware

Any substitution within the operable window or operable door assembly of operation hardware shall require the testing of one additional specimen. A reduction in the number of operation points (for example, butt hinges, pivots, casters, and so forth) shall be allowed automatically, provided the center-to-center and edge-to-center spacing between operation points is not exceeded. The addition of operation points over and above the number originally tested shall be allowed when supported by engineering analysis as stated in E.2 b).

E.5.2.3 Locking hardware for sliding-projected-dual action windows, sliding doors, and hinged doors

Any substitution within the operable window or operable door assembly of locking hardware shall require a single specimen test. A reduction in the number of lock points shall be allowed automatically, provided the center-to-center and edge-to-center spacing between lock points is not exceeded. The addition of locking points over and above the number originally tested shall be allowed when supported by engineering analysis as stated in E.2 b).

E.5.3 Storefront framing, curtain wallings, fixed windows, and mullions

Framing Members: any substitution within the framing or fixed window assembly, vertical or horizontal mullion profile shall meet the requirements of E.5.1 2nd paragraph, E.3, and E.2 b), or require a single specimen test.

E.5.4 Skylight and roof windows

a) Hinging hardware: any substitution within the fenestration assembly of hinging hardware shall require a single specimen test.

b) Locking hardware: any substitution within the fenestration assembly of locking hardware shall require a single specimen test.

E.6 Impact protective system substitutions

E.6.1 Introduction

Substitution allowances are presented in the following text for impact protective system assemblies qualified under this document.

a) These substitutions are limited to performance qualified under this document.

b) The substitution language applies to the following impact protective system types illustrated in Figure E.2. These figures are general in nature; infill, bracing, and locking methods may vary:

   1) Accordion systems — Bi-folding systems

   2) Bahama systems — Top hinging systems

   3) Colonial systems — Side hinging systems/sliding systems panel systems — Corrugated or flexible

   4) Roll systems — Slatted or continuous

E.6.2 Substitution categories

The substitution categories covered by this standard are the following.

a) Allowed automatically: no additional testing or analysis necessary.

b) Engineering analysis: demonstrated or documented performance through a review of materials that predicates a minimum of equivalent performance.

c) Single specimen: one specimen, identical to the original specimen qualified with the only difference being the element to be substituted.

d) Not allowed: three specimens are required to qualify the substitution, as for a new product.

E.6.3 General premises for substitution

Successful tests of an impact protective system shall qualify other assemblies of the same or less area, and the same or greater section modulus, provided the construction details and reinforcement are unchanged.

Any substitution which changes only the colour of a product and is deemed to not have any structural influence, in dimension and strength, shall be allowed automatically. Changes to pigments of colour of homogeneous materials shall require engineering analysis for equivalency.

Any substitution shall be allowed for materials and components only after a minimum of three initial specimens have passed the prescribed performance requirements.

Any substitution shall be qualified at an impact and pressure performance equal or less than the impact and the design pressure at which the three initial specimens were qualified. A substitution tested to a lower design pressure shall be limited to this lower pressure.

Substitution of an element shall not be allowed if a specimen failure occurs for any reason during a single specimen test of that substitution.

Automatically substituted elements shall be allowed to be combined into a system without requiring engineering analysis or testing.

Any substitution of a stronger substrate for a weaker substrate shall be allowed with engineering analysis to confirm the anchor type and strength required for the stronger substrate.

No more than three substituted elements that are individually qualified by a single test shall be combined into a system.

E.6.4 Premise for substitution — impact protection systems

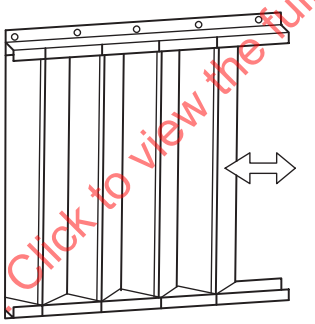
Unless otherwise stated in E.6, when substituting an element on the basis of a single specimen test refer to Figure E.3. Impact a single specimen test sample in two locations in the configuration that is considered the worst case. Order of impact is immaterial.

For systems that are substituting two track or mounting conditions refer to Figure E.4 Impact a single specimen test sample in two locations in the configuration that is considered the worst case. Order of impact is immaterial.

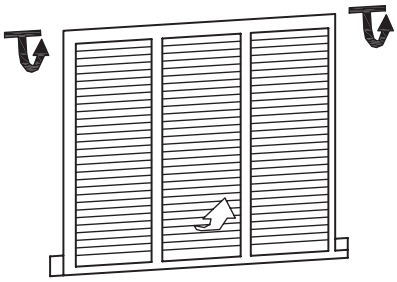
When a build-out or offset type mounting element has been tested at a given separation between the primary system track or frame and the primary substrate anchor connections and where that projection provides a build-out or offset of the primary system track or frame attachment from the plane of the primary substrate anchor connections, all other build-out or offset elements of a lesser projection or offset, using the same material thickness and basic profile, shall be allowed automatically.

