



# Standard Test Methods for Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades<sup>1</sup>

This standard is issued under the fixed designation E 2353; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 These test methods cover procedures to be followed in testing the performance of glass in permanent railing systems, guards and balustrades installed in and for assembly, commercial, educational, industrial, institutional, stadiums, recreational, and residential buildings.

1.2 These test methods are applicable to such railing, guard, and balustrade systems having glass as the major structural component or the infill panel

1.3 These test methods can be used to determine whether permanent rails, guards and balustrades having a glass component comply with anticipated performance requirements of the applicable specifications, codes, and standards.

1.4 Specifically, these test methods cover procedures for determining the static strength, impact performance, and post breakage retention characteristics of railing systems, guards, and balustrades with a glass component installed in one, two, three and four side support systems that are fastened to concrete, masonry, wood, and metal as well as related products.

1.5 No consideration is given in these test methods to any possible deterioration of the railing, guard, or balustrade system or their connections and fasteners as resulting from adverse environmental or in-service conditions. The performance of special tests covering this aspect may be desirable.

1.6 These test methods are limited to the application of concentrated and linear loads and impact resistance described herein. Whenever uniformly distributed loads are to be resisted by a railing system, guard, or balustrade in accordance with governing specifications, codes and standards, the effects of such loads on the member stresses shall be determined by calculation and the corresponding concentrated and linear

loads shall be tested. Should computations make it possible to provide the needed information, testing can be employed for verification.

1.7 These test methods address the capability of glass rails, guards, and balustrades in one, two, three and four sided support systems to continue in their function as a barrier by remaining in the designed framing system after impact or glass breakage. This specification does not address structural limitation of glass rails, guards, and balustrades or vehicular guards except when in the area of a pedestrian walkway.

1.8 All values are stated in SI units and are to be regarded as standard. Values given in parentheses are for information only. Certain values contained in reference documents cited and quoted herein may be stated in inch-pound units and must be converted by the user.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

**E 329** Specification for Agencies Engaged in Construction Inspection and/or Testing

**E 631** Terminology of Building Constructions

**E 699** Practice for Evaluation of Agencies Involved in Testing, Quality Assurance, and Evaluating of Building Components

**E 935** Test Methods for Performance of Permanent Metal Railing Systems and Rails for Buildings

**E 1481** Terminology of Railing Systems and Rails for Buildings

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.56 on Performance of Railing Systems and Rails for Buildings.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

**E 2025** Test Method for Evaluating Fenestration Components and Assemblies for Resistance to Impact Energies

## 2.2 Other Standards:

**ANSI Z97.1** Standard Glazing Materials Used in Buildings  
**16 CFR Part 1201 CPSC** Safety Standard for Architectural Glazing Materials

## 3. Terminology

**3.1 Definitions**—General terms used in this standard test method are defined in Terminologies **E 631** and **E 1481**. Terms common to this standard test method and referenced test methods are defined in the respective document unless defined herein.

### 3.2 Definitions of Terms Specific to This Standard:

**3.2.1 failure load**—a load, which, if placed upon a specimen or test piece, causes fracture of the glass.

**3.2.2 glazing retention**—the property of maintaining the glass or glazing material, post breakage, in a system, such that the glass must be held in the framing system with no opening sufficient to pass a 75 mm (3 in.) solid steel sphere through the system using a horizontally applied force of 18 N (4.0 lb).

**3.2.3 guard rail system**—a protective railing system along the outer edges of locations of an accessible roof, balcony, landing, platform, or ramp, designed to minimize the probability of an accidental fall from the walking surface.

**3.2.4 interlayer**—a layer of material acting as an adhesive between lites of glazing, which adds additional performance attributes to the finished product; for example: impact resistance, solar control, and acoustical insulation.

**3.2.5 lite**—a term for a single pane (or piece) of glass or other glazing material.

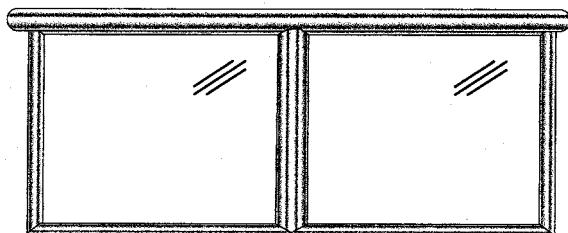
**3.2.6 specifying authority**—the design professional responsible for interpreting applicable regulations of authorities having jurisdiction and considering appropriate site specific factors to determine the appropriate values used to calculate the specified design load and furnishing other information required for performance of specified materials.

