INTERNATIONAL STANDARD

ISO 16935

First edition
2007-02-01

Glass in building — Bullet-resistant security glazing — Test and classification

Verre dans la construction — Vitrages de sécurité résistant aux balles — Essai et classification

Reference number
ISO 16935:2007(E)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

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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 16935 was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 2, *Use considerations*.

Glass in building — Bullet-resistant security glazing — Test and classification

1 Scope

This International Standard sets forth test procedures to evaluate resistance of security glazing materials and products against ballistic impact with classification by weapon and ammunition.

This International Standard is applicable to attack by handguns, ammunition fired from machine pistols or submachine guns, rifles and shotguns, on products used for glazing in buildings, for both interior and exterior use.

NOTE 1 For exterior use under extreme conditions, it is necessary to consider the influence of the outside temperature as described in 6.1 and Annex B.

This International Standard assumes the glazing will be adequately fixed, but does not apply to the glazing system or the surrounding materials and structure.

NOTE 2 Considerations for installation are given in Annex C. Considerations for the bullet-resistance of other elements of the protective structure are given in Annex D.

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, *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
glass
any glass product including annealed glass (e.g. float glass), patterned glass, wired glass, heat strengthened glass, toughened glass, laminated glass, which may include panes of any or all of the above types of glass, and plastic glazing sheet material

3.2
glazing
glass or plastic glazing sheet material

3.3
glazing system
framing or other means of holding the glass in position in use, including all fixings, beads and glazing materials such as gaskets, glazing compounds, etc.

3.4
plastic glazing sheet material
flat plastic materials in sheet form suitable for glazing into windows, etc.

NOTE The commonly available plastics for this purpose are acrylic, polycarbonate and PVC.

3.5
rigidity
product of the modulus of elasticity of a material and the moment of inertia (I) value of the material section

4 Sample

The sample shall consist of three test specimens, with at least one extra test specimen as a reserve.

The test specimens shall conform to the specification of the manufacturer and shall be representative of normal production quality.

The test specimens shall be (500 $\pm$ 5) mm square and shall be clearly identified by type and construction and with an indication of the attack face.

NOTE Sizes in use smaller than the size of the test specimens might not perform to the same level as the test specimens.

5 Apparatus

5.1 General

The apparatus shall consist of the following:

— rigid frame;

— splinter-collecting box;

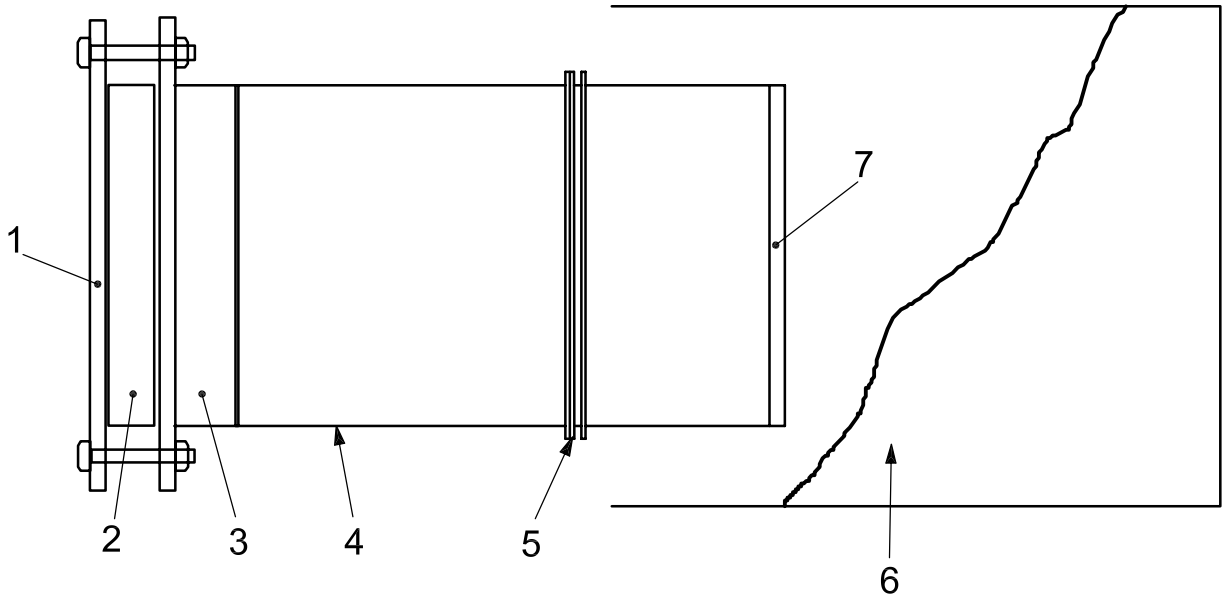
— witness foil;

