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Glass in building — Explosion-resistant security glazing — Test and classification for arena air-blast loading

Verre dans la construction — Vitrages de sécurité résistant à une explosion — Essai et classification par charge circulaire d'air

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16933 was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 2, *Use considerations*.

Introduction

This International Standard provides a method for carrying out arena blast tests in order to assess and classify the response of glazing to the overpressure and impulse characteristics of high-explosive blasts. This International Standard provides criteria for rating the level of damage to the glazing and the hazard consequences to the area located behind the glazing. The increasing use of glazing designed to protect persons and property from accidental explosions, and from the effects of terrorist attacks with high explosives, has prompted the preparation of this International Standard.

Structural response to blast loading is dependent upon specimen size and edge constraint as well as material composition and thickness. The classifications and test results derived by using this International Standard can be used in conjunction with calculation procedures and further validation tests on framed glass during the process of designing complete glazing systems against explosive threats.

The following annexes are included in this International Standard:

— Annex A (normative) Blast parameters and derivation

— Annex B (informative) Characteristics of blast shock waves and explosives

— Annex C (informative) Nominal charge size and standoff distances

— Annex D (informative) Fragment dimensions and criteria comparisons

Glass in building — Explosion-resistant security glazing — Test and classification for arena air-blast loading

1 Scope

This International Standard provides a structured procedure to determine the air-blast resistance of glazing and sets forth the required apparatus, procedures, specimens, other requirements and guidelines for conducting arena air-blast tests of security glazing. Seven standard blasts simulating vehicle bombs and seven standard blasts simulating smaller satchel bombs that can be used to classify glazing performance are incorporated in this International Standard and cover a broad range of blast parameters.

Security glazing, including that fabricated from glass, plastic glazing sheet material, glass-clad plastics, laminated glass, insulated glass, glass/plastic glazing materials and film-backed glass, can be tested and classified in a standard frame or tested but not classified in frames provided with the glazing.

Classification and ratings are assigned based on the performance of glazing loaded by air-blast pressures and impulses, and are specific to the blast characteristics under which the test takes place. Glazing that has received an air-blast classification and rating is suitable for use in blast-resistant applications only for blasts of comparable characteristics and only if installed in a properly designed frame. Design based on knowledge of the air-blast resistance reduces the risk of personal injury.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 48:1994, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

3 Terms and definitions

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

3.1
air-blast pressure history
description of the pressure of a reflected or free-field air blast, as measured at a point on the surface and consisting of two separate phases:

— positive phase, which is characterized by a nearly instantaneous rise to a maximum pressure followed by an exponential decay to ambient pressure;

— negative phase, immediately following the positive phase, during which the pressure decreases below ambient for a period of time before returning to ambient

3.2
ambient temperature
temperature at which the test is conducted

3.3
blast mat
steel or concrete pad upon or above which a high explosive may be detonated to reduce the incidence of ejecta

3.4
breach
any perforation or opening through the test specimen or between the test specimen and the support frame, evident after the test, through which a 10 mm diameter rigid bar can be gently passed without force

NOTE An opening may be caused by the glazing sheet infill pulling away from the rebate sufficiently to result in a visible gap that exposes the edge of the sheet.

3.5
cartridge paper
thick white paper for pencil and ink drawings, typically about 130 g/m^2

3.6
free-field air-blast pressure
blast pressure acting at any given point in the free field, where there is no structure or other object disturbing the blast wave propagation

NOTE Also referred to as incident pressure, being the pressure measured on surfaces incidental to or parallel with the direction of travel of the blast front.

3.7
fragment
any particle with a united dimension of 25 mm (1 in) or greater

NOTE The united dimension of a glass particle is determined by adding its width, length and thickness. Glazing dust, slivers and all other smaller particles are not accounted as fragments.

3.8
glazing
glass or plastics glazing sheet material, including glass/plastic combinations

3.9
indents
any detectable deformation of the foil or cartridge paper surface of the witness panel caused by impact of any material as a result of the blast

3.10
peak-positive air-blast pressure
maximum measured positive phase air-blast pressure

NOTE If the measured pressure-time trace has sharp irregularities, the trace should be smoothed to produce a pressure-time trace that closely matches the mean path of the recorded trace. The peak pressure, P_{max}, of relevance is the resulting smoothed value.

3.11
perforations
any holes in the foil, cartridge paper or plain surface of the witness panel caused by impact of any material as a result of the blast

3.12
positive phase impulse
integral of the measured positive phase air-blast pressure history

3.13
reaction structure
all elements of the structure designed to support the test frame or alternative means for holding the glazing to be tested

3.14
reflected air-blast pressure
pressure increase that a surface, oriented other than parallel to the line from the detonation point to the surface, experiences due to the detonation of a high-explosive charge

3.15
standoff distance
perpendicular distance from the plane of the front surface of the glazing to the centre of the explosive charge or from the centre of the glazing if not perpendicular to the explosive

3.16
test frame
reaction structure, to which are fastened all elements that are used to directly support the glazing during classification of the glazing

3.17
witness panel
panel of deformable material positioned behind the test specimen in order to register the incidence of material forcibly detached from the test specimen during test

NOTE The composition and location of the witness panel is described in 6.6.