For systems that are substituting two track or mounting conditions in combination with infill bracing substitution or other substitutions refer to Figure E.5. Impact a single specimen test sample in three locations in the configuration that is considered the worst case. Order of impact is immaterial.

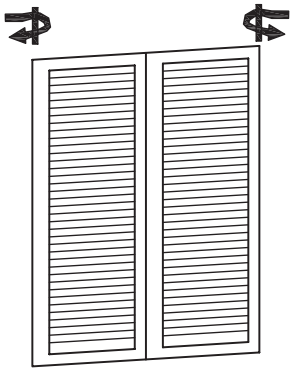
Substitutions for porous impact protective systems that require both large and small missile tests, except for infill substitutions, shall not be required to perform the small missile impact test. For infill substitutions in porous impact protective systems perform the small missile impact test on a single specimen.



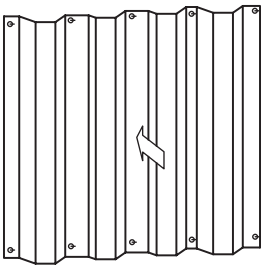
a) Impact protective system: Accordion system



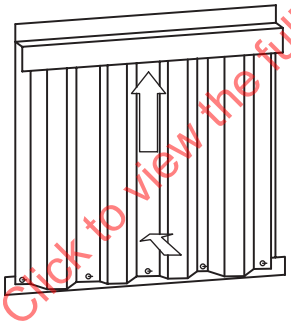
b) Impact protective system: Bahama system



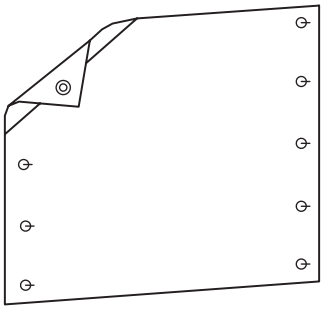
c) Impact protective system: Colonial system



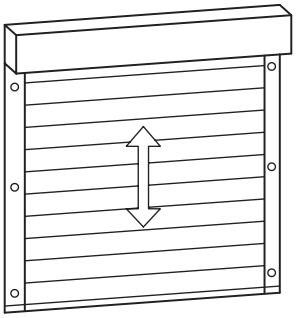
d) Impact protective system: Corrugated panel system



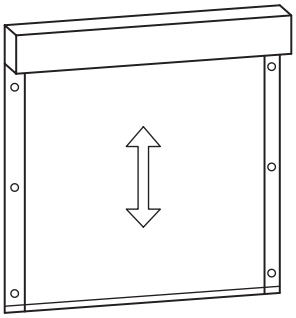
e) Impact protective system: Corrugated panel w/tracks system



