American National Standard

for safety glazing materials
used in buildings –
safety performance specifications
and methods of test

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American National Standard for Safety Glazing Materials Used in Buildings - Safety Performance Specifications and Methods of Test

Secretariat

Glazing Industry Secretariat Committee

Approved by ASC August 2003

American National Standards Institute, Inc.

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FORWARD

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This standard was developed under procedures accredited as meeting the criteria for American National Standards. The consensus committee that approved the Standard was balanced to ensure that individuals from competent and concerned interests have had an opportunity to participate. It was developed within the approved scope as stated in Section 1.1 of the standard.

This Standard is available for public review on a continuing basis. This provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large. The use of an addenda system will allow revisions made in response to public review or committee actions to be published as required.

This standard, which is the result of extended and careful consideration of available knowledge and experience on the subject, is intended to provide minimum requirements that are recommended for use, adoption, enforcement by federal, state and local authorities and by model codes. It is recommended that this standard be referenced but not incorporated in any statute.

The impact tests described in this standard are based on realistic information and criteria but it must be acknowledged that in a small number of cases, involving rare coincidence, somewhat larger impact forces could be developed.

This Standard does not recommend where safety glazing should be used or, when it is used, what type of glazing material should be used. For this information one should consult other codes, standards and manufacturer's information.

Neither the standards committee nor the secretariat feel that this standard is perfect or in its ultimate form. It is recognized that, although safety-glazing materials are widely used and accepted, new developments are to be expected and revisions of the standards are necessary as the art progresses and further experience is gained. The accredited standards committee (ASC) has carefully considered the inclusion of a widely used center punch fragmentation test in the standard as a secondary method for testing tempered glass. The ASC decided that while this test is a common quality control method used in the tempering industry, the actual evaluation and reporting of the test results needs further study. The tempering division of the Glass Association of North America (GANA) has agreed to pursue the development of this test and will propose a center punch fragmentation test for consideration at the next review of this standard.

This standard is a successor standard to the 1994 edition. The 1994 standard was a reaffirmation of the 1984 standard with various editorial changes and the 1984 standard succeeded those of the 1975, 1972 and 1966 editions.

For communication with the Committee please refer to the following page.

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This standard was processed and approved for submittal to ANSI by American National Standards Committee on Safety Requirements for Architectural Glazing Material, Z97. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the Z97 Committee had the following members:

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American National Standard for Safety Glazing Materials Used in Buildings - Safety Performance Specifications and Methods of Test

1 Scope, Purpose, and Limitations

1.1 Scope.

This standard establishes the specifications and methods of test for the safety properties of safety glazing materials (glazing materials designed to promote safety and to reduce or minimize the likelihood of cutting and piercing injuries when the glazing materials are broken by human contact) as used for all building and architectural purposes.

1.2 Purpose.

The purpose of this standard is to prescribe the safety performance characteristics of safety glazing materials. This standard affords a basis for; (l) safety standards for adoption in regulations by federal, state, and local regulatory bodies; and (2) for use by building code officials, architects, designers, specifiers and others as a reference standard. Approval of a material under this standard constitutes acceptance of its safety characteristics and the retention of those characteristics. It is not to be construed as appraisal of its durability or appearance as a glazing material.

1.3 Limitations.

1.3.1 Conformance of a material to this standard demonstrates acceptable safety characteristics of the material and retention of those characteristics.

1.3.2 While this Standard related to the minimum safety performance property test criteria for safety glazing materials, the lowest classification level herein per section 5.1.2 has NOT been accepted by all jurisdictions (e.g. CPSC 16 CFR 1201, building codes etc...) as "safe performance" for unrestricted human impact accident modes. Therefore Class C herein applies to glazing material acceptable by the authority having jurisdiction that either: (1) has restricted human impact accident modes in application; or that (2) has a combination of minimal impact characteristics with a fire safety function other than energetic human impact alone.

1.3.3 Conformance of a material to this standard is not to be construed as an appraisal of its strength, durability or appearance as a glazing material, nor does this standard specify situations in which safety-glazing materials should be used.

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1.3.4 This standard does not address the mounting or other methods used for the installation of safety glazing materials.

1.3.5 A condition of conformance to the standard is the consistent and uniform production of glazing material so that it will exhibit these safety characteristics.

1.3.6 Monolithic annealed glass in any thickness, is not considered a safety glazing material under this standard.

2 Referenced Standards

This standard is intended for use in conjunction with the following standards:

ASTM C 1036-91 (Re-approved 1997), Standard Specification for Flat Glass1.

ASTM C 1048-97b Standard Specification for Heat-Treated Flat Glass - Kind HS, Kind FT, Coated and Uncoated Glass1.

ASTM C 1172-96 Standard Specification for Laminated Architectural Flat Glass[1].

ASTM C 1349-96 Standard Specification for Architectural Flat Glass Clad Polycarbonate[1].

ASTM C 1422-99 Standard Specification for Chemically Strengthened Flat Glass[1].

ASTM C 1464-00 Standard Specification for Bent Glass[1].

ASTM D 756-93 Practice for Determination of Weight and Shape Changes of Plastics Under Accelerated Service Conditions (Discontinued 1998)[1].

ASTM D 785-98 Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials[1].

ASTM D 790-99 Standard Test Methods for Flexural Properties of Un-reinforced and Reinforced Plastics and Electrical Insulating Material[1].

ASTM D 1435-94 Standard Practice for Outdoor Weathering of Plastics[1] (note: 1999 version of standard available).

ASTM D 1499-92A Standard Recommended Practice for Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics[1]. (note: 1999 version of standard available)

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ASTM D 2565-92A Standard Practice for Xenon Arc Exposure of Plastics Intended for Outdoor Applications[1] (note: 1999 version of standard available)

ASTM D 2583-95, Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor[1].

ASTM D 2240-97e1, Standard Test Method for Rubber Property-Durometer Hardness[1].

ASTM D 6110-97, Standard Test Methods for Determining the Charpy Impact Resistance of Notched Specimens of Plastics[1].

ASTM G 23-96, Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) with and without Water for Exposure of Nonmetallic Materials[1].

ASTM G 26-84, Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[1] (note: 1996 version of standard available)

ASTM G 155-00, Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials[1].

ISO 4892.2, Plastics - Methods of Exposure to Laboratory Light Sources - Part 2 Xenon Arc Sources

3 Definitions

asymmetric material. Glazing in which component layers of its construction makeup are different in thickness, kind, type or pattern texture about its interlayer and/or central plane surface.

bent glass. Flat glass that has been shaped while hot into a body that has curved surfaces.

bubble. A visible gas pocket in the interlayer material or in the plastic glazing sheet material, or between the interlayer and another layer of glass or plastic glazing sheet material.

cracking. The visible breaking, splitting or fissuring, either partially or completely through the thickness of an individual layer of material.

[1] American Society for Testing and Materials, International. 100 Barr Harbor Drive, West Conshohocken, PA

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crack-free particle. A portion of a broken test specimen that is determined by identifying the smallest possible perimeter around all points in the portion of the broken test specimen, always passing along un-separated cracks or exposed surfaces.

crazing. The visible breaking, splitting or fissuring of a material, typically patterned with a network of fine lines that do not penetrate through the thickness of an individual layer of material.

delamination. A condition in which one of the glass or plastic glazing sheet material layers loses its bond to an interlayer and separates physically or visibly.

discoloration. A visibly noticeable chemically or processed induced color deviation in the appearance of a material.

fire-resistant wired glass. Flat clear transparent or translucent soda lime silicate glass which has a steel mesh, welded at all intersections, incorporated in the glass during its manufacturing process. To be considered as fire resistant, this product shall be covered by an appropriate listing body and when installed shall be labeled accordingly.

laminated glass. A manufactured assembly consisting of at least one sheet of glass bonded to at least one other sheet of glass or plastic glazing material with an organic interlayer. Note: when broken, numerous cracks appear, but glass fragments tend to adhere to the interlayer.