**3.2.7 stile**—one of the upright structural members of a frame or a framework of bars.

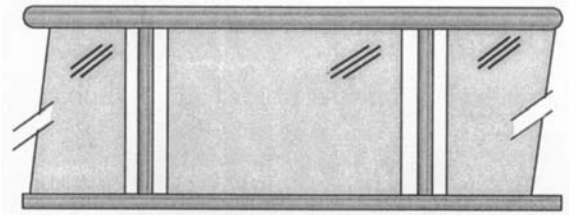
## 4. Types

**4.1** For purposes of these test methods, glass rails, guards, and balustrade assemblies are classified as types and are described in **4.1.1** through **4.1.5** and as shown in **Figs. 1-8**.

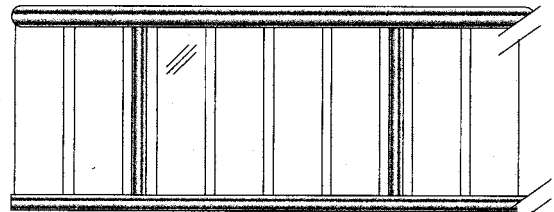
**4.1.1 Type I**—A glass rail, guard, or balustrade assembly with a single full view glazing material that is fully captured on all sides (that is, four side support).



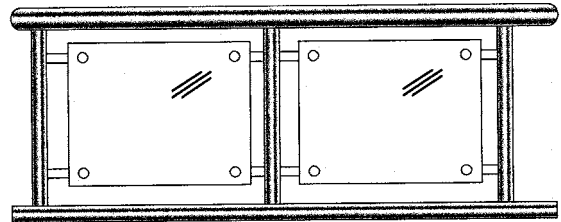
**FIG. 1 Type I: Four-side Support—Infill**



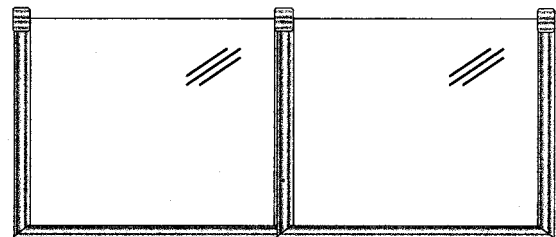
**FIG. 2 Type II: Two-side Support—Single Lite Infill**



**FIG. 3 Type II: Two-side Support—Multiple Lite Infill**



**FIG. 4 Type III: Point Fixed Glazing System—Infill**



**FIG. 5 Type IV: Three-side Support—Structural**

**4.1.2 Type II**—A glass rail, guard, or balustrade assembly with a single full view or multiple units of glazing material that are captured on two sides (that is, two side support).

**4.1.3 Type III**—A glass rail, guard, or balustrade assembly with a single full view glazing material that is held in place by a point fixed glazing system, corner brackets or other non-continuous brace along a portion of the glazing.

**4.1.4 Type IV**—A glass rail, guard, or balustrade assembly with a single full view glazing material that is fully captured on three sides (that is, three side support).

**4.1.5 Type V**—A glass rail, guard, or balustrade assembly with a single full view glazing material that is fully captured on only one side (that is, single side support). A decorative or protective top rail (**Fig. 7**), or a handrail may or may not be attached to the glass (**Fig. 8**), but does not offer structural support to the system.