f) Impact protective system: Flexible panel system

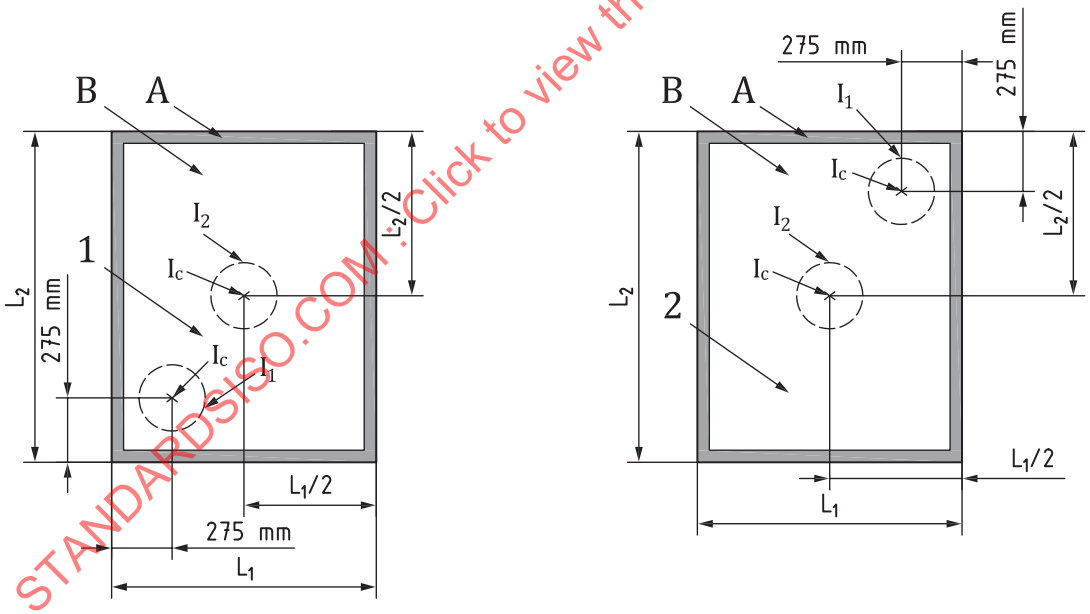


g) Impact protective system: Slatted roll system



h) Impact protective system: Continuous roll system

Figure E.2 — General types of impact protective systems

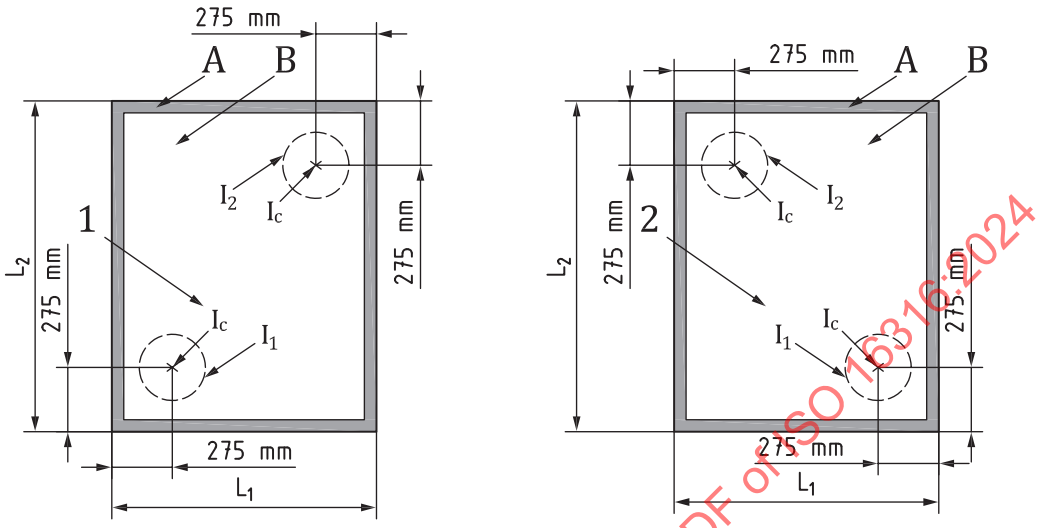


Key

I_1 impact area n°1 of each specimen
I_2 impact area n°2 of each specimen
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen

B panel (glazed or opaque) of the specimen
1 specimen option 1
2 specimen option 1

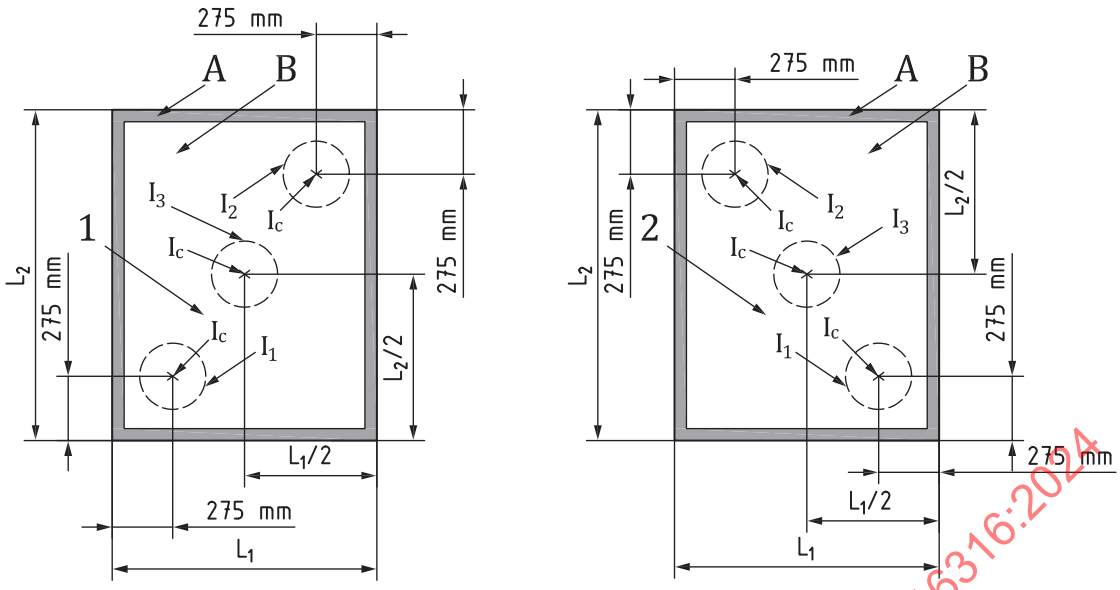
Figure E.3 — Default impact locations for substitutions based on a single specimen test