> ***2-ply glass laminates.*** A laminated glass consisting of two sheets of glass bonded together with an interlayer.
>
> ***multi-ply glass laminates.*** A laminated glass consisting of more than two layers of glass and/or plastic glazing sheet material bonded together by interlayers, where both of the outer surfaces are glass.
>
> ***glass/plastic laminates.*** A laminated glass consisting of one or more layers of glass and one or more layers of plastic glazing sheet material bonded together with one or more interlayer(s) in which the plastic surface faces inward when the glazing is installed in a structure.

mirrors. Architectural glazing materials whose intended use is based on their reflective quality. These materials are composed of a reflective surface and may have a substrate of glass, or plastic.

organic-coated glass. An assembly consisting of a sheet of glass covered on one or both surfaces with either: (1) an adhesive-applied organic film or sheeting, or (2) an applied coating. When broken numerous cracks appear, but the glass fragments tend to adhere to the applied organic material.

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plastic glazing material. A single sheet of synthetic plastic material, a combination of two or more such sheets laminated together, or a combination of plastic material and reinforcement material in the form of fibers or flakes. This material contains as an essential ingredient an organic substance of large molecular weight; is solid in its finished state; and, at some stage in its manufacture or in its processing into finished articles, can be shaped by flow.

safety glazing materials. Glazing materials so constructed, treated, or combined with other materials that, if broken by human contact, the likelihood of cutting or piercing injuries that might result from such contact is minimized.

tempered glass. (also known as a toughened glass). Glass of any shape that has been subjected to a thermal treatment process characterized by uniform heating followed by rapid uniform cooling to produce compressively stressed surface layers. See ASTM C-1048 (1997) for additional requirement information.

4 Specimens to Be Tested

(See Table 1)

TABLE 1
Grouping of Tests for Safety Glazing Materials

Test	Glazing Type[1]				
	Laminated Glasses	Tempered Glass	Organic Coated Glass	Plastic Glazing	Fire Resistant Wired Glass
Impact, Test 5.1	X	X	X	X[2]	X
Boil, Test 5.2	X[3]				
Weathering, Test 5.3	X[4]		X[4,5]	X	
Indoor aging, Test 5.4			X	X	
Hardness Test 4.7, 5.1.4 (3)				X[6]	
Modulus Test 4.7, 5.1.4 (3)				X[6]	

1Bent and mirror glazing shall be tested in accordance with requirements of the base-glazing product; see section 4.4
2Only one-test specimen needs to be impacted. If the specimen passes impact requirements, the remaining specimens need only meet the hardness and modulus requirements.
3Excludes glass/plastic laminates
4Weathering tests on laminated and organic coated glasses shall be performed on the thinnest construction of all components in clear glass with clear plastics by either the laminate fabricator or the manufacturer of the interlayer or plastic glazing sheet material.
5Products intended for indoor use only are not subject to weathering test.
6Only required if breakage occurs under impact

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4.1 Condition of Specimens.

Tests shall be applied to specimens as shipped by the manufacturer and shall be representative of commercial production, except that any protective masking material shall be removed prior to test.

4.2 Thickness of Specimens.

The thickness of the specimens to be tested shall be measured and recorded along with the nominal thickness in accordance with accepted industry practice (for glass as set forth in ASTM C 1036-91(Re-approved 1997)). No manufacturer shall mark or advertise as passing the tests, described in this standard, any product of different nominal thickness than that of the specimens passing the tests.

4.3 Size Classification of Specimens.

A description of impact specimens to be tested as required for size classification as set forth below:

Unlimited Size (U)	34 inches by 76 inches, ± 0.125 (1/8) inch (863 mm by 1930 mm, ± 3 mm)
Limited Size (L)	Appropriate to Manufacturer, Largest size commercially produced by the manufacturer less than 34 inches by 76 inches, ± 1/8 inch (863 mm by 1930 mm, ± 3 mm). Minimum specimen size: 24 inches by 30 inches, ± 1/8 inch (610 mm by 762 mm, ± 3 mm).

No manufacturer submitting specimens that are in the Limited Size Classification shall mark or advertise as passing the tests, described in this standard, any product with either dimension greater than those of the specimens passing the tests.

4.4 Specimens for Impact Tests.

For impact test (see section 5.1) of any safety glazing material, four specimens, each of the thickness and size described in sections 4.2 and 4.3 respectively, shall be required. If the test specimens are of an asymmetric material, two shall be impacted from each side.

For impact test after aging (see section 5.4) of safety glazing materials used in indoor applications, four specimens, each of the thickness and size described in sections 4.2 and 4.3 respectively, shall be required. If the test specimens are of an asymmetric material two shall be impacted from each side.

For mirror glazing products using either reinforced or non-reinforced organic adhesive backing material, four specimens each with the backing material applied, of the thickness and size described in sections 4.2 and 4.3 respectively, shall be required. The specimens shall be impacted only on the non-reinforced side and with no other material applied.

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Bent glass test methods shall be the same as for flat sample testing except as referenced in the text and figures of this standard (See **Figure 3, 3.1, 3.2** and **3.3**). Interpretation of results shall be the same.

4.5 Specimens for Boil Test.

For boil test (see section 5.2) three specimens, each 12 inches by 12 inches, representative of commercial production and of like thickness as submitted for impact testing (see section 4.4), shall be required.

4.6 Specimens for Weathering Tests.

For weathering tests (see section 5.3), specimens as described in sections 4.6.1 and 4.6.2, representative of commercial production and of like thickness as submitted for impact testing (see section 4.4), shall be required.

4.6.1 Plastic Glazing Material.

One un-backed panel, 6 inches by 6 inches, shall be exposed. One additional un-backed panel, 6 inches by 6 inches (152 mm by 152 mm), shall be kept in darkness and used as a control.

NOTE: A minimum of five specimens, each 0.5 inch by 5 inches (12.7 mm by 127 mm), is necessary for the Charpy Impact Test (ASTM D 6110-97). Alternate panel sizes may be used provided that enough material exists to cut a total of five specimens after exposure. Edges shall be trimmed from exposed panels prior to cutting specimens to minimize edge effects. For materials suspected of being anisotropic, the direction of one axis shall be marked on each panel, and all specimens shall be cut in the same direction.

4.6.2 Laminated Glass and Organic-Coated Glass.

Six specimens, each 2 inches by 6 inches (50 mm by 152 mm) shall be prepared. Three specimens shall be exposed and three shall be kept in darkness and used as controls.

4.7 Specimens for Modulus and Hardness Tests

4.7.1 Specimens for Flexural Modulus.

The specimen dimensions are dependent on the thickness of the material and the span distance capabilities of the testing machine. The dimensions shall meet the requirements of ASTM D790-99 for flatwise tests. For common plastic glazing thicknesses and common testing machine capabilities, specimens 0.5 inch (12.7 mm) wide and 5 inches (127 mm) long can meet the requirements. Decreased width and/or increased length may be needed in some cases to meet the span to depth ratio, span to width ratio and span to length requirements of the standard.

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4.7.2 Specimens for Rockwell Hardness.

The specimens shall be at least 1 inch (25 mm) square and at least 1/4 inch (6 mm) thick. Materials less than 0.25 inch (6 mm) thick may be stacked provided that the precautions noted in ASTM D785-98 are met.

5 Test Specifications

5.1 Impact Test.

Required specimens shall be tested as submitted except that any protective masking or protective material shall be removed prior to the test. Any applied coating integral to the specimens shall not be removed. The specimens shall be conditioned to a uniform test temperature between 65°F and 85°F (18.3°C and 29.4°C) for at least 4 hours with separation to permit free air circulation.

5.1.1 Apparatus.

The test apparatus shall consist of a test frame and an impactor system. The test frame consists of a main frame mounted on two base beams with stiffening members and a sub-frame, in which the specimen is held. The impactor system consists of the impactor, traction, release, and suspension devices.