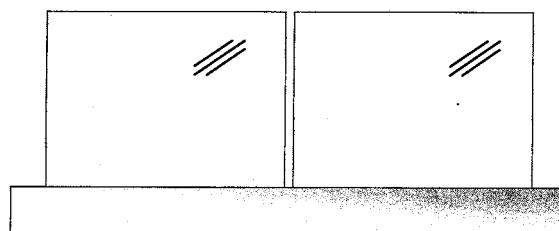


FIG. 6 Type V: One-side Support—Structural

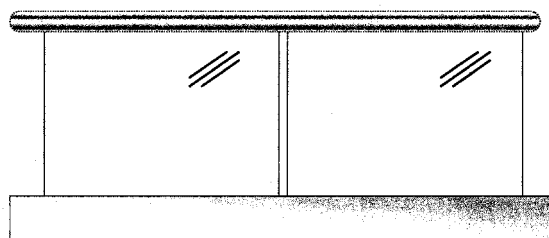


FIG. 7 Type V: One-side Support with Protective Top Rail—Structural

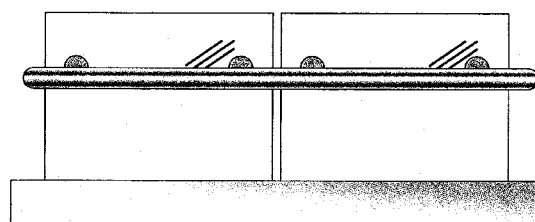


FIG. 8 Type V: One-side Support with Surface Attached / Bolted Handrail—Structural

## 5. Summary of Test Method

5.1 The procedure consists of preparing a specimen in accordance with the manufacturers or designers specifications. The supporting and embedding materials shall be in accordance with intended use. The system or infill material is tested by applying loads and impacting the glazed portion of the assembly in the prescribed sequence, as outlined in Table 1. Asymmetrical systems shall be tested from both sides.

5.2 Acceptance criteria for performance levels shall be provided by the specifying authority. Adoption of performance criteria shall be a matter for authorities having specific jurisdiction.

## 6. Significance and Use

6.1 These test methods are intended to provide information from which applicable design data can be derived for the

performance of glass in rails, guards and balustrade systems as infill panels that are fastened to concrete, masonry, wood and metal as well as related products, and to the performance of glass as the structural element of the rail, guard, or balustrade system.

6.2 Specification E 329 and Practice E 699 are standards that assist the user of these test methods to apply appropriate procedures and methods to ensure a quality result is provided.

## 7. Apparatus

7.1 *Instrumentation*, load and time-measuring devices with an accuracy of  $\pm 2\%$  or the full scale shall be incorporated in the test setups. The scale ranges used shall assure that the performance levels are within an accuracy of  $\pm 5\%$ .

7.2 *Load Attachments*, brackets, fasteners, or other devices used in performing these tests shall be designed and attached so as to minimize their influence on the test results.

7.3 *Shot Bag, Traction and Release System*:

7.3.1 The test apparatus shall be capable of supporting a 45.4 kg (100 lb) shot bag and allowing unimpeded swinging of the shot bag from a drop height of 1220 mm (48 in.). The impactor system consists of the impactor, traction, release, and suspension devices as described in CPSC 16 CFR Part 1201.

7.3.2 The impactor shall consist of the leather bag described in Fig. 9, a commercial punching bag<sup>3</sup> with its bladder left in place, or any other leather bag of nominally identical shape and size. The bag shall be filled with lead shot of  $2.4 \pm 0.1$  mm diameter (nominal USA No. 7 1/2 or European No. 7 lead shot) and taped. After filling with lead shot, the top shall be either pulled over the metal sleeve and tied with a cord; or twisted around the threaded eyebolt shaft and tied below the metal sleeve, or both. To reduce bag damage during testing, the exterior of the leather bag surface shall be completely covered with glass filament reinforced pressure sensitive polyester adhesive tape,<sup>4</sup> 12 to 15 mm (0.5 to 0.6 in.) in width and 0.15 mm (0.006 in.) thick. Tape the entire bag, using three (3) rolls or 165 m (180 yd) total length, and taping in a diagonal-overlapping manner. Tape the neck of the bag separately, with additional glass filament reinforced tape of the same kind. The total mass of the impactor assembly shall be  $45.4 \pm 0.1$  kg (100 lb  $\pm 4$  oz), excluding traction system attachments.

7.3.3 A traction system shall be used which enables the impactor to be brought into its launch position. The launch position depends on the drop height selected. The traction cable shall be connected to the impactor traction system by a release mechanism, with provisions for rotating the impactor.

TABLE 1 Test Summary

| Type        | Test 1:<br>Frame <sup>A</sup> | Test 2:<br>Glazing Infill Impact 1 <sup>B</sup> | Test 3:<br>Glazing Infill Impact 2 <sup>C</sup> |
|-------------|-------------------------------|-------------------------------------------------|-------------------------------------------------|
| I through V | A, B, and C                   | Shot Bag                                        | Pendulum                                        |

<sup>A</sup> Tests performed as outlined in Test Method E 935.