— bullet and debris stop;

— velocity measuring equipment;

— ballistic testing equipment.

The apparatus is shown schematically in Figure 1.



Key

1 clamping plate
2 glazing
3 rigid frame
4 splinter-collecting box
5 witness foil
6 bullet and debris stop
7 steel plate, 6 mm

Figure 1 — Schematic diagram of the apparatus

5.2 Rigid frame

The preconditioned test specimen shall be mounted in a frame, along the full length of all four edges, with a sight size (440 ± 2) mm × (440 ± 2) mm.

The frame shall be provided with a clamping plate to hold the glazing in position and means for producing uniform clamping of the glazing.

The test specimen shall be mounted in the frame in a manner which meets the following requirements.

— The test specimen shall have an edge cover of not less than 25 mm on all edges.

— The test specimen shall be separated from the frame and the clamping plate by continuous rubber strips, (4 ± 0,5) mm thick, (30 ± 5) mm wide and of hardness (50 ± 10) IRHD, in accordance with ISO 48.

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

— All four edges of the test specimen shall be uniformly clamped with a clamping pressure sufficiently large that the edges remain in position during the test.

The clamping pressure has relatively little effect on the test results for glass but can have considerable influence on the test results for plastic glazing sheet materials. For these materials, the manner of support and retention should be reported.

The test specimen in the frame shall be placed normal to the direction of attack with an accuracy of ± 1 in any orientation.

NOTE A high degree of accuracy can be obtained by ensuring the reflection of the weapon is in the centre of the test specimen when viewed through the sights with the weapon in position.

5.3 Splinter-collecting box

A splinter-collecting box shall be mounted between the rigid frame and the witness foil. The splinter-collecting box should have an opening of at least 440 mm × 440 mm that matches the sight size of the glazing and should fully enclose the gap between the frame and the witness foil. The splinter-collecting box should extend beyond the witness foil and be terminated with a 6 mm steel plate in order to contain target and low-residual-velocity bullet fragments that can pass through the witness foil for visual inspection. It is not intended to arrest all bullets which can pass through targets at high velocity.

5.4 Witness foil

The witness foil shall consist of a sheet of aluminium of thickness 0,02 mm and density 54 g/m^2, mounted parallel to the test specimen, with a clear surface of at least 440 mm × 440 mm that matches the sight size of the glazing.

The witness foil shall be at a distance of (500 ± 10) mm behind the test specimen.

The witness foil shall be mounted by its edges in a manner that stretches it tight and ensures it remains in position during the test, but with no tendency for the witness foil to tear at the edges.

5.5 Bullet and debris stop

For the safety of test personnel, observers and others, the target and its mounting shall be placed in front of a means of stopping the bullet should it miss the target or pass through it with substantial retained velocity.

5.6 Velocity measuring equipment

The velocity of the bullet (see Tables 1 and 2) shall be measured or determined with an electronic measuring system no more than 3 m in front of the test specimen. The measuring mechanism shall be accurate to 1,0 m/s.

For each test specimen, the mean velocity of the bullets shall be within ± 10 m/s of the required velocity.

For classification SG2, both of the individual bullet velocities shall be within ± 10 m/s of the required velocity.

For each classification requiring three shots, at least two of the individual bullet velocities shall be within ± 10 m/s of the required velocity and the other bullet velocity shall be within ± 15 m/s of the required velocity.

