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Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings[1]

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INTRODUCTION

Historical records show that fragments from glazing that has failed as the result of intentional or accidental explosions present a serious threat of personal injury. Glazing failure also allows blast pressure to enter the interior of buildings thus resulting in additional threat of personal injury and facility damage. These risks increase in direct proportion to the amount of glazing used on the building facade. This test method addresses only glazing and glazing systems. It assumes that the designer has verified that other structural elements have been adequately designed to resist the anticipated airblast pressures.

1. Scope

1.1 This test method sets forth procedures for the evaluation of hazards of glazing or glazing systems against airblast loadings. The specifying authority shall provide the airblast loading parameters.

1.2 This test method allows for glazing to be tested and rated with or without framing systems.

1.3 This test method is designed to test and rate all glazing, glazing systems, and glazing retrofit systems including, but not limited to, those fabricated from glass, plastic, glass-clad plastics, laminated glass, glass/plastic glazing materials, and film-backed glass.

1.4 The values stated in SI units are to be regarded as the standard. Values given in parentheses are for information only. For conversion of quantities in various systems of measurements to SI units, see SI 10.

1.5 *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.* See Section 9 for specific hazards statements.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E997 Test Method for Structural Performance of Glass in Exterior Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Destructive Methods

SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *ambient temperature*—24 ± 11°C (75 ± 20°F).

3.1.2 *blast mat*—a steel or concrete pad upon which high explosive may be detonated to reduce the incidence of ejecta.

3.1.3 *effective positive phase duration (T)*—the duration of an idealized triangular positive phase reflected airblast pressure history, having an instantaneous rise to the measured P, with a linear decay to ambient, such that the impulse of the idealized pressure history equals i of the measured positive phase reflected airblast history.

3.1.3.1 *Discussion*—The idealized triangular airblast wave is considered to provide a reliable standard measure of the positive phase airblast intensity.

3.1.4 *glazing*—transparent materials used for windows, doors, or other panels.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.5 *glazing system*—the assembly comprised of the glazing, its framing system, and anchorage devices.

3.1.6 *peak positive pressure (P)*—the maximum measured positive phase airblast pressure, kPa.

3.1.7 *positive phase impulse (i)*—the integral of the measured positive phase reflected airblast pressure history, kPa-ms (psi-ms) (more correctly called the *specific positive phase impulse*).

3.1.8 *reflected airblast pressure*—the pressure increase that a surface, oriented other than parallel to the line from the detonation point to the surface, experiences due to the detonation of a high explosive charge.

3.1.8.1 *Discussion*—The reflected airblast pressure history, whether reflected or otherwise, as measured at a point on the surface, consists of two separate phases. The positive phase is characterized by a nearly instantaneous rise to a maximum pressure followed by an exponential decay to ambient pressure. In the negative phase, which follows immediately the positive phase, the pressure decreases below ambient for a period of time before returning to ambient.

3.1.9 *simply supported glazing*—glazing supported in accordance with Test Method E997 with the edges of the glass extending a minimum of 3-mm (0.125-in.) beyond the neoprene supports.

3.1.10 *test director*—the individual identified by the independent testing laboratory as being responsible to complete the specified tests as required and to document the results, in accordance with this test method.

4. Summary of Test Method

4.1 This test method prescribes the required apparatus, procedures, specimens, and other requirements necessary to determine the hazard rating of a glazing or glazing system subjected to an airblast loading.

5. Significance and Use

5.1 This test method provides a structured procedure to establish the hazard rating of glazing and glazing systems subjected to an airblast loading. Knowing the hazard rating provides the ability to assess the risk of personal injury and facility damage.

5.2 The hazard rating for a glazing or glazing material does not imply that a single specimen will resist the specific airblast for which it is rated with a probability of 1.0. The probability that a single glazing or glazing construction specimen will resist the specific airblast for which it is rated increases proportionally with the number of test specimens that successfully resist the given level of airblast to the hazard level for which it is rated.

6. Number of Specimens

6.1 *Number of Specimens*—A minimum of three test specimens representative of a glazing or glazing system, or a glazing retrofit system, shall be tested at a given level of airblast, defined in terms of P and i.