<sup>B</sup> Tests performed as described in ANSI Z97.1 and 13.3 of this standard.

<sup>C</sup> Tests performed as described in Test Method E 2025 and 13.4 of this standard.

<sup>3</sup> Such as 230 mm (9 in.) diameter by 360 mm (14 in.) high Everlast 4207 (raw, full grain 85-g (3-oz) cowhide) or Everlast 4212 (split 85-g (3-oz) cowhide) available from Everlast Sports, Bronx, New York, USA. These are tradenames. This information is given for the convenience of users and does not constitute an endorsement of any product named. Equivalent products may be used if they can be shown to lead to the same results. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.

<sup>4</sup> Such as 3M No. 898 (a tradename), or equal. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.

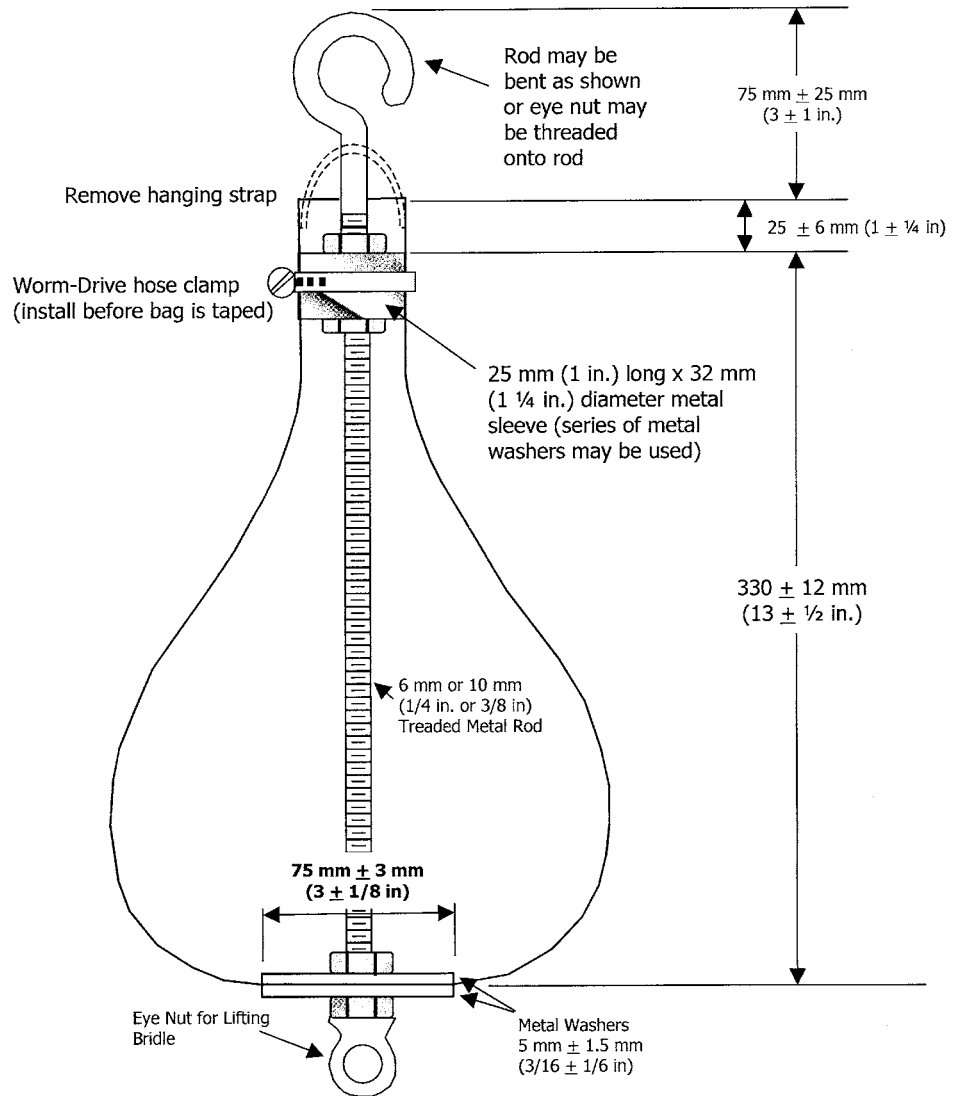


FIG. 9 Shot Bag Impactor

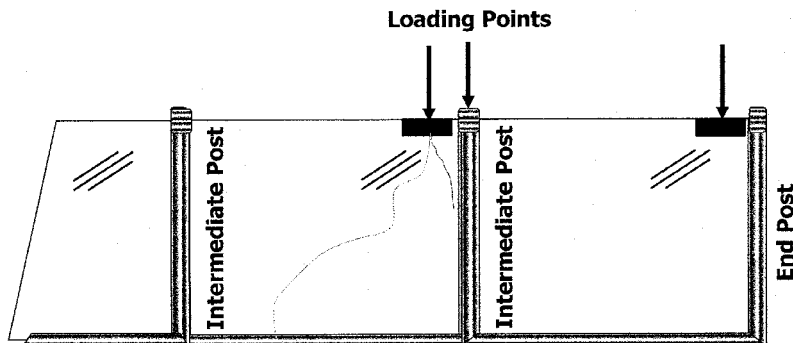


FIG. 10 Vertical Loading Points and Glass Failure

#### 7.4 Pendulum Impactor:

7.4.1 Apparatus specified in Section 6 of Test Method E 2025 with the specifications noted in sections 6.4.2 and 6.4.3.

#### 7.4.2 Impactor:

7.4.2.1 The impactor shall be a pendulum system made of steel and capable of delivering horizontal impacts of up to 100

J (74 ft-lbf). The striking end of the impactor shall have a removable steel hemispherical nose approximately 30 mm (1.25 in.) diameter.

#### 7.4.3 Impact Nose:

7.4.3.1 The impact nose shall be  $63 \pm 5$  mm ( $2.5 \pm 0.2$  in.) in diameter and the radial tolerance shall be within 3.2 mm ( $\frac{1}{8}$  in.). The nose shall be made of steel. No chips, irregularities, or surface blemishes that may affect the outcome of the impact shall be present on the impact nose.

## 8. Hazards

8.1 Glass breakage may occur during the application of loads or forces required by the test methods. Take adequate precautions to protect personnel from broken glass.

8.2 Glazing anchorage, glass, and other test specimen components may suddenly fail when loads and forces are applied during these test methods, causing the assembly to rapidly move. Take adequate precautions to protect personnel from rapidly moving weights and test specimen components.