(1) ***Main Frame.*** The main frame shall be constructed to minimize movement, deflection, twisting or racking of its members during testing. For this purpose, the structural framing members shall be steel angles 3 inches by 5 inches by 0.25 inch (76 mm by 127 mm by 6 mm) or other sections and materials of equal or greater rigidity. The main frame shall be welded or securely bolted at the corners and braced as shown in **Figure 1** and **Figure 2.**

The main frame is mounted to a rigid floor and/or wall. Horizontal members made of steel sections connect the main frame to a rigid wall. The base beams are connected to the main frame by diagonal members of steel sections (see **Figure 1** and **Figure 2**). Attach the two base beams of the main frame to a concrete base or floor using bolts M16 or equivalent.

Internal dimensions of main frame[2]1 (**Figure 2**) shall be:
Internal width: 32.9 inches ±0.2 inch (835 mm ±5 mm)
Internal height: 74.9 inches ± 0.2 inch (1902 mm ±5 mm)

[2] The internal dimensions of the main frame shall be 1.1 inch (28 mm) less than unlimited-size (34 inches by 76 inches [863 mm by 1930 mm]) specimen dimensions.

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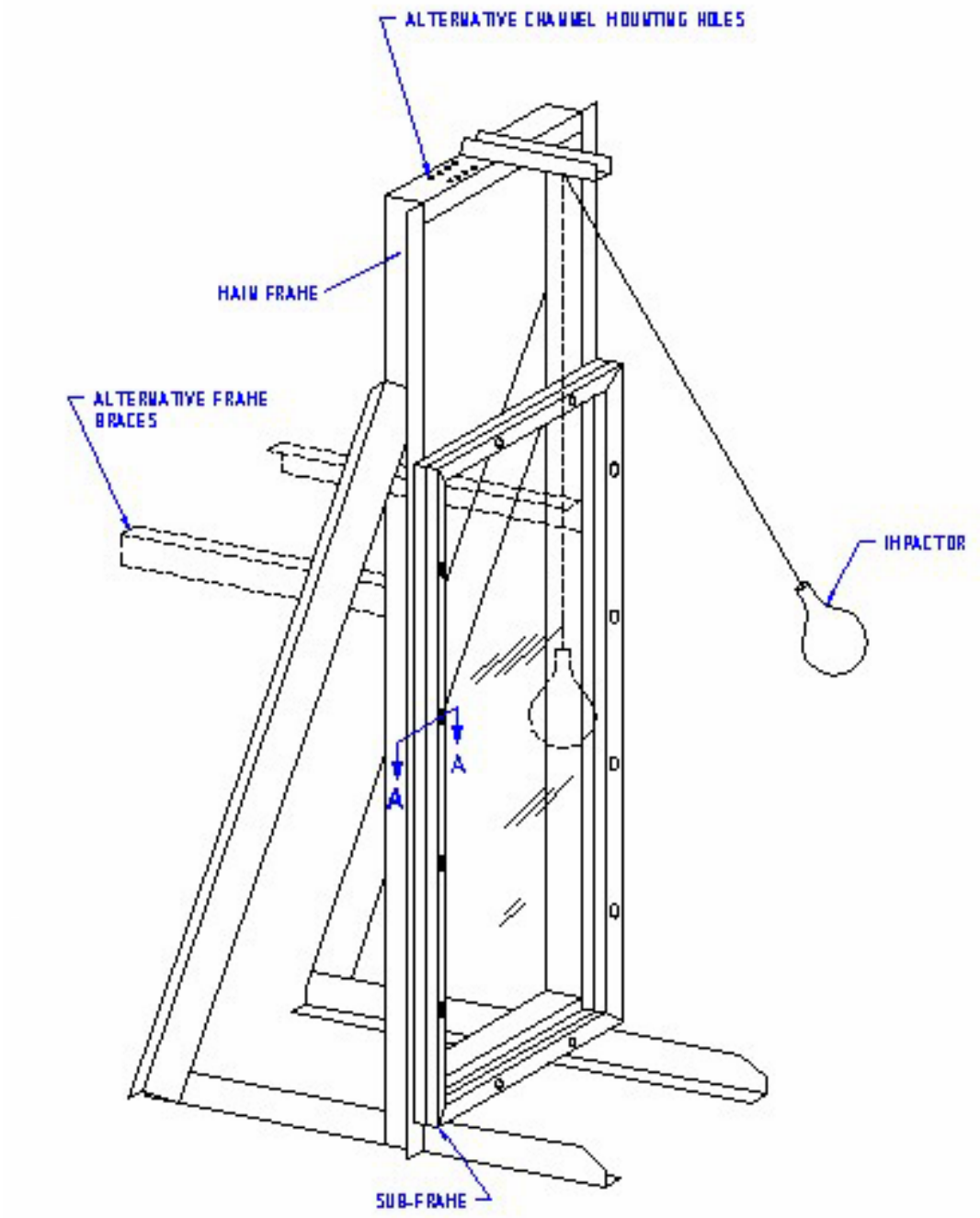

Figure 1 Impact Test Structure

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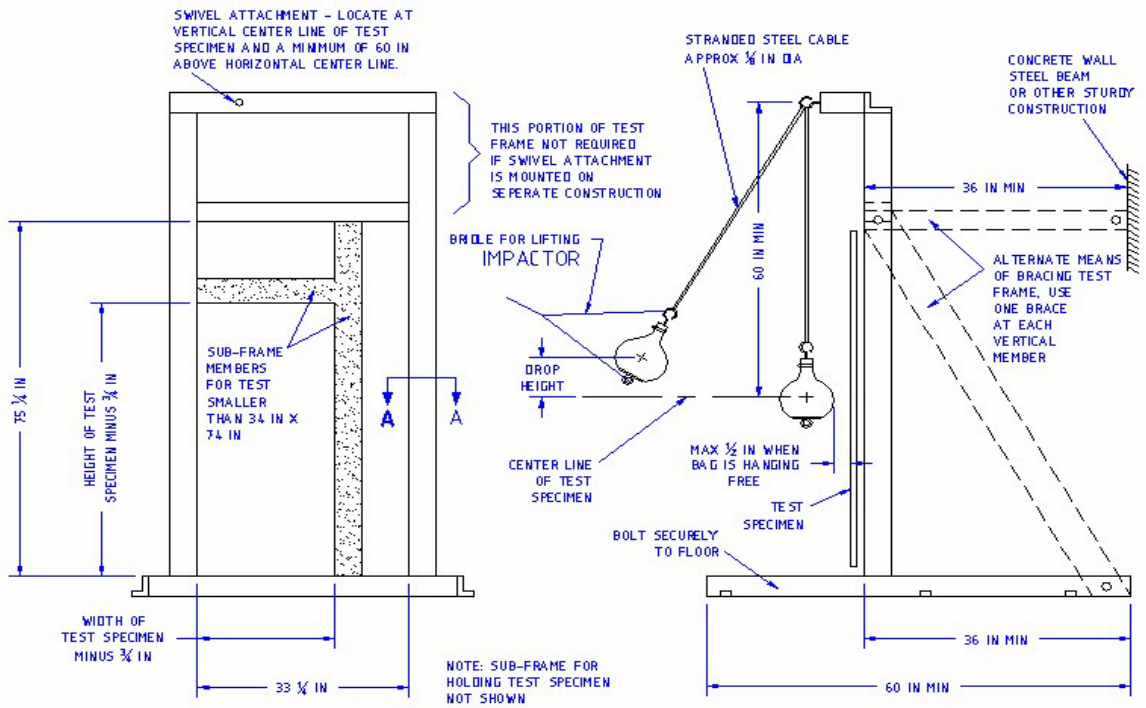