5.7 Ballistic testing equipment

The ballistic testing equipment shall conform to the weapons and ammunition requirements for bullet composition, mass and velocity given in Tables 1 and 2. In the case of the open class, the weapon, bullet composition, mass and velocity shall be in accordance with the requirements and tolerances given before the start of the test.

It is not necessary that the equipment be the specific weapon listed, but may be specially designed equipment to give the required striking velocity. Attainment of the specified striking distance and accuracy can require special barrels and special sights; and attainment of the specified velocity can require the use of specially selected or manufactured ammunition. Classification in accordance with this International Standard pre-supposes the use of purpose-designed equipment in a fixed firing range usually using remotely fired weapons to obtain consistency of results in a safe manner.

6 Test method

6.1 General

The test method is given for testing for glazing for interior use.

Alternatively, if the glazing is intended for use under extreme conditions, the test specimens shall be tested at one or both of the following extreme temperatures as required: (-20 ± 3) °C or $(+40 \pm 3)$ °C, and the test shall be conducted according to Annex B.

If there is a requirement for natural weathering, all the test specimens shall be subjected to the weathering regime prior to the test.

6.2 Conditioning

The test specimens shall be stored for at least 12 h at a temperature of (18 ± 5) °C immediately prior to the test; see also Annex B.

6.3 Procedure

6.3.1 Ballistic testing equipment

The weapon and ammunition shall be selected from Tables 1 or 2 according to the level of bullet-resistance required.

If it is required that the glazing be tested to particular specifications of weapon or ammunition not in accordance with Tables 1 and 2, it shall be tested according to the "open class" (see Table 3). For the purpose of comparing products, it is recommended that the test requirements given in Annex A be respected. In the case of the open class, the type of weapon, ammunition, mass and velocity shall be in accordance with the requirements and tolerances given before the start of the test.

6.3.2 Mounting the test specimen

The test specimen shall be mounted in the frame and positioned at the appropriate distance from the muzzle of the weapon according to Tables 1 or 2. In the case of the open class, the distance shall be in accordance with the requirements and tolerances given before the start of the test. Unless there is good reason or a special requirement, the distance shall be not less than the relevant range stated in Tables A.1 and A.2 of Annex A.

6.3.3 Test conditions

The test temperature shall preferably be $\left(18\ ^{+10}_{-5}\right)$ °C. In the case of unheated or external ranges, the glass shall be mounted and tested within 10 min of removal from the conditioning area. For testing at extreme temperatures, see also Annex B.

6.3.4 Strike positions

Mark the centre of the test specimen. The position(s) of the strike points shall be marked as follows:

— Classes HG1, HG2, HG3, (three shots): at the vertices of an equilateral triangle of side length (110 ± 2) mm around the centre of the test specimen;

— Classes R1, R2, SG3 (three shots): at the vertices of an equilateral triangle of side length (120 ± 2) mm around the centre of the test specimen;

— Class SG2 (two shots): at positions (60 ± 2) mm directly above and directly below the centre of the test specimen;

— Class SG1 (one shot): impact point shall be the centre (± 2 mm) of the specimen;

— Class O: positions of the strike points shall be in accordance with the requirements and tolerances given before the start of the test. Preferably the strike points shall be positioned as given above for three, two or one shot(s); see Annex A.

The strike points shall be marked clearly for the marksman.

6.3.5 Test method

The test specimen shall be subjected to the required number of shots in the required positions.

The centre-to-centre distance of the strikes shall be measured to an accuracy of 5 mm.

The test specimen shall be examined for any opening (perforation) between back and front.

Perforation of the glazing shall be determined by

— the presence of openings between the attack face and the rear face, or

— the presence of fragments of bullet in the splinter-collecting box.

The witness foil shall be inspected against a strong light to determine if there are any perforations.

The validity of the test shall be determined in accordance with 6.4.