## 9. Test Selection, Sampling, Test Specimens, and Installation

### 9.1 Test Selection:

9.1.1 The only tests that need to be performed are those that are considered necessary to provide information required by the requesting party, testing agency and regulatory body involved.

### 9.2 Sampling:

9.2.1 A minimum of three representative replicate specimens of each type of system shall be tested.

9.2.2 Sequential testing of the same specimen shall be permissible provided no breakage of any component occurs during the previously performed tests.

### 9.3 Test Specimens:

9.3.1 The specimen installation, including the post spacing, shall be the same as the actual field installation. The specimen shall have a minimum of three posts or have a minimum linear length of 3 m (10 ft). Each unique attachment scenario shall be tested.

9.3.2 Multiple types of infill panels shall be qualified within one test provided each panel is individually glazed into the system prior to the start of the test. No substitution of infill product shall be permitted once testing has commenced.

### 9.4 Installation:

9.4.1 The glass rail, guard, or balustrade system being tested shall be installed in accordance with the manufacturers or designers specifications.

## 10. Preparation of Apparatus

10.1 The glass rail, guard, or balustrade assembly shall be mounted in accordance with the manufacturers written installation instructions or as to be constructed.

10.2 Glazing shall be mounted so as to apply impact from the side of the upper floor level.

## 11. Conditioning

11.1 The specimens shall be conditioned to a uniform test temperature between 18 and 30°C (65 and 85°F) for at least 4 h with separation to permit free air circulation.

## 12. Procedure

### 12.1 Glazing Infill Evaluation—Type I, II, and III:

12.1.1 Test loads shall be applied in both directions.

12.1.2 Load Removal—At the conclusion of each test, remove all loads before starting the next test.

12.1.3 Structural evaluation according to Test Method A, Application of Horizontal Static Load to Top Rail, of Test Method E 935 shall be performed.