Key

I_1 impact area n°1 of each specimen
I_2 impact area n°2 of each specimen
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen
1 specimen option 1
2 specimen option 1

Figure E.4 — Impact locations for substituting two track or mounting conditions based on a single specimen test



Key

I_1 impact area n°1 of each specimen
I_2 impact area n°2 of each specimen
I_3 impact area n°3 of each specimen
I_c centre of the impact area
L_1 width of each specimen
L_2 height of each specimen
A frame of the specimen
B panel (glazed or opaque) of the specimen
1 specimen option 1
2 specimen option 1

Figure E.5 — Impact locations for substituting two track or mounting conditions in combination with infill bracing or other substitutions based on a single specimen test

E.6.5 Accordion systems

Any substitutions of a different centre locking mechanism shall require a single specimen test with a minimum of one impact to the centre lock mechanism.

Any substitution of locking system location different from the original passing specimens shall require the testing of one additional specimen.

The inclusion of additional locking mechanisms in the same system shall require the testing of one additional specimen.

A schematic representation of Accordion system is given in Figure E.2 a).

E.6.6 Bahama systems

Any substitution of an alternate locking or retaining system shall require the testing of one additional specimen.

Any substitution of backing material shall not be allowed.

A schematic representation of Bahama system is given in Figure E.2 b).

E.6.7 Colonial systems

Any substitution of an alternate locking or retaining system shall require the testing of one additional specimen.

Any substitution of backing materials shall not be allowed.

A schematic representation of Colonial system is given in Figure E.2 c).

E.6.8 Panel systems

Any modification to mounting hole size, shape, or location shall require the testing of one additional specimen, provided the diameter or the shape, or both, of the hole are not increased or altered.

Any substitution of larger diameter or increased area mounting holes shall not be allowed.

A schematic representation of panel systems is given in Figure E.2 d), e) and f).

E.6.9 Roll systems

Any substitution of an alternate locking or retaining system shall require the testing of one additional specimen.

A schematic representation of Roll systems is given in Figure E.2 g) and h).

Annex F
(informative)

Test program examples

F.1 Scope

The test programs shown in this Annex are general examples. Their purpose is to give the reader an idea of what is qualified and some ideas of conditions that are not qualified if not tested or not tested in certain ways. These do not cover all possible options or conditions. In general, each specific or distinctive condition shall be tested to be qualified, although some conditions may be justified by engineering calculations without testing them, depending on what the ordering party requires.

The examples shown in this informative annex should not be interpreted to represent actual requirements by the ordering party, which can vary in size, design pressure rating, configurations, options, interlayers, etc. as compared to what is shown here. Testing of the examples shown in this annex will not necessarily satisfy any or all of the requirements of the ordering party, they are shown for illustrative purposes only.

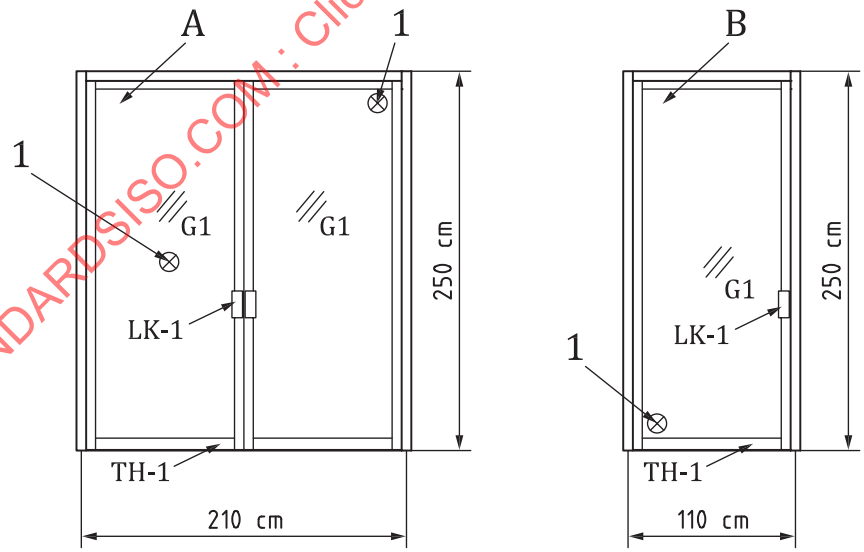
Anything other than missile impact or cyclic loads, is not addressed in this document. The same specimens listed in this document can be used optionally for other tests beforehand.