Figure 2 Impact Test Frame

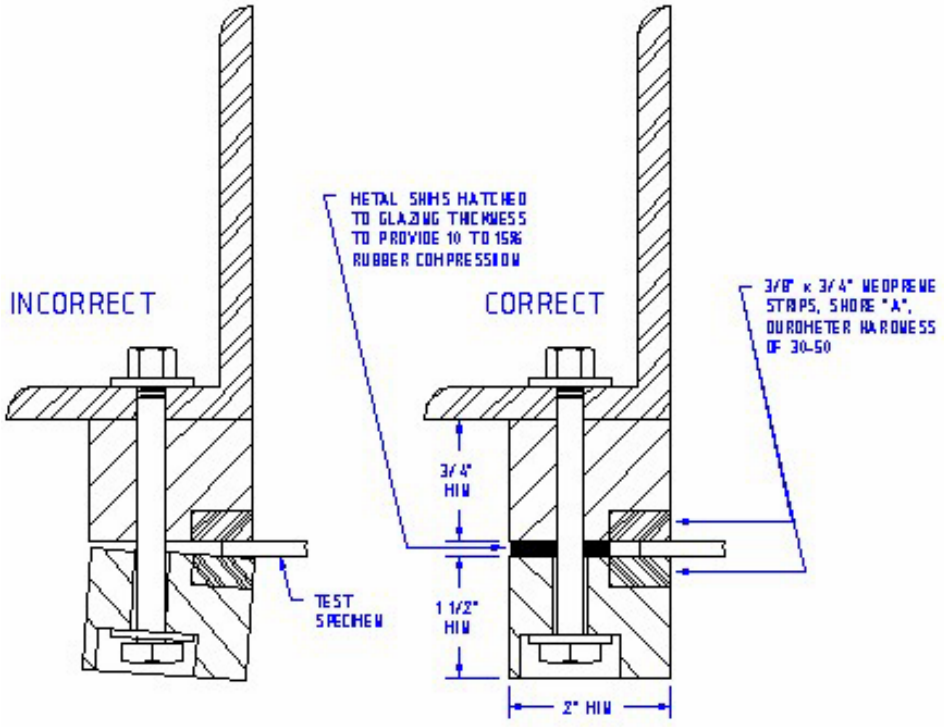

Figure 2.1 Detail of Section A-A

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Properly and Improperly Clamped Test Specimen (>1/8 inch (3 mm))

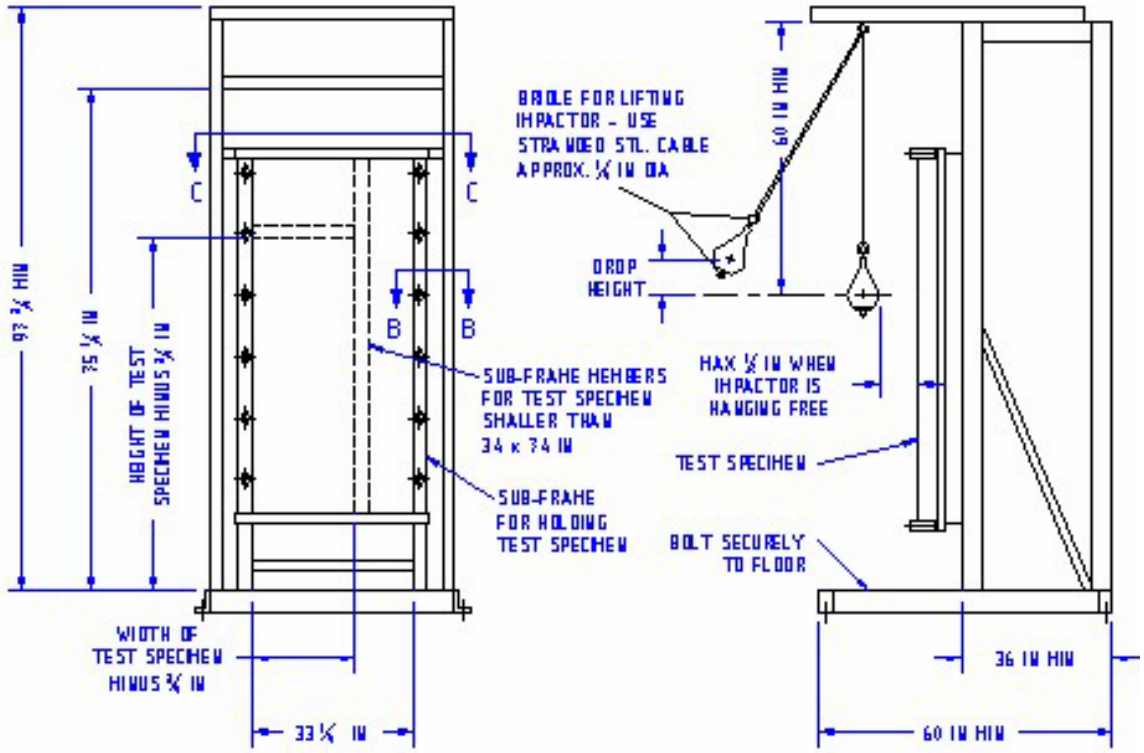

Figure 3 Bent Glass Impact Frame

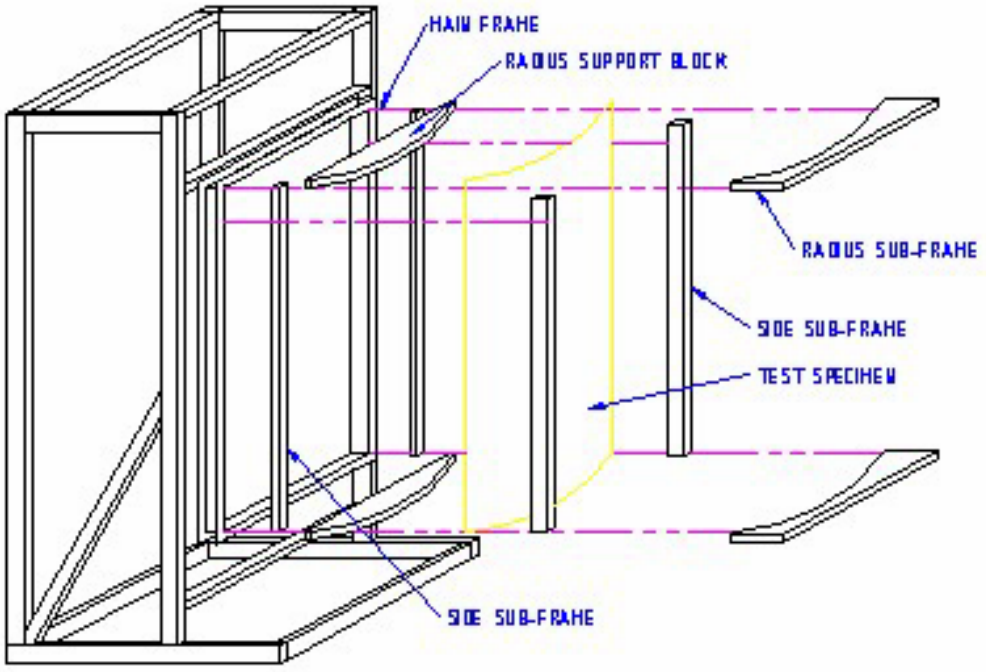

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Figure 3.1 Bent Glass Impact Test Frame (Exploded View)

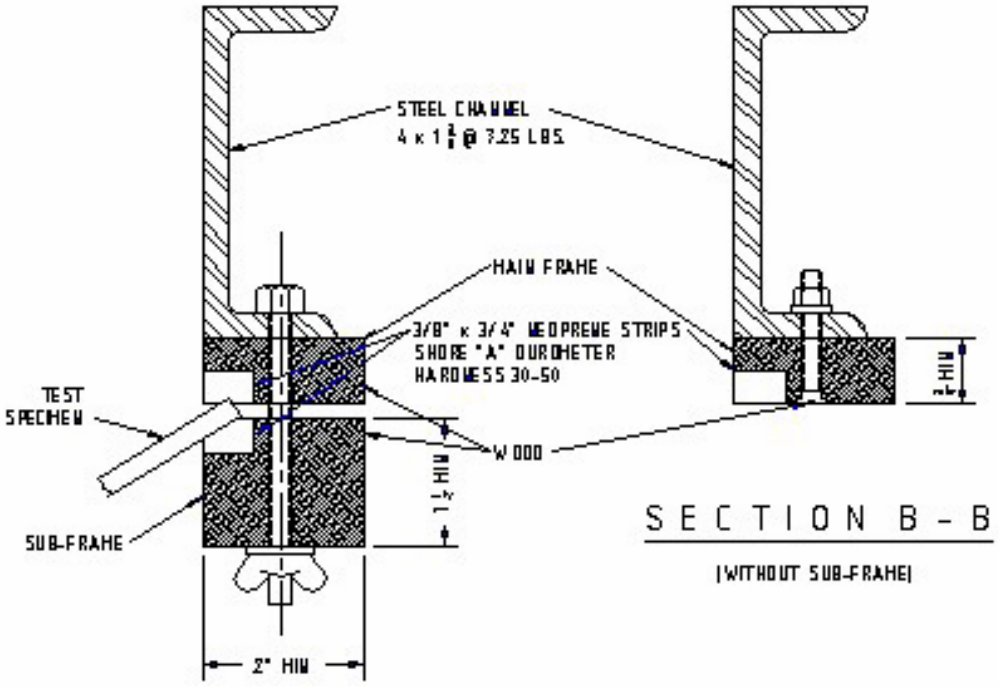

Figure 3.2 Bent Glass Impact Test Frame (Exploded View Section B-B)