6.4 Validity of the test

The test is valid for a particular class either

— if the bullet velocity is within the limits specified (see Tables 1 and 2 and 5.6); and the measured spacing of the bullet strikes is (110 ± 10) mm for HG1, HG2, and HG3; (120 ± 10) mm for R1, R2; (60 ± 10) mm for SG2; and within ± 10 mm of the centre of the target for SG1;

— if the test specimen passes the test with appropriate spall performance (see Clause 7), despite the bullet velocity being higher than the prescribed velocity or the strikes being closer than the prescribed spacing.

The test is not valid if either the bullet velocity is lower than the specified limits or the measured spacing of the bullet strikes is greater than the specified limits.

7 Performance requirements

7.1 General

Each of the three test specimens shall conform to at least one of the following requirements:

a) spall (S): No perforation of the glazing, but with perforations in the witness foil;

b) reduced spall (RS): No perforation of the glazing, with loss of material from the non-attack surface but no perforations in the witness foil;

c) no spall (NS): No perforation of the glazing, with no loss of material from the non-attack surface and no perforations in the witness foil.

7.2 Classification criteria

If there is perforation of any one of the three test specimens, the glazing cannot be classified at the level tested.

If any one of the three test specimens meets only the requirement 7.1 a), then the classification is given the additional letter “S” (spalling).

If all of the test specimens meet the requirement 7.1 b), then the classification is given the additional letter “RS” (reduced spalling).

If all of the test specimens meet requirement 7.1 c), then the classification is given the additional letter “NS” (no spalling).

8 Classification

The bullet-resistant glazing intended to withstand a certain level of attack shall be classified according to Tables 1, 2 or 3. When possible, one of the specified classifications (HG1, HG2, HG3, R1, R2, SG1, SG2, SG3) shall be used. When any detail of the test requirement varies outside the specified classifications, then the open class shall be used and a full and unambiguous description shall be given of the following:

— weapon;

— ammunition type;

— bullet mass and tolerance;

— bullet velocity and tolerance;

— number and position of strikes and tolerance;

— range and tolerance.

The full specification, including a full description and source of the weapon/calibre for the open class, shall be agreed in writing between the test house and the client before the test is started.

Although the classifications in this International Standard are for specific weapons, glazing conforming to this International Standard also gives good bullet-resistance against similar weapons.

The higher classifications of handgun can be considered as *de facto* giving protection against weapons tested or covered by the lower classifications when glass laminates are being tested, i.e. glazing conforming to HG2 also conforms to HG1 and glazing conforming to HG3 also conforms to both HG2 and HG1. The same principle applies to the two classifications for rifles. However, different weapon types have different effects on the glazing, so for a product requiring a handgun, rifle and shotgun classification, for example, it is necessary that it be tested and classified against all three appropriate weapons.

The performance requirements specified in Clause 7 are known to apply only to glass laminates. When materials other than glass laminates are being tested, additional tests shall be conducted to establish the relative penetrative resistance in relation to the classifications.

Table 1 — Classification of bullet-resistance — Handguns and rifles

Classification	Weapon/ calibre	Bullet [a]	Mass g	Velocity [b] m/s	Number of strikes	Minimum range m	Kinetic energy [c] J
HG1	9 mm luger	FJ(2)/RN/LC	8,0 ± 0,1	380	3	5	578
HG2	0,357 magnum	JSP	10,2 ± 0,1	425	3	5	921
HG3	0,44 magnum	FJ(2)/FN/SC	15,6 ± 0,1	440	3	5	1 510
R1	5,56 × 45 mm	FJ(2)/PB/SCP	4,0 ± 0,1	920	3	10	1 693
R2	7,62 × 51 mm	FSJ/PB/SC	9,5 ± 0,1	830	3	10	3 272

[a] Abbreviations:

FSJ	full steel jacket (plated)	FN	flat nose	JSP	jacketed soft point
FJ(2)	copper alloy jacket	SC	soft core	PB	pointed bullet
RN	round nose	LC	lead core	SCP	soft core lead with steel penetrator (as NATO round SS109)

[b] See 5.6 for tolerances.

[c] The calculated kinetic energy, E_K, expressed in newton-metres (joules), of each shot (informative) is calculated from the equation: $E_K = 0{,}5 \times m \times V^2$, where m is the mass, expressed in kilograms, and V is the stated velocity, expressed in metres/s.