F.2 French door test program

Test mock-ups examples are represented in Figure F.1. For that mock-ups, the tests to perform are:

— large missile impact: level D;

— cyclic load: P_d = +3 830 Pa and -3 830 Pa.



Key

A	mock-up #1
B	mock-up #2
1	large missile impact location

G1 glass type: 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass
LK-1 LOCK #1
TH-1 threshold type n°1 for test mock-up

Figure F.1 — French door test program: test mock-ups examples

Qualified conditions from mock-up #1 and mock-up #2 include:

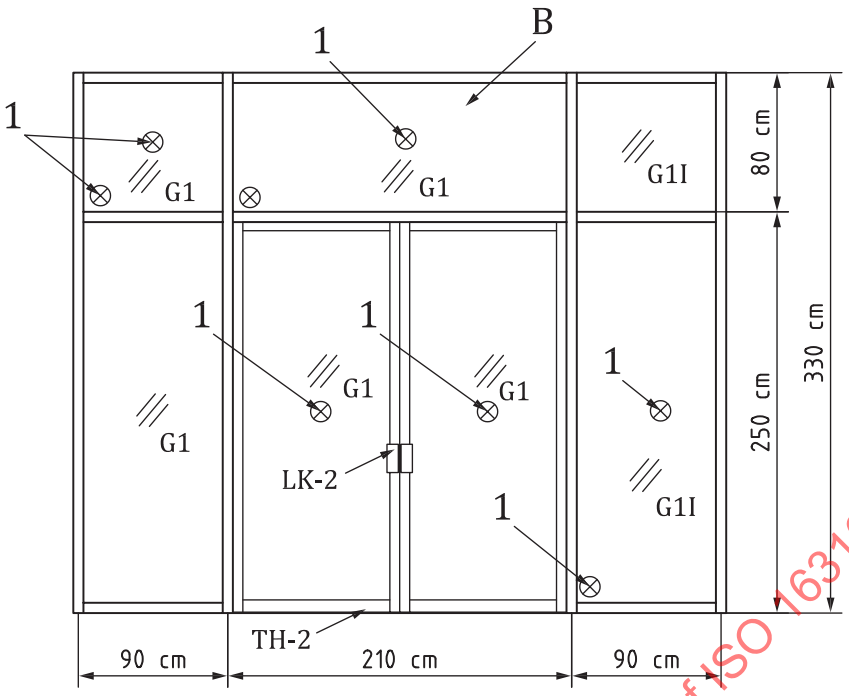
— Double door, maximum size 210 cm W x 250 cm H at 3 830 Pa, impact level D.
— Single door, maximum size 110 cm W x 250 cm H at 3 830 Pa, impact level D.
— Laminated glass G1: 6 mm H.S. + 2,28 mm interlayer + 6 mm H.S.
— Wet glazed, with silicone used (3 lites required).
— One lock option (Lock #1).

Conditions not qualified from mock-up #1 and mock-up #2 include:

— Insulated-laminated glass.
— Sidelite option.
— Different threshold.
— Transom option.
— Additional silicone.
— Intermediate horizontal.
— Multiple hardware or lock options.

Options for revising mock-up #2 are represented in Figure F.2. For this mock-up, the tests to perform are:

— large missile impact: level D.
— cyclic load: P_d = +3 830 Pa and -3 830 Pa.



Key

B	mock-up #2
1	large missile impact location
G1	glass type: 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass
G1I	glass type: 6 mm F.T. glass + 12 mm air space + 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass
LK-2	lock #2
TH-2	threshold type n°2 for test mock-up

Figure F.2 — French door test program: revised mock-up #2

Qualified conditions from mock-up #1 and revised mock-up #2 include:

— Double door, maximum size 210 cm W x 250 cm H at 3 830 Pa, impact level D.

— Single door, maximum size 110 cm W x 250 cm H at 3 830 Pa, impact level D.

— Glass Types:

  — laminated glass G1: 6 mm H.S. + 2,28 mm interlayer + 6 mm H.S;

  — insulated laminated glass G1I: 6 mm F.T. + 12 mm air space + 6 mm H.S. + 2,28 mm interlayer + 6 mm H.S.

— Transom option for 210 cm W x 80 cm H size.

— Sidelite option for 90 cm W x 330 cm H with intermediate horizontal. Please note that the sidelite is being qualified with only one panel per glass type since the sidelite DLO is within the width and overall area of the door leaf.

— Threshold types TH-1 and TH-2.

— Two lock options (Lock #1 and Lock #2).