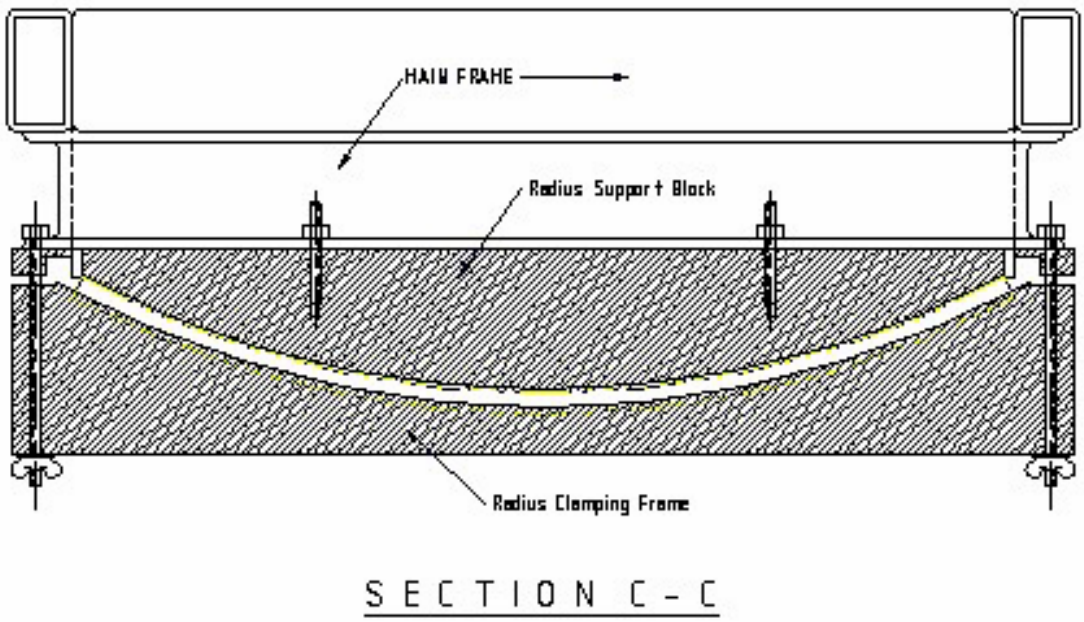

Figure 3.3 Bent Glass Impact Test Frame (Exploded View Section C-C)

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(2) ***Sub-frame.*** (Test Specimen Mounting Frame). (See **Figure 1** and **Figure 2**) The sub-frame for securing the specimens on all four edges consists of two parts made from wood or other material which is hard enough to withstand the pressure exerted by the clamping forces. Each part shall be provided with a groove or rebate in which a strip of elastomeric rubber is laid; the specimen shall only contact the elastomeric rubber strips.

The inner sub-frame (**Figure 2.1**), which is in contact with the specimen, is 2- inches by 0.75 inch (50 mm by 19 mm) minimum. The outer part of the sub-frame holds the specimen and is 2 inches by 1.5 inches (50 mm by 38 mm) minimum.

The sub-frame is fixed to the main frame by at least twelve bolts M10 bolts, scissors clamps or equivalent). These shall be fixed at the points marked on **Figure 1**, with no fewer than two on any edge and spaced no more than 18 inches (450 mm) apart.

To provide and limit elastomeric rubber compression and avoid sub-frame distortion, non-compressible shims appropriate to glazing thickness shall be used to separate the inner and outer parts of the sub-frame (**See Figure 2.1**).

The elastomeric rubber strip, the only element that the test specimen shall come into contact with, shall be 0.8 inch (20 mm) wide by 0.4 inch (10 mm) thick and have a Shore-A hardness of 40 + 10. (ASTM D2240-97, Standard Test Method for Rubber Property - Durometer Hardness).

NOTE: Modifications that clearly do not alter the function or performance of the main frame or sub-frame are acceptable. Any reasonable means may be used to secure the sub-frame to the main frame provided the mounting is secure and the pressure on the glazing specimen in the sub-frame is controlled.

(3) ***Impactor.*** The impactor shall consist of the leather bag described in **Figure 4**, a commercial punching bag[3] 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 mm + 0.1 mm diameter (nominal USA No. 71/2 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[4], 0.5 inch to 0.6 inch (12 mm to 15 mm) in width and 0.006 inch (0.15 mm) thick. Tape the entire bag, using three- (3) rolls or 180 yards (165-m) 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 100 lb +4 oz (45.4 kg + 0.2 kg), excluding traction system attachments.

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[3] Such as 9 inch (229 mm) diameter by 14 inch(356 mm) high Everlast 4207 (raw, full grain 3-ounce(85 grams) cowhide) or Everlast 4212 (split 3-ounce(85 grams) 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.

[4] Such as 3M No. 898 (a tradename), or equal. (See Footnote 3 regarding tradename).

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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.

NOTE: To reduce bag damage during testing, a thin homogeneous or non-woven plastic film no more than 0.005 inch (0.13 mm) thick or a loosely draped woven cloth towel weighing no more than 0.05 g/cm2 (0.0113 oz./in2) may be suspended vertically from its top edge directly in front of the surface of the specimen at a distance no more than 0.4 inch (10 mm).

The impactor shape shall be maintained constant during testing. To reduce visible deformation of the impactor, it shall be removed from the suspension device and pummeled with a rubber mallet into its approximate original shape.

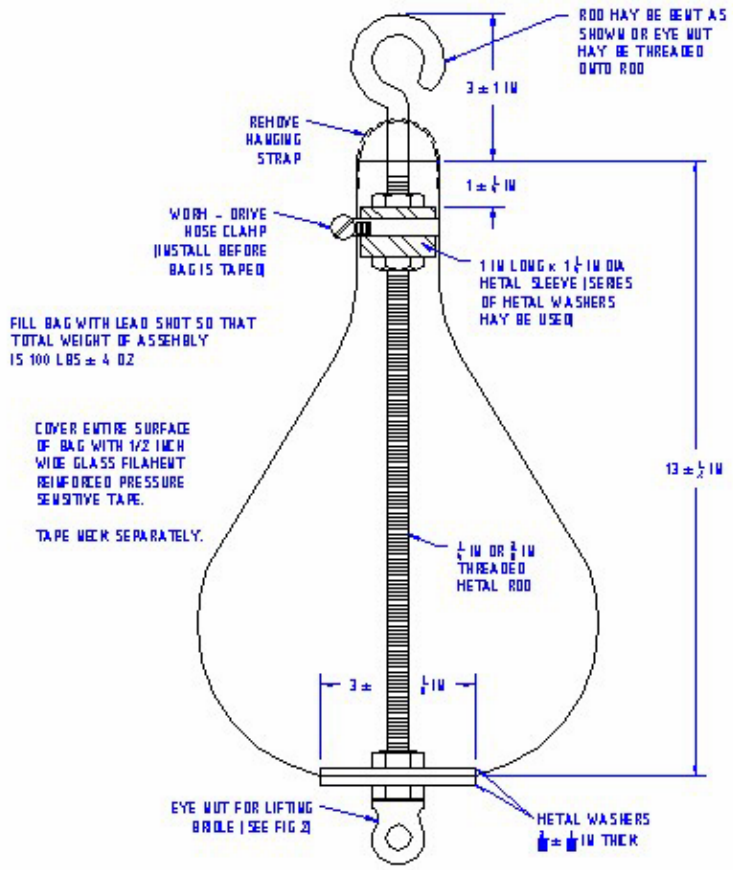

Figure 4 Impactor

(4) ***Suspension Device.*** The impactor is suspended by means of a single, stranded steel cable, approximately 0.125 inch (3 mm) diameter, from an upper swivel-fixture above the head of the main frame at an elevation of which the minimum distance between the swivel-fixture and impactor centerline is 60 inches (152.4 mm). The upper swivel-fixture must be rigid to ensure the point of suspension remains stationary. The lower swivel(s) or

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equivalent shall be provided on the bag for rotation of the impactor about its suspension device axes between impact events.