Table 2 — Classification of bullet-resistance — Shotguns

Classification	Weapon/ calibre	Bullet [a]	Mass g	Velocity m/s	Number of strikes	Minimum range m	Kinetic energy [c] J
SG1	Shotgun 12/70	Brenneke slug	31 ± 1	420 ± 10	1	10	2 734
SG2	Shotgun 12/70	Brenneke slug	31 ± 1	420 ± 10	2	10	2 734
SG3	Shotgun 12/70	Brenneke slug	31 ± 1	420 [b]	3	10	2 734

[a] Original Brenneke (solid lead) slugs. The specification for supply of this ammunition shall state “Original Brenneke”, to distinguish it from other varieties of Brenneke.

[b] See 5.6 for tolerances.

[c] The calculated kinetic energy, E_K, expressed in newton-metres (joules), of each shot (informative) is calculated from the equation in footnote c, Table 1.

Table 3 — Classification of bullet-resistance — Open class

Classification	Weapon/ calibre	Bullet	Mass g	Velocity m/s	Number of strikes	Range m
O	Open	a	a	a	a	a

[a] To be specified, together with tolerances where appropriate, before the test is undertaken; see Annex A.

9 Test report

The test report shall include at least the following information:

— manufacturer's name or trade mark;

— product name and type and/or serial number;

— description of the marking or labelling of the product by the manufacturer;

— date of manufacture;

— name of the test house;

— test date;

— class of bullet-resistance for which the product was submitted for test;

— the case of the open class, the full specification as described in Clause 8;

— test temperature;

— preconditioning weathering, if appropriate;

— for each test specimen:

  — bullet velocity,

  — strike positions,

  — witness foil inspection results,

  — presence or absence of splinters,

  — whether there was perforation of the test specimen;

— whether the product passed or failed;

— appropriate spall category subscript letters (“S”, “RS” or “NS”);

— classification in accordance with this International Standard.

10 Marking

The product might or might not have a permanent mark or have a non-reusable label indicating the name of this International Standard, the classification assigned including the spall category and the attack face as required by the end user.

Annex A
(normative)

Testing the bullet-resistance of glazing for the open class

The procedures of this International Standard may be used to test the ballistic resistance of materials to any ballistic threat not listed herein (open classification), providing all other conditions of numbers of shots, shot spacing and failure criteria are rigidly observed; see Table A.1.

Table A.1 — Test parameters

Type of weapon	Number of strikes	Minimum range m	Spacing mm
Handgun	3	5	triangle 110 ± 10
Rifle	3	10	triangle 120 ± 10
Shotgun (one shot)	1	10	central
Shotgun (two shots)	2	10	vertical 120 ± 10
Shotgun (three shots)	3	10	triangle 120 ± 10

The bullet velocity specified for the test should be representative of that developed by the weapon and ammunition, preferably at the higher end of the range of possible velocities. The tolerance on the velocity should be that given in 5.6. Three examples of open-class test specifications are given in Table A.2. The range selected, particularly for HC bullets, should be sufficient to enable the bullet flight to stabilize; e.g. 25 m for HC.

Table A.2 — Examples of open-class test specifications

Classification	Weapon/ calibre	Bullet [a]	Mass g	Velocity [b] m/s	Number of strikes	Minimum range m	Kinetic energy [c] J
O_1	Kalashnikov AK 47	FSJ/PB/HC [d]	8,0 ± 0,1	720	3	10	2 074
O_2	7,62 × 51	FJ(2)/PB/HC1[e]	9,5 ± 0,1	833	3	10	3 295
O_3	0,22 LR	L/RN	2,6 ± 0,1	360	3	10	168

[a] Abbreviations:

FSJ	full steel jacket	L	lead
PB	pointed bullet	RN	round nose
HC	steel hard core	FJ(2)	full copper alloy jacket
LR	long rifle		

[b] See 5.6 for tolerances.

[c] The calculated kinetic energy, E_K, expressed in newton-metres (joules), of each shot (informative) is calculated from the equation in footnote c, Table 1.

