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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 The data obtained from testing under this method shall be used to determine the glazing or glazing system hazard rating using Specification F2912.

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

1.4 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.

1.5 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~~E699.

1.6 *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~~7 for specific hazards statements.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E699 Practice for Evaluation of Agencies Involved in Testing, Quality Assurance, and Evaluating of Building Components

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~~F2912 ~~American National Standard for Use of the International System of Units (SI): The Modern Metric System~~Specification for Glazing and Glazing Systems Subject to Airblast Loadings

2.2 *ISO Standard:*

ISO/IEC International Standard 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.3 *ANSI Standard:*

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

[1] This test method is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipmentand is the direct responsibility of Subcommittee F12.10 on Systems Products and Services.

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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. Terminology

3.1 *Definitions:*

3.1.1 *airblast pressure*—the pressure increase that a surface experiences due to the detonation of a high explosive charge.

3.1.1.1 *Discussion*—

The airblast pressure history, 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.

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

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

3.1.4 *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.

3.1.4.1 *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.

3.1.5 *glazing system*—*hazard level*—the assembly comprised of the glazing, its framing system, and anchorage devices.rating assigned to the performance of the glazing system based on the amount and location of integral materials expelled from the system under specific blast conditions of the test.

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.

3.1.8 *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.

3.1.9 *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 4.1 This test method prescribes the required apparatus, procedures, specimens, and other requirements necessary to determine the hazard rating execute a physical test for the purpose of determining the hazard rating for a single test specimen, in accordance with Specification F2912, 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 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.

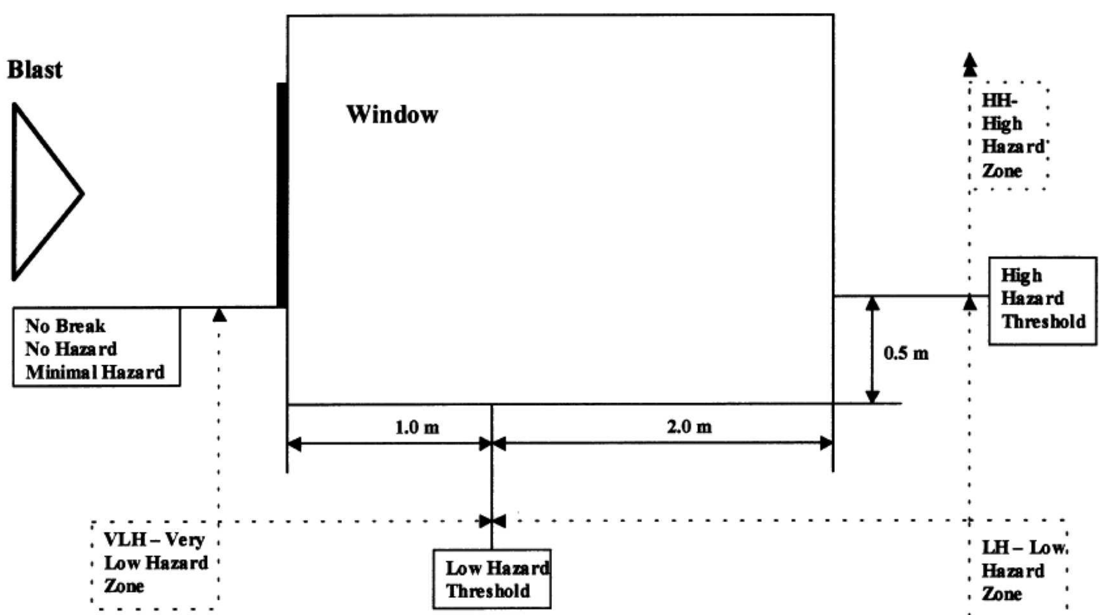

FIG. 1 Cross-sectionCross-Section Through Witness Area

6. Apparatus

6.1 *Test Facility*—Test facilities shall be accredited for this method to the requirements of ISO/IEC 17025 or qualified according to Practice E699. 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 with inboard and outboard surfaces of the test specimen at ambient temperature in accordance with ~~Section~~ 3.1.1.

6.2 *Airblast Load*—Either a ~~shocktube~~ shock tube 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.

6.3 *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.

6.4 *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.

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

6.6 *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.

6.6.1 *Discussion*—For doors, curtain wall, storefront or window wall systems that may span slab to slab, the witness area shall include a floor at the specified finished floor level for each level. And, the back wall of the witness area shall be 3.0 ± 0.15 m (120 ± 6 in.) from the most interior glazing face of the specimen at all levels.

6.7 *Instrumentation:*

6.7.1 *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.

6.7.2 *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.

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

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

6.7.5 *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.

7. Hazards

7.1 Storage, handling, and detonation of high explosive material or the operation of a ~~shocktube should~~ shock tube shall be conducted in accordance with applicable state and federal statutes ~~by experienced professionals.~~and regulations by experienced professionals qualified by a U.S. government agency to handle explosives.

8. Specimens

8.1 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.~~In addition the test sponsor shall provide complete specimen documentation, to include but not be limited to drawings and material specifications. In addition, strength certifications for each component used in the load path of the glazing product shall be provided.

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

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

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

8.5 ~~To ensure proper support of glazing system test specimens, the test director shall obtain engineering information on anchoring details from the manufacturer.~~Glazing systems shall be installed per manufacturer's instructions.