When at rest the maximum diameter of the impactor shall be located no more than 0.5 inch (13 mm) from the surface of the specimen and no more than 2 inches (51 mm) from the center of the specimen.

(5) **Traction and Release System.** 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 is connected to the impactor traction system by a release mechanism, with provisions for rotating the impactor.

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.

5.1.2 Impact Classification.

Glazing materials shall be submitted for impact testing to a selected drop height class.

5.1.2.1 Drop Height Class.

Glazing materials conforming to this standard are classified by their performance under the impact test at the selected drop height.

Class A - glazing material that complies with the requirements of section 5.1.4 when tested by the procedure of section 5.1.3 at a drop height between 48 inches and 48.5 inches (1219 mm and 1232 mm) using an impact specimen appropriate to the size classification.

Class B - glazing material that complies with the requirements of section 5.1.4 when tested by the procedure of section 5.1.3 at a drop height of between 18 inches and 18.5 inches (457 mm and 470 mm) using an impact specimen appropriate to the size classification.

Class C - shall apply only for fire-resistant wired glass. It is a material that complies with the requirements of section 5.1.4 when tested by the procedure of section 5.1.3 at a drop height of between 12 inches and 12.5 inches (305 mm and 318 mm) using an impact specimen size of 34 inches by 76 inches (863 mm by 1930 mm).

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5.1.2.2 Drop Height Qualification.

Glazing material qualified for classification at the higher impact drop height level "Class A", shall be deemed to comply with the lower impact drop height level "Class B".

5.1.3 Procedure.

(1) Place and center each specimen in the sub-frame so each edge is encased in the elastomeric rubber strip to a depth of at least 0.4 inch (10 mm). With the specimen mounted, the elastomeric rubber strip shall not be compressed by more than 15% of its thickness. For bolts, torque shall be 15 ft-lb. + 4 ft-lb (20Nm+ 5Nm). The impactor shall be suspended from an overhead support, located so when at rest it will, at its maximum diameter, be no more than 0.5 inch (13 mm) from the surface of the specimens and no more than 2 inches (51 mm) from the center of the specimen.

(2) Select a drop height classification from section 5.1.2.1. Rotate the impactor as required. Raise the impactor to the selected drop height intended for classification and stabilize it. At the selected drop height, the suspension device shall be taut and the axes of the impactor and cable shall be in line.

(3) The impactor, stabilized in the launch position in a vertical plane normal to the test specimen, is released and falls without initial velocity or axial rotation. One impact shall occur on each test specimen.

(4) Inspect each test specimen after each impact, record and report whether:
(a) it remained unbroken, or
(b) it broke in an acceptable manner according to the requirements of section 5.1.4, or
(c) it broke and failed to comply with the requirements of section 5.1.4.

(5) If any of the required specimens fail to comply with the requirements of section 5.1.4, terminate the test. The material shall not be classified for impact.

(6) For asymmetric materials, the test shall be carried out on both sides using equal numbers of separate specimens.

(7) When the required number of specimens are impacted and inspected, report the impact classification as described in section 5.1.2. If all specimens tested by impact either do not break, or break according to the requirements of section 5.1.4, the glazing material shall be classified as described in section 5.1.2, at the impact level tested. Classification shall comprise the word "Class", followed by a letter designation ("A" or "B" or "C") for drop height class.

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(8) If it is required to test the material to a higher impact classification level, repeat the test on the required number of undamaged specimens of the same material at the higher impact level. At the fabricator's discretion, previously tested but unbroken specimens may be used for higher impact classification testing.

(9) Each specimen of bent glass will be impacted on the convex surface at the center of the specimen perpendicular to the frame from the selected drop height (see **Figure 3**).

Note: The convex surface is tested due to the realistic constraints of the test set-up in impacting the concave surface. Additionally, as of the date of this publication no data was available that showed one surface is more or less likely to break during impact.

5.1.4 Interpretation of Results.

A glazing material shall be judged to pass the impact test, if any one of the following criteria is met by each of the required number of impact specimens tested:

(1) When breakage occurs with appearance of numerous cracks and fissures, but remains substantially in one piece and no tear or shear or opening develops within the vertical specimens through which a 3.0 inch (76 mm) diameter sphere can pass freely using a horizontally applied force of 4.0 lb. (18 N) or less.

(2) When breakage occurs, the 10 largest crack-free particles shall be selected within 5 minutes subsequent to the impact and shall weigh no more than the equivalent weight of 10 square inches (640 square millimeters) of the original specimen. For purposes of impact test evaluation when breakage occurs, the average thickness of a tempered glass specimen containing grooves, bevels, or other thickness altering fabrication shall be considered the average of the thinnest measurement of each of the ten (10) geometrically largest crack-free particles. This average thickness will then be used to determine the maximum allowable weight of the ten (10) largest crack-free particles.

NOTE: The weight in ounces of 10 square inches of glass is equal to 14.5 times the glass thickness in inches. The weight in grams of 10 square inches of glass is equal to 412 times the glass thickness in inches (16.18 grams/mm).

(3) When breakage occurs due to impact, the stiffness and hardness of the specimens shall be determined. A modulus of elasticity (see ASTM D 7906) less than 750,000 psi (5.17Gpa) and a Rockwell hardness (see ASTM D 785 7) less than M or R 140 shall indicate satisfactory compliance. This shall apply to plastic glazing material only.

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(4) The specimen does not break, remains intact and remains clamped in the frame after impact.

(5) The specimen separates from the frame and no breakage is caused by impact.

(6) The entire specimen separates from the frame after impact, but meets the requirements of sections 5.1.4(1) and 5.1.4(2). An adhesive backing, coating or film shall not contain the ten (10) largest crack-free particles.

5.2 Boil Test for Laminated Glass.

This test shall be made to determine the probable effect of exposure to high temperature and humidity conditions for a long period of time.

5.2.1 Procedure.

Three 12 inch by 12 inch flat specimens, as submitted, shall be immersed, vertically, in water at 150°F + 10°F (65.6°C + 6°C) for 3 minutes and then quickly transferred to and similarly immersed in boiling water. The specimens shall be kept in the boiling water for 2 hours and then removed.

5.2.2 Interpretation of Results.

The glass itself may crack in this test, but no bubbles or other defects shall develop more than 0.5 inch (12 mm) from the outer edge of the specimen or from any crack that may develop. Any specimen in which the glass cracks to an extent confusing the results shall be discarded without prejudice, and another specimen shall be tested in its stead.

5.3 Weathering Tests for Laminates, Organic-Coated Glass and Plastics.

The purpose of these tests is to determine whether these safety-glazing materials will successfully retain their safety characteristics after exposure to weathering conditions for an extended period of time. The weathering methods described in section 5.3.1 shall be used. After weathering, plastics shall be tested as described in section 5.3.2.1, organic-coated glass shall be tested as described in section 5.3.2.2 and laminates shall be tested as described in section 5.3.2.3 in order to evaluate whether or not the safety glazing meets the weathering requirements.