[d] M43.

[e] HC1: steel hard core, mass, 4,6 g ± 0,1 g; hardness more than 60 HRC.

Annex B
(normative)

Testing the bullet-resistance of glazing at extreme temperatures

B.1 Application

The influence of the outside temperature should be considered when glazing is intended for use under extreme conditions. Tests should be made after the entire test specimen has been conditioned at the specified temperature, that is, −20 °C or +40 °C.

B.2 Test method

B.2.1 Conditioning

The test pieces should be stored for at least 48 h at the specified temperature, that is, (−20 ± 3) °C or (+40 ± 3) °C.

Alternatively, if appropriate to the application in which the glazing is used, it is permitted to expose only one surface and the edges of the glazing for 48 h to the high or low temperature, that is, (−20 ± 3) °C or (+40 ± 3) °C, while the other surface is maintained at (18 ± 3) °C. In this case, the surface exposed to the high or low temperature shall be clearly marked, and the test report shall indicate that this alternative method of conditioning was used.

If it is certain that thermal equilibrium is reached in less than 48 h in either method of conditioning, it is permissible to reduce the conditioning time accordingly. In this case, the test report shall indicate the actual conditioning time.

B.2.2 Mounting of the test piece

Mount the conditioned test piece as described in 6.3.2. If the glazing was conditioned with only one surface at the high or low temperature, unless otherwise specified, the bullet(s) shall impact the surface exposed to the high or low temperature.

B.2.3 Test firing

Subject the test pieces to a firing test at normal incidence in accordance with the details in 6.3.3 to 6.3.5 within 10 min of removal from the conditioning area.

Annex C
(informative)

Considerations for installation of bullet-resistant glazing

C.1 Openings

There should be no direct openings in the glazing or the framing or other parts of the protective screen.

C.2 Glazing system

It should not be possible to deglaze the glazing from the attack side. All fixings, beads, etc., should be accessible only from the protected side. There should be no opening windows.

The glazing system should be designed

— to have the same bullet-resistance as the glazing,

— in such a way that there are no weak points where bullets, including those fired at angles other than normal, can penetrate through joints,

— to resist penetration and deglazing by manual attack implements,

— to be fixed securely to the surrounding structure so that complete removal is not possible.

C.3 Protective structure

Other elements of the protective structure that include the bullet-resistant glazing should have similar bullet-resistance; see Annex D.

It should be ensured that there are no hidden access points, such as above false ceilings, where the protective structure can be bypassed.

Any doors or hatches through the protective structure, which can be used by an attacker, should be kept securely locked at all times and have appropriate resistance to forced entry using either guns or manual attack implements.

Annex D
(informative)

Considerations for the bullet-resistance of other elements of a protective structure

D.1 Materials covered by other bullet-resistance standards

Where there are appropriate bullet-resistance standards for the materials forming elements of a protective structure, these standards should be used to specify the material thicknesses and types for an equivalent level of bullet-resistance to the glazing.

D.2 Materials not covered by a bullet-resistance standard

D.2.1 Sheet materials and panel constructions

Sheet or panel constructions can be tested according to this International Standard by inserting test specimens of the sheet or panel material into the specimen holder instead of the glazing. The test methods, performance requirements and classification of this International Standard may then be used.

D.2.2 Frames, fixtures and fittings

Representative test specimens should be constructed and firmly held in place. All non-glazing features of an assembly containing one or more glazings shall have every non-glazing feature tested with at least one shot of the same ballistic threat as that used to test the glazing(s). The features tested shall include but not necessarily be limited to glazing frames, seams, locks, handles, hinges, mullions, mounting hardware, weldments or other variations. The same ballistic test equipment and range should be used for assessing the test specimen. In addition to assessing the component's resistance to bullet impact normal to (i.e. at right angles to) the structure, consideration should be given to examining the structure for areas of weakness (e.g. at joints), specifically targeting these and striking the test specimen at an angle other than normal if this can be more likely to result in perforation or spalling.

The performance requirements and classification of this International Standard may then be used.

ICS 81.040.20

Price based on 13 pages