12.1.4 Test Method B, Application of Vertical Static Load to Top Rail, of Test Method E 935 shall be performed on a new specimen, or the same undamaged specimen that has passed tests 12.1.3.

12.1.5 Test Method C, Application of Horizontal Static Load to Infill Areas of Baluster and Panel Railing Systems, of Test Method E 935 shall be performed on a new specimen, or the same undamaged specimen that has passed tests 12.1.3 and 12.1.4. Perform only one test per glazing infill type on each of the three specimens at the most critical point of the system.

12.1.6 The Shot Bag Impact Test (see 13.3) shall be performed on a new specimen, or the same undamaged specimen from tests 12.1.3 and 12.1.4.

12.1.7 The Pendulum Impact Test (see 13.4) shall be performed on a new specimen, or the same undamaged specimen from 12.1.3 and 12.1.4.

### 12.2 Structural Glazing Evaluation—Type IV and V:

12.2.1 Test loads shall be applied in both directions.

12.2.2 Load Removal—At the conclusion of each test, all loads shall be removed before starting the next test.

12.2.3 Test Method E 935 Test Method A, Application of Horizontal Static load to Top Rail, shall be performed using a bearing plate a maximum of 100 mm (4 in.) long, with a minimum width equivalent to that of the top rail or 52 mm (2 in.) wide, whichever is less, with appropriate cushioning between the plate and glass.

12.2.4 Test Method E 935 Test Method B, Application of Vertical Static Load to Top Rail, shall be performed on a new specimen, or the same undamaged specimen passing test 12.2.3. Using a bearing plate a maximum of 100 mm (4 in.) long (see Fig. 7), the test load and forces shall be applied at a rate not to exceed 4.5 kg/s (10 lb/s). the performance loads shall be maintained for a period of  $60 \pm 5$  s.

12.2.5 Test Method E 935 Test Method C, Application of Horizontal Static Load to Infill Areas of Baluster and Panel Railing Systems, shall be performed on a new specimen, or the same undamaged specimen passing test 12.2.3 and 12.2.4. Only one test shall be performed per glazing infill type on each of the three specimens at the most critical point of the system.

12.2.6 The Shot Bag Impact Test (see 13.3) shall be performed on a new specimen, or the same undamaged specimen from 12.2.3, 12.2.4, and 12.2.5.

12.2.7 The Pendulum Impact Test (see 13.4) shall be performed on a new specimen, or the same undamaged specimen passing test 12.2.3, 12.2.4, or 12.2.5.

## 13. Test Methods

13.1 Static Loads—Static loads shall be applied in accordance with Test Method E 935 Sections 12 through 34 as appropriate and unless specified differently in this test method.

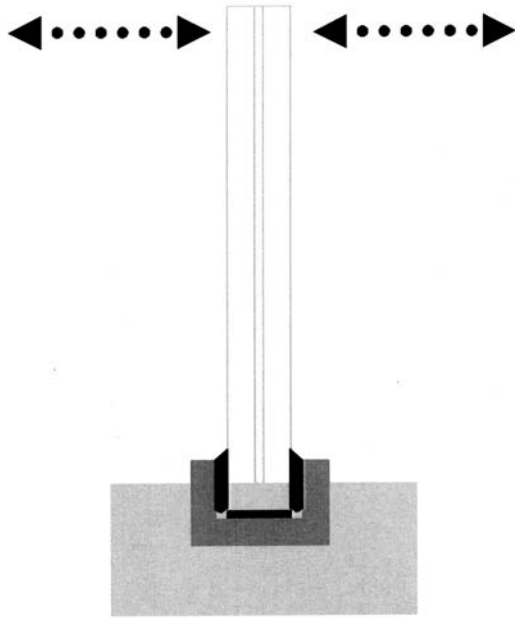


FIG. 11 Horizontal Load Application

13.2 For multiple balusters between stiles (posts) (see Fig. 3, Type II); the specimen shall be impacted two times with the shot bag. The first impact shall be targeted to impact at the center of a baluster and the second impact shall be targeted to impact between two balusters.

#### 13.3 Shot Bag Impact Test:

13.3.1 Any protective masking or decorative components shall be removed from the glazing material.

13.3.2 To position the impactor at the selected drop height, a traction force shall be applied to raise the impactor such that the axis of the impactor shall be aligned with the suspension cable, with the cable remaining taut. To ensure this, the top and bottom ends of the impactor shall be connected to the release device by a suitable link.