9. Preparation of Apparatus and Specimens

9.1 *Instrumentation:*

9.1.1 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.~~ panel. 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.~~

9.1.2 For shock tube tests, two pressure transducers shall be installed on the test frame and one on the sidewall of the shock tube. 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 shock tube.

9.1.3 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.

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

9.2 *Test Frames:*

9.2.1 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.

9.2.2 ~~The~~ Unless specified otherwise, 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.

9.3 *Specimens:*

9.3.1 The test director shall assign a number, and mark accordingly, each test specimen.

9.3.2 Thickness measurements of the glazing material shall be made at each corner, ~~1 in.~~ 25 mm (1 in.) in from the edges, and recorded. Measurements of the lengths of the edges of the specimens shall be made and recorded.

9.3.3 For ~~glazing system specimens, one of the specimens provided by the test sponsor shall be selected at random and disassembled for the purpose of taking measurements. The measurements shall include~~ specimens to be tested, measurements verifying compliance with manufacturer's drawings shall be performed. The measurements shall include but not be limited to the edge dimensions of the frame and the glazing material, the cross-sectional dimensions of the frame, and thickness measurements of the glazing material. ~~The materials frame and glazing materials shall be verified to comply with the manufacturer's specifications.~~

9.4 *Photography:*

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

9.4.2 If a photographic record of the response of the test specimens during the test is desired, high speed motion picture cameras or high speed video cameras, or both, shall be set up.

9.5 *Witness Panels:*

9.5.1 Witness panels shall be put in place to record spalling from the test specimen.

10. Report

10.1 ~~Upon completion of a test of glazing specimen(s), the test director shall report the results of the test.~~ Report the following mandatory information:

10.1.1 *General:*

10.1.1.1 Name and address of testing agency, name and address of test sponsor, date and time of test, and date of report,

10.1.1.2 The name(s) of individual(s) conducting the test and the author of the test report, and

10.1.1.3 Signatures of persons responsible for supervision of the tests and a list of official observers.

10.1.2 *Specimen Description*—~~Description of test glazing or glazing system specimens, including pertinent dimensions, construction, glazing materials, and~~ Manufacturer, model number, trade name, or other product designation of test specimens; operation type, materials, required material certifications and other pertinent information of test specimens; description of locking and operating mechanisms if applicable; connection and anchorage description, glass thickness, type, and method of glazing; weather seal dimensions, type, and material; installed location of specimens relative to ~~the~~ witness ~~area,~~area.

10.1.3 *Specimen Drawings*—~~Complete description of framing,~~Detailed drawings of the specimen showing dimensioned section profiles, sash dimensions and arrangement, framing location, panel arrangement, installation and spacing of anchorage, details of connections, weatherstripping, locking arrangement, hardware, sealants, glazing details, and any other pertinent construction details. The test director shall verify that these drawings match the tested specimen. Any modification made on the specimen to obtain the reported test values shall be noted.

~~12.1.3 Number of specimens tested,~~

~~12.1.4 Ambient temperature measured no more than 30 min prior to the test,~~

~~12.1.5 Temperature of the glazing measured no more than 5 min prior to the test,~~

10.1.4 ~~Peak positive pressure measured from each reflected airblast pressure transducer on the frames supporting the test specimens,~~*Test Parameters:*

10.1.4.1 Ambient temperature measurement no more than 30 min prior to the test.

10.1.4.2 Temperature of the glazing measured no more than 15 min prior to the test.

10.1.4.3 Peak positive pressure measured from each airblast pressure transducer on the frames supporting the test specimens.

10.1.4.4 Positive phase duration measured from each airblast pressure transducer on the frame supporting the test specimen.

10.1.4.5 Positive phase impulse, i, calculated for each airblast pressure transducer on the frames supporting the test specimens.

10.1.4.6 The recorded airblast pressure history in graphical form from each pressure transducer.

~~12.1.7 Positive phase duration measured from each reflected airblast pressure transducer on the frames supporting the test specimens,~~

~~12.1.8 Positive phase impulse, *i*,~~

~~12.1.9 The recorded airblast pressure history from each pressure transducer,~~

~~12.1.10 Condition of the test specimens immediately following the test,~~

~~12.1.11 Damage to the witness panels as determined by detailed examination,~~

10.1.5 *Results of Testing*—~~Status~~Number of ~~the specimens (that is, what hazard level rating~~ specimens and results of each specimen tested ~~received).~~in terms of hazard level in accordance with Specification F2912. The results of each specimen shall be reported, each specimen being properly identified, particularly with respect to distinguishing features or differing adjustments. Any additional data or information considered to be useful to provide a better understanding of the test results, conclusions, or recommendations.

10.1.6 *Compliance Statement*—A statement that the tests were conducted in accordance with this test method, or a complete description of any deviation from this test method.

10.2 The test report shall contain the photographic record of the test setup in accordance with ~~11.4~~9.4. In addition, the test report shall contain detailed photographs of each test specimen following the test. Each specimen shall be labeled in the post-test photographs to allow for clear identification.

10.3 If any motion picture records are made of the performance of the test specimens, such motion picture records shall become part of the test report.

10.4 The original copy of the test report shall be furnished to the sponsor of the test. The test director shall keep a copy of the test report on file.