4 Hazard rating

A hazard rating is applied to glazing based on its performance under the blast conditions chosen for the test. The rating is specific only to those blast conditions.

5 Test specimens

5.1 Number of test specimens

For the purpose of classifying glazing a minimum of three test specimens, each (1 100 ± 5 mm) mm × (900 ± 5) mm shall be tested at a given level of air blast, defined in terms of peak positive air-blast pressure and positive phase impulse. One additional specimen shall be provided for pre-test measurements. Glazing of other sizes may be tested if the manufacturer supplies framed glazing or frame specifications. As such non-standard glazing assemblies may only be tested but not classified in accordance with this standard, the number of test specimens will be as agreed prior to test.

5.2 Multiple specimens

The air-blast resistance capacity of glazing does not imply that a particular specimen resists the specific air blast for which it is rated with a probability of 1,0. However, the probability that a single glazing or glazing system will resist the specific air blast at the particular level for which it is rated increases proportionally with the number of test specimens that successfully resist that air blast at that level. The protection afforded against a blast by a single item of glazing depends not only upon the glazing but also upon the manner in which it is attached to the structure in which it is mounted.

5.3 Handling and storage

The test specimens shall be handled and stored in compliance with the manufacturer's instructions.

5.4 Marking

Each specimen shall be marked with the manufacturer's model and serial numbers and the date of manufacture. The attack side is intended to be oriented towards the explosive charge and shall be marked by the manufacturer to assure proper installation in the test frame. A number shall be assigned to each test specimen and shall be marked accordingly.

5.5 Measurements

Thickness measurements of the glazing material shall be made at each corner, 25 mm from each edge, and recorded. If the specimens are supplied already mounted in a frame, one of the specimens shall be selected at random and inspected for details. Measurements shall include the edge dimensions of the frame and the glazing material, the cross-sectional dimensions of the frame and thickness measurements of the glazing material. The frame and glazing materials shall be verified to comply with the manufacturer's specifications. Measurements and records shall be made of the bolts, screws or other devices used for fixing the test frame or other glazing support system to the reaction structure.

5.6 Photography

Prior to the test, a photographic record that adequately portrays the test specimens, the test frame and the test configuration shall be made. This photographic record shall consist of still photographs and may include motion pictures or video.

6 Facilities and equipment preparation

6.1 Test facility

The test facility shall consist of an open-air arena located on clear and level terrain. The test facility shall be situated, and of sufficient size, to safely accommodate detonation of the amount of explosive required to provide the desired peak positive air-blast pressure and positive phase impulse. Potential environmental impact issues shall be analyzed and resolved prior to testing. Unless otherwise specified, testing shall be conducted at ambient temperature as defined in 3.2 and Clause 8.

6.2 High-explosive charge

A high-explosive charge shall be used to generate the desired peak positive air-blast pressure and positive phase impulse on the test specimens. The explosive composition, shape, mass, height and location shall be adjusted to meet these required parameters within the tolerances allowed.

6.3 Blast mat

If there is a possibility of crater ejecta interfering with the test, the high-explosive charge shall be placed on a blast mat. The decision to use a blast mat, its size and thickness shall be at the discretion of the test director.

6.4 Test frame and reaction structure

For classifying the glazing, the following test frame and reaction structure requirements shall apply.

a) Test specimen(s), each with a vision size of 1 000 mm × 800 mm, shall be mounted on a test frame, along the full length of all four edges. The test frame and reaction structure shall be capable of resisting the air blast with deflections that do not exceed $L/360$, where L denotes the dimension of a test frame or reaction structure member measured between the lines of support.

b) The test frame shall be fixed securely in a vertical position to the reaction structure. The test frame shall be provided with clamping plates to hold each glazing in position and means for producing uniform clamping of the glazing.

   Bolt spacing of not more than 100 mm is recommended around the perimeter of each glazing.

c) The test specimens shall be mounted in a manner that meets the following requirements.

— Mount standard-sized test specimens so that the bottom edge is between 0,5 m and 1,0 m above the floor of the witness area.

— Each test specimen shall have an edge capture of not less than 45 mm on all edges.

— Each test specimen shall be separated from the test frame and the clamping plate by continuous rubber strips (4 ± 0,5) mm thick, (50 ± 5) mm wide and of hardness (50 ± 10) IRHD in accordance with ISO 48:1994.

— At the bottom of the rebate, each test specimen shall be seated on rubber strips (4 ± 0,5) mm thick, of hardness (50 ± 10) IRHD in accordance with ISO 48:1994 and of width equal to the full thickness of the test piece.

— All four edges of each test specimen shall be uniformly clamped with a clamping pressure of (140 ± 30) kN/m^2.