The conditions not qualified from mock-up #1 and revised mock-up #2 is:

— Intermediate horizontals for widths greater than 90 cm.

F.3 Horizontal rolling window test program

Test mock-ups examples are represented in Figure F.3.

For mock-up #1 the tests to perform are:

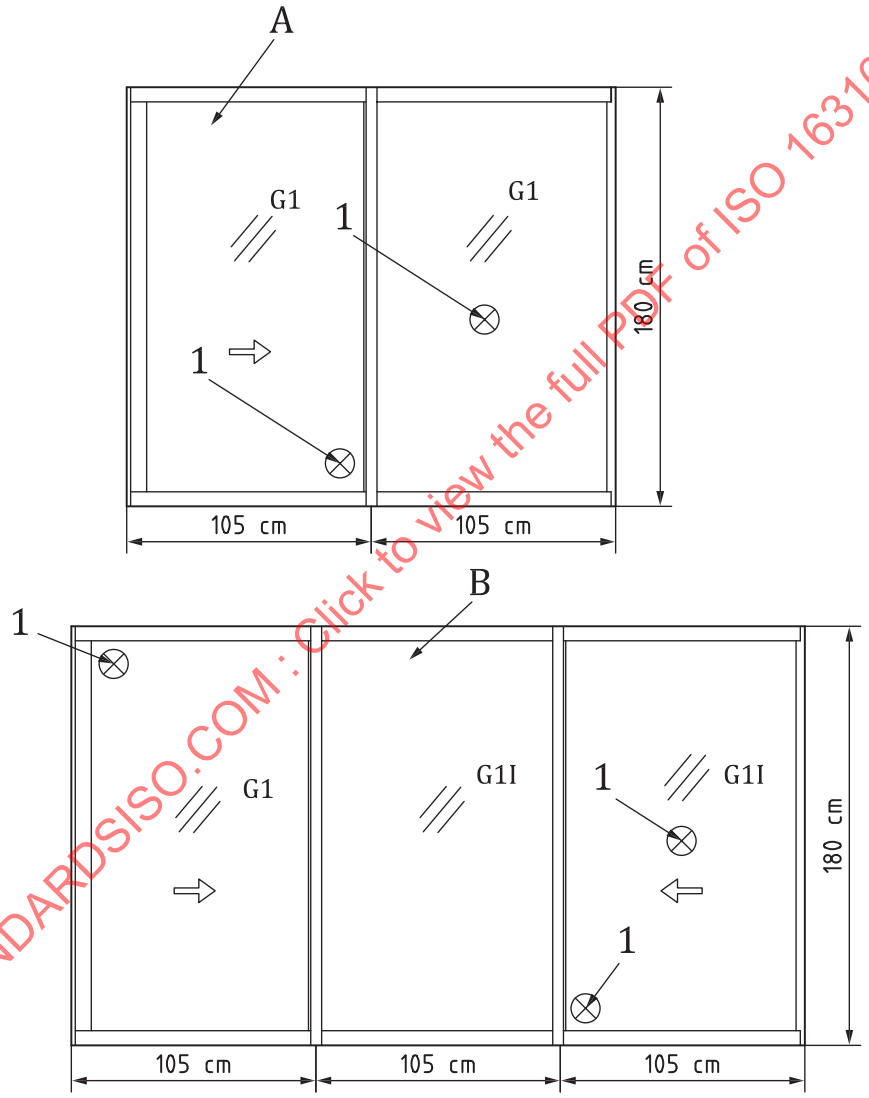
— large missile impact: level D;

— cyclic load: P_d = +3 591 Pa and -3 591 Pa.

For mock-up #2 the tests to perform are:

— large missile impact: level D;

— cyclic load: P_d = +3 591 Pa and -3 591 Pa.



Key

A	mock-up #1
B	mock-up #2
1	large missile impact location
G1	glass type: 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass
G1I	glass type: 6 mm F.T. glass + 12 mm air space + 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass

Figure F.3 — Horizontal rolling window test program: test mock-ups examples

Qualified conditions from mock-up #1 and #2 include:

— Maximum window panel size 105 cm W x 180 cm H at 3 591 Pa, impact level D, for:

  — Laminated glass G1: 6 mm H.S. + 2,28 mm interlayer + 6 mm H.S.

  — Insulated-Laminated glass G1I: 6 mm F.T. + 12 mm air space + 6 mm H.S. + 2,28 mm interlayer + 6 mm H.S.

— Wet glazed, with silicone used (3 lites required).

— 1/2W-1/2W and 1/3W-1/3W-1/3W window configurations for 105 cm W x 180 cm H maximum panel dimensions.