5.3.1 Weathering Methods.

The specimens shall be subjected to one of the following three weathering exposure alternatives. For laminated and organic-coated glass, three specimens with the side marked for exterior exposure shall be exposed to the energy source. The other three

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specimens shall be controls and shall be held in darkness at 73.4°F + 3.6°F (23°C + 2°C) until needed (see sections 5.3.2.2 and 5.3.2.3). For the plastics, see section 4.6.1.

5.3.1.1 One Year Outdoor Exposure in South Florida

Procedure: The specimens shall be exposed in accordance with ASTM D-1435-94 using a 26° North latitude, direct exposure, facing South, open-backed mounting. On average, a one year exposure approximates a Total Ultraviolet (TUV) exposure of 300 + 25 MJ/m2 at 295-385 nm.

5.3.1.2 Enclosed Twin Carbon-Arc Exposure

Apparatus:	The specimens shall be subjected to exposure in a twin carbon-arc lamp apparatus specified as Type D or DH in ASTM D-23-95.
Procedure:	The specimens shall be exposed 2,000 hrs in accordance with ASTM-D1499-92A.
Cycle:	18-min. water spray every 2 hrs (120 min.) with continuous irradiation.
Exposure:	On average, a 2,000 hr twin Carbon-Arc exposure approximates a TUV exposure of 300 + 25 MJ/m2 equivalent to one year South Florida exposure @ 26° North Latitude direct exposure facing South.

5.3.1.3 Xenon-Arc Type Operating Light Exposure

Apparatus:	The specimens shall be subjected to exposure in a Xenon-Arc Type Operating Light Apparatus as specified in ASTM G26-84 or ASTM G155.
Procedure:	The specimens shall be exposed 3,000 hrs in accordance to ASTM D2565-92A (or ISO 4892.2) and the following conditions:
Filter Type:	Borosilicate inner and outer (or equivalent)
Cycle:	102 minutes of irradiation, 18 minutes of irradiation and water spray.
Black Panel Temperature:	158° + 5°F (70° + 3°C)

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Relative Humidity:	50% + 5%
Spray Water:	Deionized
Level of Irradiance:	0.35 to 0.50 watts/m^2@ 340 nm.
Exposure:	Xenon-Arc Exposure - 3780 KJ/m2 @ 340 nm. TUV Exposure - 300 + 25 MJ/m2 @ 295-385 nm. (On average a 3000 hour Xenon arc exposure approximates a one-year direct South Florida exposure @ 26° North Latitude, facing South)

5.3.2 Tests after Weathering

5.3.2.1 Tests for Plastics Only.

Specimens shall be evaluated before and after exposure in accordance with ASTM D 6110-97, Charpy Impact Test, method B, with the following exceptions:

(1) The specimens shall not be notched.
(2) The specimens shall be tested with the exposed surface in tension.
(3) The specimens shall be exposed and tested flatwise.
(4) The span shall be reduced to 2 inches for thin material that may slip through the supports without breaking.
(5) The average of five specimens shall be reported.

Plastic materials shall be acceptable for use as safety glazing if the impact strength as measured by the Charpy Impact Test is not reduced by more than 25% as a result of the outdoor exposure. Some discoloration may develop but defects other than this discoloration shall not develop. No bubbles or other physical degradation shall develop in the exposed portion.

5.3.2.2 Tests for Organic-Coated Glass Only.

Specimens shall be judged satisfactory if they pass the adhesion test (see section 5.3.2.2.1) and the tensile strength test (see section 5.3.2.2.2).

5.3.2.2.1 Adhesion Test.

Six specimens, (nominally 2 inch by 6 inch) prepared as described in section 4.6.2 shall be tested. The specimens shall be conditioned just prior to the performance of the adhesion test at 73.5oF + 3.5oF (23oC + 2oC) and 50% + 2% relative humidity for 24 hours.

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(1) **Apparatus.** The test apparatus shall be (a) a tensile tester of the constant-rate-of-extension (CRE) type with the moving crosshead set to move at 12 inches per minute and the load range set so that the average peel force will fall at 30%-50% of full scale and (b) a cutting device containing new razor blades for cutting 1 inch-wide specimens (use each blade one time only.

(2) **Procedure.** Using the 1 inch razor cutting device, cut a straight strip of the organic coating in the lengthwise direction of the glass sample. Peel back about 2 inches of one end of the 1 inch-wide organic strip. Attach a strip of pressure-sensitive tape to the side of the organic strip opposite the adhesive to extend this free end to about 8 inches in length. Place the end of the glass panel from which the organic strip was removed in the lower clamp of the tensile tester and the free end of the tape in the upper clamp. Peel the remainder of the organic strip from the glass mechanically and obtain a record of the peel value. Determine the average pull for each specimen from the chart record.

(3) **Interpretation of Results.** The organic-coated glass adhesions shall be judged satisfactory if the average adhesion value of the three exposed specimens is no less than 75% of the average adhesion value of the three control (unexposed) specimens.

5.3.2.2.2 Tensile Strength Test.

The samples for this test are the same specimens used in the adhesion test (see section 5.3.2.2.1) and conditioned as in section 5.3.2.2.1.

(1) **Apparatus.** The test apparatus shall be (a) a CRE tensile tester set as follows: gage length - 2 inches; crosshead speed - 2 inches per minute; load range - set full-scale load so that specimens will break at 30%-60% of full scale and (b) a cutter containing new razor blades for cutting 1/2 inch-wide specimens (use each blade one time only).

(2) **Procedure.** Using the 1/2 inch razor cutting device, cut a straight strip of the organic coating in the lengthwise direction of the glass sample for the full 6 inch length. Carefully peel this strip from the glass panel and test it for breaking strength in the tensile strength tester.

(3) **Interpretation of Results.** The organic-coating tensile shall be judged satisfactory if the average tensile value of the three exposed specimens is no less than 75% of the average tensile value of the three control specimens.

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5.3.2.3 Test for laminated glass only.

After exposure, the test specimens may be cleaned, if necessary, using a procedure recommended by their manufacturer to remove any residues present. Both the unexposed and exposed specimens shall be conditioned prior to examination or further testing for a minimum of 48 hours at 22 °C to 24 °C (71 °F to 75 °F) and 50% ± 2% relative humidity. When irradiated and conditioned, the exposed specimens shall be examined and compared visually with the unexposed controls. Specimens shall be placed in a vertical position. The viewer shall look through the specimen using daylight without direct sunlight, or using a background light suitable for observing blemishes. View at 910 mm (36 inch). Any improvement in clarity or discoloration is acceptable. When examined after ultraviolet exposure, each exposed test specimen shall be substantially free of noticeable decomposition as defined by absence of the following specific kinds of developed defects or blemishes, when observed by this inspection method in comparison to unexposed control specimen(s):

(a) No bubbles or delamination shall be visible more than 10 mm (0.4 inch) from any outer edge of the specimen, and
(b) No crazing, cracking or discoloration is allowed.

If no noticeable decomposition and no other defects develop upon exposure, the glazing material shall be reported as visually acceptable. Otherwise, unacceptable glazing material shall be reported as visually blemished.

5.4 Aging Tests for Plastics and Organic-Coated Glass Used in Indoor Applications Only.

The purpose of these tests is to determine whether plastic and organic-coated glass for indoor use only will successfully retain their safety characteristics after exposure to simulated aging conditions for an extended period of time. The specimens described in 4.4 for impact test after aging shall be used.

5.4.1 For Plastics

(1) **Apparatus.** The apparatus described in Section 3 of ASTM D 756-93 shall be used.

(2) **Procedures.** The plastic shall be subject to exposure to warm, humid and dry cycles. Four plastic specimens shall be subjected to 10 complete humid/dry test cycles (480 hours) in accordance with Procedure A of ASTM D 756-93. One additional specimen shall be retained unexposed as a control for the effects of the exposure cycling. Then, all specimens shall be tested as described in section 5.4.3.

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5.4.2 For Organic-Coated Glass

(1) **Apparatus.** A conditioning chamber of sufficient size to hold up to 34 inch by 76 inch panels vertically and capable of maintaining conditions of 140°F + 5°F, 100°F + 5°F and 95% + 5% relative humidity, and 0°F + 5°F.