7. Hazard Rating

7.1 The hazard rating of the glazing or glazing system shall be according to the rating criteria definitions provided below and further demonstrated in Fig. 1. The hazard rating that glazing or glazing systems receive is based upon the severity of fragments generated during an airblast test. The fragment severity is determined based upon the number, size and location of fragments observed during post-test data gathering. Fragments to be considered in rating the glazing or glazing

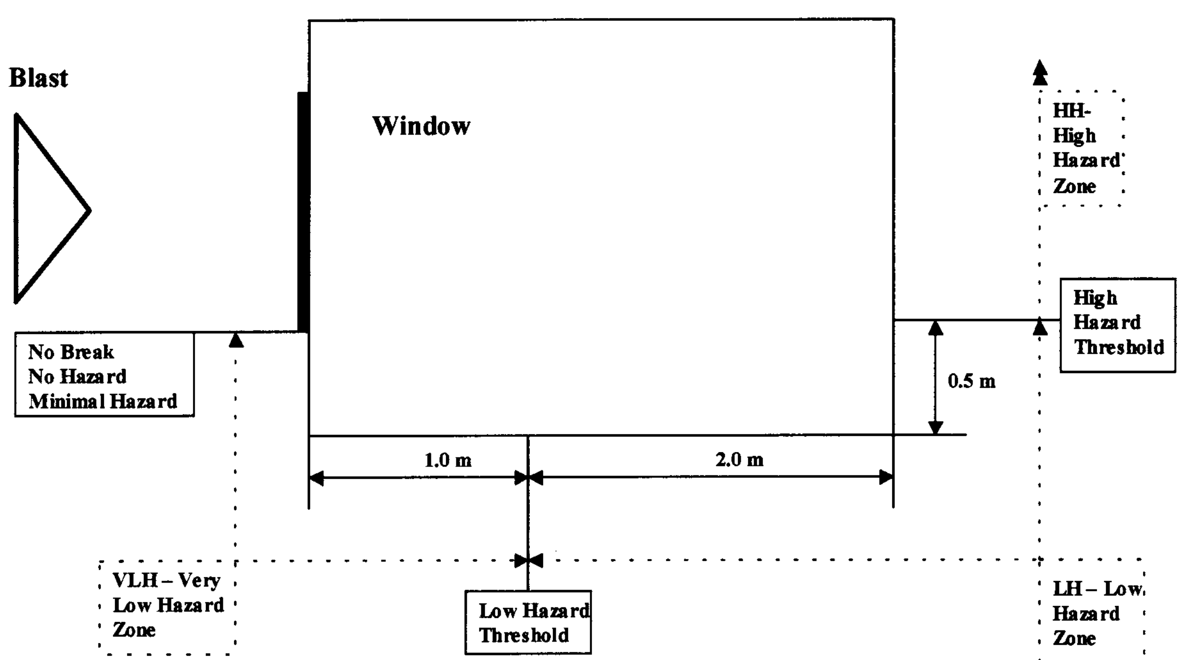

FIG. 1 Cross-section Through Witness Area

system include those generated by the glazing, and any other parts of the glazing system not considered to be part of the test facility. See 8.1 for a definition of the test facility.

7.1.1 *No Break*—The glazing is observed not to fracture and there is no visible damage to the glazing system.

7.1.2 *No Hazard*—The glazing is observed to fracture but is fully retained in the facility test frame or glazing system frame and the rear surface (the side opposite the airblast loaded side of the specimen) is unbroken.

7.1.3 *Minimal Hazard*—The glazing is observed to fracture and the total length of tears in the glazing plus the total length of pullout from the edge of the frame is less than 20 % of the glazing sight perimeter. Also, there are three or less perforations caused by glazing slivers and no fragment indents anywhere in a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and there are fragments with a sum total united dimension of 25 cm (10 in.) or less on the floor between 1 m (40 in.) and 3 m (120 in.) from the interior face of the specimen. Glazing dust and slivers are not accounted for in the rating.

7.1.3.1 *Discussion*—Fragments are defined as any particle with a united dimension of 2.5 cm (1 in.) or greater. The united dimension of a glass particle is determined by adding its width, length, and thickness. Glazing dust and slivers are all other smaller particles.

7.1.4 *Very Low Hazard*—The glazing is observed to fracture and is located within 1 m (40 in.) of the original location. Also, there are three or less perforations caused by glazing slivers and no fragment indents anywhere in a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and there are fragments with a sum total united dimension of 25 cm (10 in.) or less on the floor between 1 m (40 in.) and 3 m (120 in.) from the interior face of the specimen. Glazing dust and slivers are not accounted for in the rating.