Condition not qualified from mock-up #1 and #2 is:

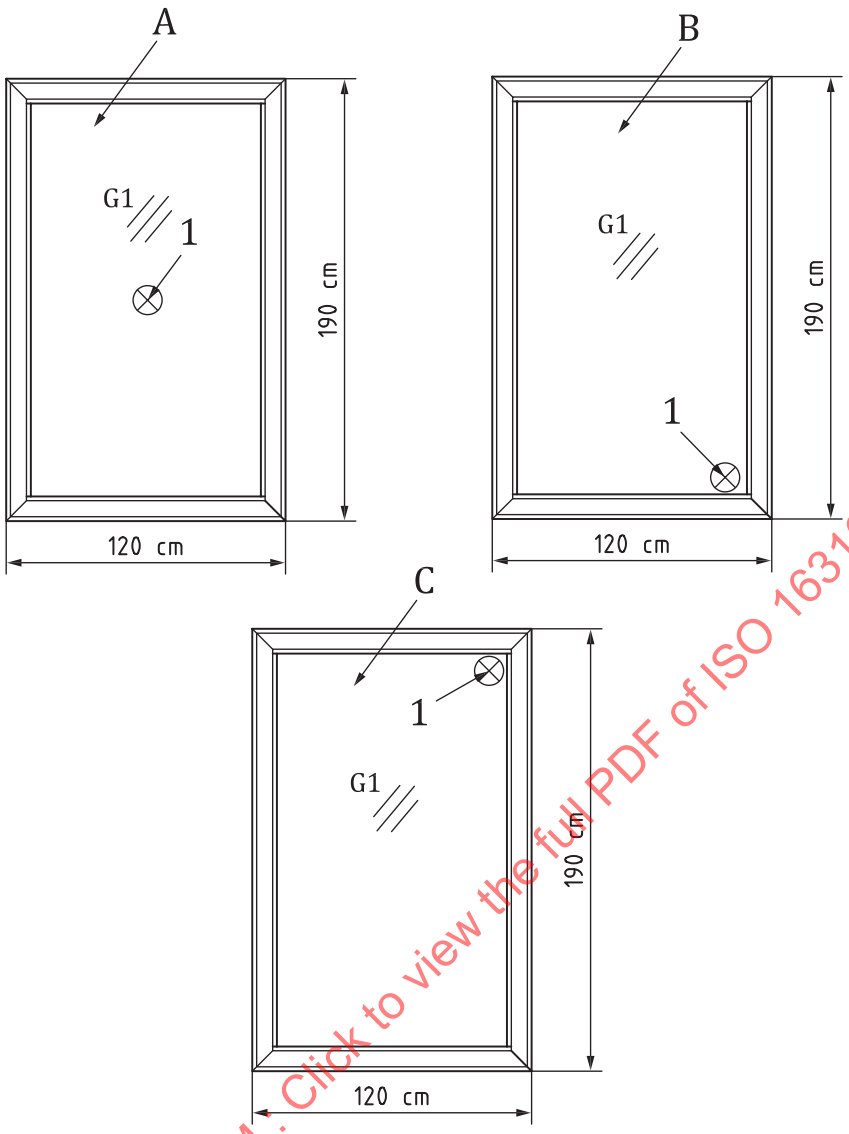
— 1/4W-1/2W-1/4W window configuration for panel dimensions beyond tested size.

F.4 Fixed window test program

Test mock-ups examples are represented in Figure F.4. For mock-up #1, #2 and #3 the tests to perform are:

— large missile impact: level D;

— cyclic load: P_d = +3 830 Pa and -3 830 Pa.



Key

A	mock-up #1
B	mock-up #2
C	mock-up #3
1	large missile impact location
G1	glass type: 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass

Figure F.4 — Fixed window test program: test mock-ups examples

Qualified conditions from mock-up #1, #2 and #3 include:

— Maximum fixed window size 120 cm W x 190 cm H at 3 830 Pa, impact level D, for laminated glass 6 mm H.S. + 2,28 mm interlayer + 6 mm H.S.

— Wet glazed, with silicone used (3 lites required).

Conditions not qualified from mock-up #1, #2 and #3 include:

— Insulated-laminated glass.

— Additional silicone.

— Alternate shapes.

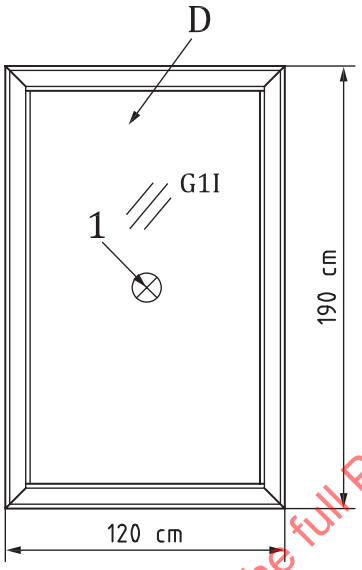
— Intermediate horizontal.