(2) **Procedure.** Place four of the organic-coated glass specimens positioned vertically and spaced at least 1 inch apart in the chamber. Raise the temperature to 140°F + 5°F within 3 hours and maintain for 21 hours. Change the chamber conditions to 100°F + 5°F and 95% + 5% relative humidity in 3 hours and maintain for 21 hours. This represents one complete cycle. Expose the specimens to 10 complete cycles. At the completion of the tenth cycle, change the chamber conditions to 0°F + 5°F in 3 hours and maintain for 21 hours. The fifth specimen shall be retained unexposed as a control for the effects of the exposure cycling. Upon completion of the required number of exposure cycles, all specimens shall be tested as described in section 5.4.3.

5.4.3 Impact Test after Aging for Plastics and Organic-Coated Glass

(1) **Apparatus.** The apparatus described in section 5.1.1 shall be used.

(2) **Procedure.** All the specimens exposed as described in either section 5.4.1 or section 5.4.2 shall be conditioned as described in section 5.1 and evaluated by the procedure in section 5.1.2.

(3) **Interpretation of Results.** The exposed specimens shall again satisfactorily complete the impact test in accordance with section 5.1.3. Some discoloration or milkiness may develop but defects other than these shall be cause for rejection.

6 Marking of Safety Glazing Material

After having successfully passed the appropriate tests in this standard, like products and materials produced in the same manner as specimens submitted per test shall be legibly and permanently marked with a label.

6.1 Label Content.

The label shall contain the following information:

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(1) Supplier's name, distinctive mark or designation.

(2) The words "American National Standard Z97.1-2004" or the characters "ANSI Z97.1-2004."

(3) Classification of test size (L or U) and drop height class (A, B or C). Plastic glazing does not require drop height.

(4) Place of fabrication (if fabricator has more than one location fabricating the product).

NOTE: Additional details and information, such as thickness and date of manufacture, are permitted.

6.2 Application of Label.

The appropriate party using the following guidelines shall apply the permanent label:

(1) Laminated and fire-resistant wired glass stock sheets (ie, size produced by the manufacturer) shall be labeled by the manufacturer of the stock sheet.

(2) All glazing products including cut size laminates, fire-resistant wired glass and tempered glass) shall be labeled by the company producing the finished cut to size glass product.

(3) The fabricator or manufacturer shall label plastic glazing materials.

(4) The installer of the safety film shall label field-applied organic coatings (films).

6.3 Special Application Labeling.

Certain types of glazing material shall also be marked with additional information as appropriate.

6.3.1 Safety Glazing Materials Used in Indoor Applications Only.

After having successfully passed the appropriate tests (see 5.4), like products and materials produced in the same manner as specimens submitted for testing shall be legibly and permanently marked with the words- "Indoor Use Only".

6.3.2 Organic-Coated Glass Only.

Organic-coated glass materials shall be legibly and permanently marked with the words "Glaze This Side In," to indicate to the installer, inspector, or user which side of the

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organic-coated glass should be exposed to the elements if there is a specific side that should be exposed.

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APPENDIX

(This Appendix is not part of American National Standard Z97.1-2004, but is included for information only.)

Basis of Safety Performance Specifications and Methods of Test

A1. General

One purpose in the development of this standard is to provide a single functional test that will simulate such human contact as normally results in cutting and piercing injuries. The performance of each safety glazing material is evaluated by impacting in the normally installed position. The test should be conducted from the direction that human impact would occur. Only such auxiliary tests as are considered necessary to evaluate the continued performance level, are used in the case of glazing containing organic material.

A2. Safe Performance Criteria (See 5.1.2)

The performance criteria are directly related to the reduction of cutting and piercing injuries to persons who impact the glazing used in buildings.

The 100-ft . lbf and 150-ft . lbf energy levels were established as practically related to those situations in which the limited acceleration path precluded, in most cases, the possibility of an individual developing his full kinetic energy (ke) potential (see Section 1.3.2).

The 400-ft . lbf impact level was established for relatively unlimited acceleration paths in which it might be reasonable to expect that an energetic teenager might develop something approaching his or her full impact velocity.

As Section A3 of this Appendix indicates, the independent safety experts who considered the matter judged that these values were practical. (See Section A3 and Figure A1.)

A3. Development of Human Engineering Data Chart

Safety experts indicate that a 100-lb person is representative of glass breakage accident victims. From Figure A1 it is apparent that a 100-lb person running at the rate of a 4-minute mile has about 755 ft . lbf of kinetic energy. The amount of this energy a person might deliver to a glazed opening would depend upon the way the glazed surface was impacted. A "straight-arm" would transmit more energy to the glazing material than an arm that flexes with the impact.

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For test purposes, Standards Committee Z97 decided, after extensive evaluation, to use a readily available leather punching (speed) bag filled with 100 pounds of lead shot to simulate the running (person). The test impact values were selected as representative of energy levels likely to be delivered by humans in practical situations involving interior doors and patio doors. These test levels were set considerably below the 755-ft . lbf kinetic energy level of the typical victim, since the impact energy delivered to the glazing material - perhaps first by the hands, then by the head, and then by the knees - is much less than the kinetic energy of the running (person). Also, the impact will be at less than normal (90-degree) incident angle in most cases.

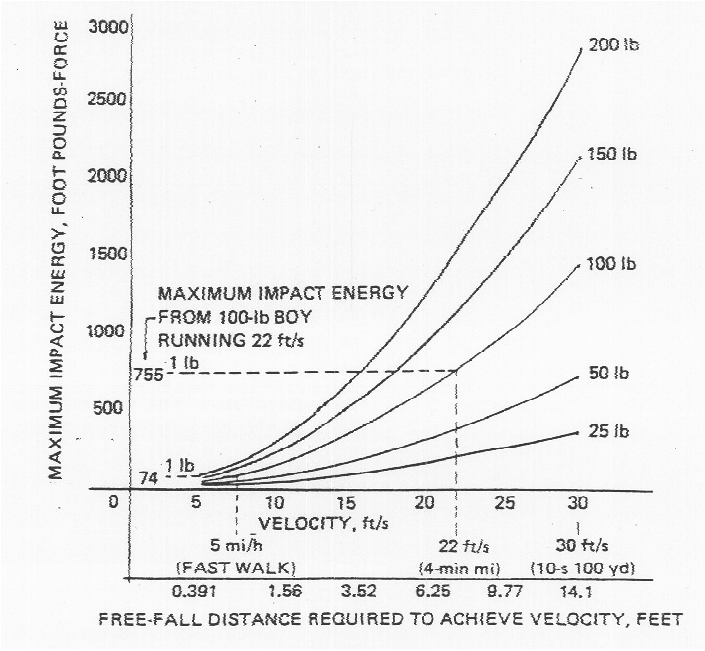

Figure A1: Human Engineering Data

Figure A1 was developed to assist Standards Committee Z97 in establishing performance criteria for safety glazing materials subject to human impact. It is based on the following kinetic energy formula:

$ke = 1/2mv^2$

where

ke = kinetic energy in foot pounds-force
m = mass of missile
= weight of missile in pounds/(32.2 ft/s^2)
v = velocity of missile in feet per second

Maximum impact energy equals the kinetic energy of the person in motion at the moment of impact. Actual impact energy (that which the person delivers) is considerably less, except perhaps in the case of a person falling on a non-vertical surface.

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A4. Interpretation of Results (See 5.1.4)

Within the scope of this standard, which has as its objective minimizing the frequency of cutting and piercing injuries, it is evident that a material that does not break under impact is safe from these types of injuries.

"Break safe" criteria were developed largely as a matter of judgment based on observation of available glazing materials breaking under the test conditions. It is intended that any material that meets any one of the criteria in Sections 5.1.4 be considered safe within the scope of this standard.

To allow for practical interpretation of results, which admittedly may appear loosely defined to the uninitiated, rather severe impact levels were selected. The safety experts and the members of the original drafting committee who observed the many tests conducted in developing the standard were confident that laboratory personnel will quickly develop an ability to apply objective judgments using these criteria.

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