7.1.5 *Low Hazard*—The glazing is observed to fracture, but glazing fragments generally fall between 1 m (40 in.) of the interior face of the specimen and 50 cm (20 in.) or less above the floor of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen. Also, there are ten or fewer perforations in the area of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and higher than 50 cm (20 in.) above the floor and none of the perforations penetrate through the full thickness of the foil backed insulation board layer of the witness panel as defined in 8.7.5.

7.1.6 *High Hazard*—Glazing is observed to fracture and there are more than ten perforations in the area of a vertical witness panel located 3 m (120 in.) from the interior face of the specimen and higher than 50 cm (20 in.) above the floor or there are one or more perforations in the same witness panel area with fragment penetration through the first layer and into the second layer of the witness panel.

8. Apparatus

8.1 *Test Facility*—The test facility shall consist of either a shock tube or an open-air arena from which the airblast loading is generated. Open-air arenas should be sited on clear and level terrain and be of sufficient size to accommodate the detonation of the required amount of explosives to provide the desired peak positive pressure and positive phase impulse. The test facility shall also consist of a test frame and witness area as described below. The test director shall ensure that potential environmental impact issues are determined and resolved prior to testing. The test director shall ensure that testing is conducted at ambient temperature in accordance with Section 3.1.1.

8.2 *Airblast Load*—Either a shocktube or a high explosive charge shall be used to generate the desired peak pressure and the positive phase impulse on the test specimen. If an explosive charge is used, the charge shall be hemispherical and detonated either at ground level or elevated by placing the explosive on a table. Elevation of the base of the explosive shall be between 60 cm (24 in.) and 120 cm (48 in.) above the ground where the explosive will be detonated. Other explosive charge configurations can be used. The effects of using other explosive charge configurations must be accounted for and documented. See Annex A1 for information to be used in calculating pressures, impulses, and durations, and for accounting for different types of explosives. Note that the procedures in Annex A1 account for loading from a hemispherical charge imparting load on a large facade and do not address the issues of clearing or other explosive shapes.

8.3 *Blast Mat*—If there is a possibility of crater ejecta interfering with the test, the explosive charge shall be placed on a blast mat. The decision to use a blast mat shall be at the discretion of the test director.

8.4 *Test Frame*—A test frame suitable for supporting glazing or glazing systems shall be part of the test facility. Glazing tested without a specific framing system shall be, as a minimum, supported in a simple support subframe that is attached to the test frame. At the request of a test sponsor, other subframe support conditions may be used. If a glazing system is tested, the glazing system shall be mounted to the test frame in a manner that closely models the manner in which it will be mounted in the field. The test frame shall be capable of resisting the airblast loads with deflections that do not exceed $L/360$ along lines of support for the simple support subframe or the glazing system. The area immediately behind the test specimens shall be designated as the witness area. For arena testing, the witness area shall be enclosed to prevent airblast pressure from wrapping behind the test specimens, and shall be designed to resist the wrap around pressures.

8.5 *Simple Support Subframe*—A subframe, attachable to the test frame, to support glazing in accordance with Test Method E997.

8.6 *Witness Area*—The witness area shall have the following dimensions. The floor shall be 500 ± 50 mm (20 ± 2 in.) below the subframe opening used to receive the glazing or glazing system, unless the specifying authority dictates that the glazing or glazing system shall be tested per its position in a building. The ceiling shall be a minimum of 10 cm (4 in.) from the top of the subframe opening used to receive the glazing or glazing system. The sides shall be a minimum of 10 cm (4 in.) from the subframe opening used to receive the glazing or glazing system. The back wall of the witness area shall be 3.0 ± 0.15 m (120 ± 6 in.) from the interior glazing face of the specimen.

8.7 *Instrumentation:*

8.7.1 *Pressure Transducers*—A minimum of three reflected and one free field airblast pressure transducers shall be used in each test frame or in a separate transducer panel for arena testing. A minimum of three reflected pressure transducers shall be used for shocktube testing. The airblast pressure transducer shall be capable of defining the anticipated airblast pressure history within the linear range of the transducer. The transducers shall have a rise/response time and resolution sufficient to capture the complete event. Limited low frequency response transducers shall have a discharge time constant equal to approximately 30 to 50 times the initial positive phase duration of the anticipated reflected airblast pressure history.