Options for qualifying different components or different shapes include:

a) Adding Mock-Up #4 to qualify the insulated-laminated glass as represented in Figure F.5. For this mock-up the tests to perform are:

   1) large missile impact: level D.

   2) cyclic load: P_d = +3 830 Pa and -3 830 Pa.



Key

D	mock-up #4
1	large missile impact location
G1I	glass type: 6 mm F.T. glass + 12 mm air space + 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass

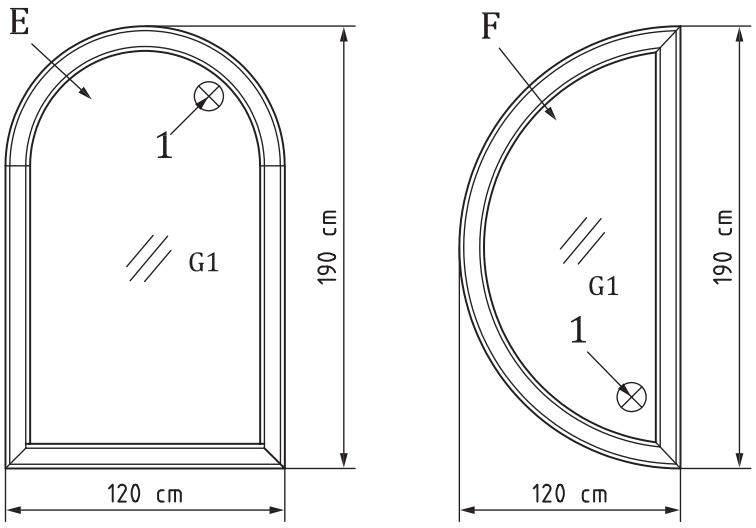
Figure F.5 — Fixed window test program: new mock-up #4

b) For a substitution in silicone type: three additional lites are required if the substitution has a lower strength and/or movement capability. Only one lite is permitted to qualify the substitution if the option has an equal or higher strength and movement capability. Silicone bites to be the same. If Mock-Up #4 is tested, provided the silicone bites are the same in laminated or insulated-laminated glass options, an equal or better silicone option can be qualified by testing in Mock-Up #4.

c) Substitute Mock-Ups #2 and #3 by Mock-Ups #5 and #6 to qualify the alternate shapes as represented in Figure F.6. For these mock-ups the tests to perform are:

   1) large missile impact: level D.

   2) cyclic load: P_d = +3 830 Pa and -3 830 Pa.



Key

E	mock-up #5
F	mock-up #6
1	large missile impact location
G1	glass type: 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass

Figure F.6 — Fixed window test program, qualifying alternate shapes: new mock-up #5 and #6

d) Add Mock-Up #7 to qualify an additional laminated glass with a stronger interlayer of the same thickness to the same size and pressure (see Figure F.7). For this mock-up the tests to perform are:

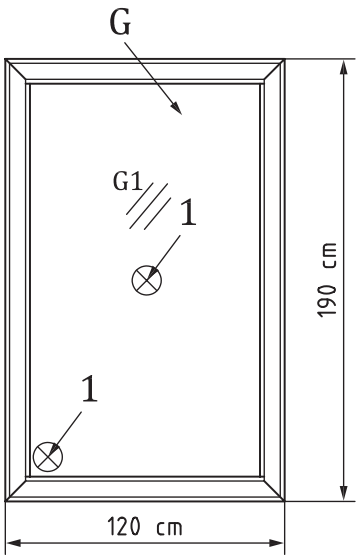
1) large missile impact: level D.

2) cyclic load: P_d = +3 830 Pa and -3 830 Pa.

The qualification of this glass, in addition to the already qualified glass type in Mock-Up #4, qualifies without further testing, the two following laminated and insulated options:

— 6 mm H.S. + 2,28 mm Interlayer + 6 mm H.S.

— 6 mm + 12 mm air space + 6 mm H.S. + 2,28 mm Interlayer + 6 mm H.S.



Key

G	mock-up #7
1	large missile impact location
G1	glass type: 6 mm H.S. glass + 2,28 mm interlayer + 6 mm H.S. glass

Figure F.7 — Fixed window test program, qualifying additional laminated glass: new mock-up #7

F.5 Window wall test program

Test mock-ups examples are represented in Figure F.8. For this mock-up the tests to perform are:

— large missile impact: level D.

— cyclic load: P_d = +3 830 Pa and -3 830 Pa.