NOTE The clamping pressure can have a significant effect on the test results.

d) If the glazing is supplied with its own unique frame or in a fenestration assembly, it shall be attached to the reaction structure as directed by the manufacturer and in a manner that closely models the manner in which it will be mounted in the field. Non-standard test specimens may be mounted at heights appropriate to the manner in which they will be mounted in the field.

e) All test specimens and witness panels shall be completely enclosed in a structure designed to prevent air-blast pressure from wrapping behind the test specimens.

f) Unless otherwise specified, each test frame shall be placed so that the test specimens are oriented perpendicular to a line from the detonation point to the centre of the test frame in order that they experience reflected pressures. The above directions assume such an orientation with the test specimen mounted vertically. Any other orientation shall be agreed with the test sponsor in advance of testing and shall be recorded as required in 9.1c) as it can affect failure modes and hazard ratings.

g) The classification blast values are based upon tests using reaction structures (test cubicles) having face dimensions approximately 3 m × 3 m as described in Annex C. If the reaction structure is oriented perpendicular to the line of the detonation point, the face of the reaction structure should not be less than 2,4 m wide × 2,4 m high. This is in order to avoid excessive reductions in reflected impulse that arise owing to the effects of blast clearing from the edges of small targets. For further information on assessing the blast relative to the size of the reaction structure, tests, criteria and effects on glazing, see Reference [8].

6.5 Instrumentation

6.5.1 Pressure transducers

A minimum of three air-blast pressure transducers shall be mounted on the exterior of each reaction structure. The air-blast pressure transducers shall be flush with the surface of the reaction structure on the air-blast side. The transducers shall be located such that the pressure and impulse in the centre of each test specimen can be computed. As an alternative, the pressure transducers may be installed on a transducer panel of the same size as the test frame and located and oriented in the same manner with respect to the charge as the test frame.

All pressure transducers shall be capable of defining the anticipated air-blast pressure history within the linear range of the transducer. Each transducer shall have a rise/response time and resolution sufficient to capture the complete event. Limited low-frequency response transducers shall have a discharge-time constant equal to approximately 30 times to 50 times the initial positive phase duration of the anticipated air-blast pressure history. Calibration records shall be maintained that demonstrate the equipment can measure pressure within an accuracy of ± 5 %.

At least one free-field pressure transducer shall be used in each test. The free-field pressure transducer shall be located at least 5 m or the width of the reaction structure, whichever is greater, from any reaction structure and at the same horizontal distance from the high-explosive charge as the centre of the glazing.

Optionally, appropriate pressure transducers may also be located within the enclosure behind the glazing to measure the pressure within the protected area during the blast. All pressure transducers shall be attached to the data-acquisition system and tested prior to the blast to verify proper operation.

All pressure-time readings shall be examined to derive the peak pressure values from the smoothed path of the measured trace. The individual peak pressure values subsequently recorded shall in each case be that adjusted by smoothing as necessary to eliminate sharp spikes arising from recording and instrumentation irregularities. The value derived from several of these individual, adjusted peak pressures for comparison with the classification criteria is referred to as the “mean peak air-blast pressure", as in Clause 8 and Tables 2 and 3. Where a transducer panel is used, this is simply the “mean” or the “average” of the adjusted peak pressures recorded by at least three transducers near the simulated centre of the target. Where blast measurements have been taken from transducers around the edge of the test specimens, it can be necessary to derive the “mean peak pressure” determined for the centre by more complex computation. For further information, see Annexes A and B.

6.5.2 Data-acquisition system

The data-acquisition system shall consist of either an analog or a digital recording system with a sufficient number of channels to accommodate all pressure transducers and any other electronic measuring devices. The data-acquisition system shall operate at a minimum sampling rate of 100 000 samples per second (a sampling interval of 0,01 ms) with a rise-time sensitivity response to peak pressure of 10 µs. A higher sampling rate is recommended for the satchel tests. The system shall be capable of recording reliably the peak positive air-blast pressure and the complete pressure-time trace through the negative phase loading as well. The data-acquisition system shall also incorporate filters to exclude alias frequency effects from the data.

6.5.3 Photographic equipment

Adequate photographic equipment shall be available to document the test.

6.5.4 Temperature-measuring device

A temperature-measuring device shall be used to accurately measure glazing-surface temperature and air temperature no more than 30 min prior to the blast.

6.6 Witness panels

A witness panel (3.17) shall be mounted behind each test specimen and inside the air-blast-resistant enclosure, parallel to the plane of the test specimen. Unless otherwise specified, the witness panel shall be placed (3 ± 0,15) m behind the test specimen. The witness panel shall cover the full area projected behind the test specimen and extend down to the floor of the witness area. The witness panel shall have a width at least that of the minimum permitted reaction structure defined in 6.4, or the width of the test specimen if greater, and a height extending from the level of the collecting mat to 200 mm above the top of the test specimen, or the ceiling of the reaction structure if less.

The witness panel shall consist of sheets of non-ductile, foam insulation board, of material equivalent to extruded polystyrene, polyisocyanurate or urethane, of density (30 ± 5) kg/m^3. The board shall be in one or two layers of combined thickness at least 35 mm, mounted in a frame capable of remaining in place even if forcibly impacted by failed pieces of the test specimen. In order to aid recording of the damage and to reduce waste, the board may contain a removable face layer at least 12 mm thick and the witness panel may be