13.3.3 To reduce bag deformation during testing, the bag shall be rotated about the axis of its suspension device before each specimen or sample set, by no less than 30 degrees, and by no more than 90 degrees.

13.3.4 To reduce bag damage during testing, a thin homogeneous or non-woven plastic film no more than 0.13 mm (0.005 in.) thick or a loosely draped woven cloth towel

weighing no more than 0.05 g/cm<sup>2</sup> (0.0113 oz./in.<sup>2</sup>) shall be permitted to be suspended vertically from its top edge directly in front of the surface of the specimen at a distance no more than 10 mm (0.4 in.).

13.3.5 When at rest the maximum diameter of the impactor shall be located no more than 12 mm (½ in.) from the surface of the specimen and no more than 50 mm (2 in.) from the center of the specimen. The impactor shall be suspended from an overhead support, located so when at rest it will, at its maximum diameter, be no more than 12 mm (0.5 in.) from the surface of the specimens and no more than 50 mm (2 in.) from the center of the specimen.

13.3.6 Raise the impactor to the required height (460 or 1220 mm [18 or 48 in.]) and stabilize it. The suspension device shall be taut and the axes of the impactor and cable shall be aligned.

13.3.7 The impactor, stabilized in the launch position in a vertical plane normal to the test specimen, shall be released and falls without initial velocity or axial rotation. One impact with a force of 1.8 kN (400 ft-lbf) shall occur on each glazing configuration of the test specimen.

13.3.8 Each test specimen shall be inspected after each impact and report condition of specimen.

#### 13.4 Pendulum Impactor Test:

13.4.1 Impact testing shall be performed using outlined apparatus in Section 6 of this standard with mounting and testing procedures as outlined in Test Method E 2025 Sections 8 and 11 respectively.

##### 13.4.2 Impact Location:

13.4.2.1 For a continuous lite between support stiles, a total of three impacts shall be performed on the same lite of glass, impacting at the geometric center of the glazing and within 150 mm (6 in.) of adjacent corners as shown in Fig. 12.

13.4.2.2 If multiple balusters are used between support stiles made of a material other than glass, the pendulum impact shall be adjusted so as to impact the first baluster, the nearest point to geometric center staying within 75 mm (3 in.) of an edge, and last baluster between the stiles at the center of the middle baluster and within 150 mm (6 in.) of adjacent corners as shown in Fig. 13. Multiple impacts to a single baluster shall be permitted.

13.4.2.3 If infill balusters are single or multiple units installed in a manner in which they are at an angle to the top rail (Fig. 14), the pendulum impactor nose shall be positioned to impact the innermost location (furthest from the impactor) of