8.7.2 *Data Acquisition System (DAS)*—The DAS shall consist of either an analog or digital recording system with a sufficient number of channels to accommodate the pressure transducers and any other electronic measuring devices. The DAS must operate at a sufficiently high frequency to record reliably the peak positive pressure. The DAS shall also incorporate filters to preclude alias frequency effects from the data.

8.7.3 *Photographic Equipment*—Photographic equipment shall be available to document the test.

8.7.4 *Temperature Measuring Device (TMD)*—A TMD shall be used to accurately measure glazing surface temperatures.

8.7.5 *Witness Panels*—A witness panel for glazing or glazing systems being tested shall be mounted parallel to and at a distance no greater than 3.0 ± 0.15 m (120 ± 6 in.) from the interior face of the specimens. The witness panel shall cover the entire back wall of the witness area and shall consist of two layers of material. The witness panel shall consist of a rear layer of 25-mm (1-in.) extruded Styrofoam with a density of 28.0 kg/m^3 (1.8 lb/ft^3) to 32.0 kg/m^3 (2.0 lb/ft^3) and a front layer consisting of 12.5-mm (0.5-in.) rigid foam plastic thermal insulation board composed of polyisocyanurate foam bonded to a durable white-matte non-glare aluminum facer and a reflective reinforced aluminum facer. The reflective surface shall be placed toward the window glazing. The insulation board shall have a density of 32.0 kg/m^3 (2.0 lb/ft^3). The reflective reinforced facer shall be 0.008-cm (0.003-in.) thick and shall be reinforced through lamination to Kraft paper. To accommodate high-speed photography, a hole no greater than 10 by 10 cm (4 by 4 in.) may be made in the upper or lower one-ninth quadrants of the witness panel.

9. Hazards

9.1 Storage, handling, and detonation of high explosive material or the operation of a shocktube should be conducted in accordance with applicable state and federal statutes by experienced professionals.

10. Specimens

10.1 The test sponsor shall provide the test specimens. The number of specimens provided shall consist of the number of specimens to be tested but no less than three specimens per pressure and impulse combination for which testing is to be accomplished, plus one additional specimen for pretest measurements.

10.2 The test director shall ensure that the test specimens are handled and stored in compliance with manufacturer's instructions.

10.3 Each specimen shall be marked indelibly with the manufacturer's model and serial numbers and the date of manufacture.

10.4 Each specimen shall be marked clearly to indicate its proper orientation to the explosive charge to preclude improper installation in the test frame.

10.5 To ensure proper support of glazing system test specimens, the test director shall obtain engineering information on anchoring details from the manufacturer.

11. Preparation of Apparatus and Specimens

11.1 *Instrumentation:*

11.1.1 For arena tests, three pressure transducers shall be installed on the test frame or on a transducer panel of the same size as the test frame and located and oriented in the same manner as the test frame. The pressure transducers shall be flush with the surface of the test frame or transducer panel, facing the detonation point. For test frames capable of supporting multiple specimens, the transducers shall be located on the horizontal centerline of the test specimens at a distance from the edge of the test specimens not to exceed one half the shortest dimension of the specimen. For test frames capable of holding only a single specimen, two transducers shall be located on the horizontal centerline of the specimen and one at the top of the vertical centerline of the specimen. The distance from the edge of the test specimen shall not exceed one half the shortest dimension of the specimen. For shocktube tests, two pressure transducers shall be installed on the test frame and one on the sidewall of the shocktube. The two pressure transducers on the test frame shall have one located on the horizontal centerline and one located on the vertical centerline of the test specimen.

11.1.2 For arena tests, at least one free-field pressure transducer shall be used in each test. The free-field pressure transducer shall be located at least 760 cm (25 ft) from any frame at the same distance from the high explosive charge as is the frame.

11.1.3 The pressure transducers shall then be connected to the DAS and tested to verify proper operation.

11.2 *Test Frames:*

11.2.1 The test specimens shall be installed in the test frame. The face of the test frame with the test specimens installed shall be approximately a plane surface. No openings shall exist in this surface through which airblast pressure can infiltrate behind the test specimens. The area immediately behind the test specimens shall be enclosed to prevent airblast pressure from wrapping behind the test specimens.

11.2.2 The test frame shall be placed so that the test specimens are oriented perpendicular to a line from the detonation or air release point to the center of the test frame.