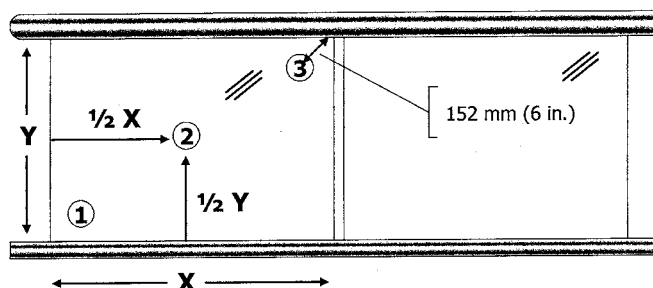


FIG. 12 Locations for Pendulum Impacts Single Lite Baluster

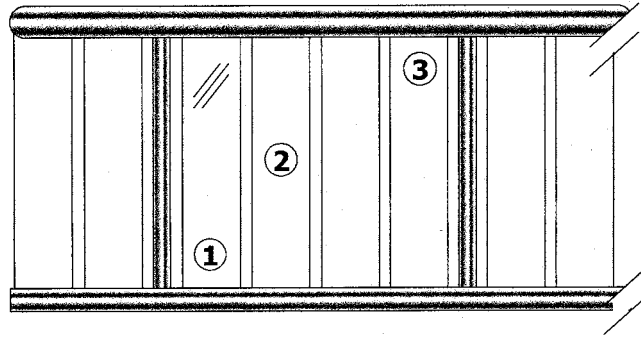


FIG. 13 Locations for Pendulum Impacts Multiple Balusters

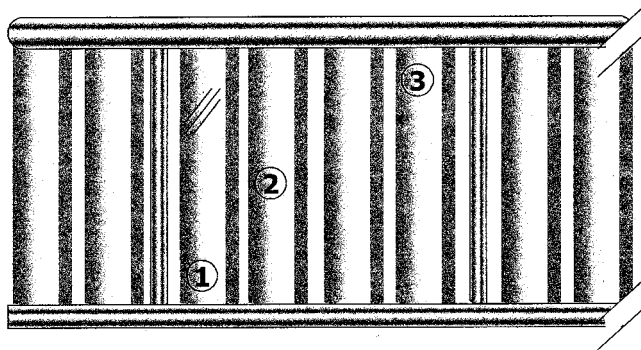


FIG. 14 Locations from Pendulum Impacts Multiple Balusters Non-parallel

the baluster. The impactor shall be positioned so the nose, at rest, is closest to the innermost point of the baluster without contacting any portion of the baluster itself. The impact locations shall be as described in 13.4.2.1 and 13.4.2.2 of this standard as appropriate for the glazing type.

#### 14. Calculation or Interpretation of Results

14.1 Load deformation data for tests cited in 12.1.3 and 12.1.4 of this standard shall be calculated according to Section 9 of Test Method E 935.

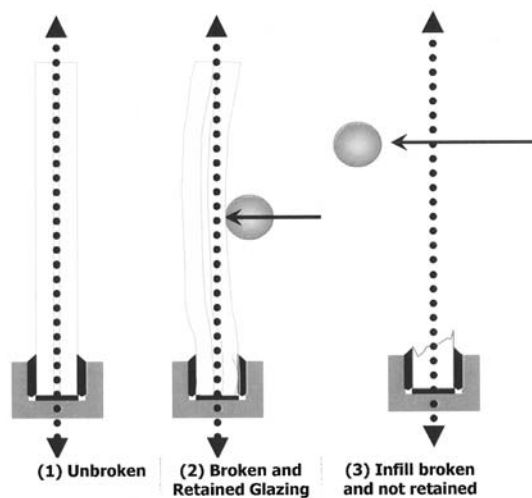


FIG. 15 Glazing Retention

14.2 Any glass fracture associated with tests performed under 12.1.3 and 12.1.4 shall constitute a failure.

14.2.1 Impact performance as tested in 12.2.6 shall be classified as: (1) unbroken, (2) broken and retained, or (3) infill broken and not retained (see Fig. 15). Retention of the product in the frame is based on the definition of glazing retention in 3.2.2 of this standard.

## 15. Report

15.1 The report shall contain a description of the results of the test(s) performed in accordance with these test methods.

15.2 The report shall also include at least the following:

15.2.1 Identification of the glass rail, guard, or balustrade assembly;

15.2.2 Detailed description of glazing materials including glass type, glass treatment, glass thickness, and component manufacturers and copy of the report certifying glazing test results in accordance with the test requirements of 14.1 and 14.2;

15.2.3 Bill of materials;

15.2.4 Assembly drawing with glazing details;

15.2.5 Performance level and load used;

15.2.6 A statement by test method as to the performance of the glass rail, guard or balustrade specimen(s);

15.2.7 A description of the method of installation or installation fastening; and

15.2.8 A description of the test methods used.

## 16. Precision and Bias

16.1 These test methods do not generate numerical values. They establish a pass/fail condition that cannot generate numerical values for precision and bias.

## 17. Keywords

17.1 balcony; balustrades; fall-out; flat glass; glass; glazing; guards; impact; laminated glass; rails; retention; safety; safety glazing; tempered glass

# APPENDIX

## (Nonmandatory Information)

### X1. PERFORMANCE LEVELS

X1.1 The products evaluated by this specification are potentially subjected to a wide variety of forces and impacts that could cause breakage and lead to the potential fall-out if the glazing vacates the frame. This specification outlines a test methodology that takes into account the various impacts from a sharp blow of a knee, a blunt object impact or a full body

impact. Although not every form of impact and force can be accounted for in a test method, this specification provides a means of establishing a level of retention that may help glazing in rails; guards and balustrades perform their intended function of protection and fall-out prevention.

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