Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials[1]

1. Scope

1.1 This test method determines the performance of exterior windows, curtain walls, doors, and impact protective systems impacted by missile(s) and subsequently subjected to cyclic static pressure differentials. A missile propulsion device, an air pressure system, and a test chamber are used to model some conditions which may be representative of windborne debris and pressures in a windstorm environment. This test method is applicable to the design of entire fenestration or impact protection systems assemblies and their installation. The performance determined by this test method relates to the ability of elements of the building envelope to remain unbreached during a windstorm.

1.2 The specifying authority shall define the representative conditions (see 10.1).

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

1.4 *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.* Specific hazard statements are given in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 330 Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference

E 631 Terminology of Building Constructions

E 997 Test Method for Structural Performance of Glass in Exterior Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Destructive Methods

E 1233 Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential

2.2 *ANSI/ASCE Standard:*

ANSI/ASCE 7, American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures[3]

2.3 *American Lumber Standard:*

Document PS20-94—American Softwood Lumber Standard[4]

3. Terminology

3.1 *Definitions:* General terms used in this test method are defined in Terminology E 631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *2 × 4 in. lumber*—a dressed piece of surface dry, softwood lumber as defined in Document PS20-94.

3.2.2 *air pressure cycle*—beginning at a specified air pressure differential, the application of positive (negative) pressure to achieve another specified air pressure differential and returning to the initial specified air pressure differential.

3.2.3 *air pressure differential*—the specified differential in static air pressure across the specimen, creating an inward (outward) load, expressed in Pa (lb/ft^2). The maximum air pressure differential (P) is specified or is equal to the design pressure.

3.2.4 *basic wind speed*—the wind speed as determined by the specifying authority.

3.2.5 *design pressure*—the uniform static air pressure difference, inward or outward, for which the test specimen would be designed under service load conditions using conventional

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[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.51 on Performance of Windows, Doors, Skylights, and Curtain Walls.

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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] Available from the American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191.

[4] Available from the American Lumber Standard Committee, Inc., P.O. Box 210, Germantown, MD 20875.

structural engineering specifications and concepts. This pressure is determined by either analytical or wind tunnel procedures (such as are specified in ANSI/ASCE 7).

3.2.6 *fenestration assembly*—the construction intended to be installed to fill a wall or roof opening.

3.2.7 *missile*—the object which is propelled toward a test specimen.

3.2.8 *positive (negative) cyclic test load*—the specified difference in static air pressure, creating an inward (outward) loading, for which the specimen is to be tested under repeated conditions, expressed in Pa (lb/ft^2).

3.2.9 *impact protective system*—construction applied, attached, or locked over an exterior glazed opening system to protect that system from windborne debris during high wind events.

3.2.9.1 *Discussion*—Impact protective system include types that are fixed, operable, or removable.

3.2.10 *specifying authority*—the entity responsible for determining and furnishing information required to perform this test method.

3.2.11 *test loading program*—the entire sequence of air pressure cycles to be applied to the test specimen.

3.2.12 *test specimen*—the entire assembled unit submitted for test.

3.2.13 *windborne debris*—objects carried by the wind in windstorms.

3.2.14 *windstorm*—a weather event, such as a hurricane, with high sustained winds and turbulent gusts capable of generating windborne debris.

4. Summary of Test Method

4.1 This test method consists of mounting the test specimen, impacting the test specimen with a missile(s), and then applying cyclic static pressure differentials across the test specimen in accordance with a specified test loading program, observing and measuring the condition of the test specimen, and reporting the results.

5. Significance and Use

5.1 Structural design of exterior windows, curtain walls, doors, and impact protective systems is typically based on positive and negative design pressure(s). Design pressures based on wind speeds with a mean recurrence interval (usually 25–100 years) that relates to desired levels of structural reliability and are appropriate for the type and importance of the building **(1)**.[5] The adequacy of the structural design is substantiated by other test methods such as Test Methods E 330 and E 1233 which discuss proof loads as added factors of safety. However, these test methods do not account for other factors such as impact from windborne debris followed by fluctuating pressures associated with a severe windstorm environment. As demonstrated by windstorm damage investigations, windborne debris is present in hurricanes and has caused a significant amount of damage to building envelopes **(2-7)**. The actual in-service performance of fenestration assemblies and impact protective systems in areas prone to severe windstorms is dependent on many factors. Windstorm damage investigations have shown that the effects of windborne debris, followed by the effects of repeated or cyclic wind loading, were a major factor in building damage **(2-7)**.

5.1.1 Many factors affect the actual loading on building surfaces during a severe windstorm, including varying wind direction, duration of the wind event, height above ground, building shape, terrain, surrounding structures, and other factors **(1)**. The resistance of fenestration or impact protective systems assemblies to wind loading after impact depends upon product design, installation, load magnitude, duration, and repetition.

5.1.2 Windows, doors, and curtain walls are building envelope components often subject to damage in windstorms. The damage caused by windborne debris during windstorms goes beyond failure of building envelope components such as windows, doors, and curtain walls. Breaching of the envelope exposes a building's contents to the damaging effects of continued wind and rain **(1, 4-7)**. A potentially more serious result is internal pressurization. When the windward wall of a building is breached, the internal pressure in the building increases, resulting in increased outward acting pressure on the other walls and the roof. The internal pressure coefficient (see ANSI/ASCE 7), which is one of several design parameters, can increase by a factor as high as four. This can increase the net outward acting pressure by a factor as high as two.

5.1.3 The commentary to ANSI/ASCE 7-93 discusses internal pressure coefficients and the increased value to be used in designing envelopes with "openings" as follows:

> "Openings" in Table 9 (*Internal Pressure Coefficients for Buildings*) means permanent or other openings that are likely to be breached during high winds. For example, if window glass is likely to be broken by missiles during a windstorm, this is considered to be an opening. However, if doors and windows and their supports are designed to resist specified loads and the glass is protected by a screen or barrier, they need not be considered openings. (109)

Thus, there are two options in designing buildings for windstorms with windborne debris: buildings designed with "openings" (partially enclosed buildings) to withstand the higher pressures noted in the commentary to ANSI/ASCE 7-93 and, alternatively, building envelope components designed so they are not likely to be breached in a windstorm when impacted by windborne debris. The latter approach reduces the likelihood of exposing the building contents to the weather.

5.2 In this test method, a test specimen is first subjected to specified missile impact(s) followed by the application of a specified number of cycles of positive and negative static pressure differential **(8)**. The assembly must satisfy the pass/fail criteria established by the specifying authority, which may allow damage such as deformation, deflection, or glass breakage.

5.3 The windborne debris generated during a severe windstorm varies greatly, depending upon windspeed, height above the ground, terrain, surrounding structures, and other sources of debris **(4)**. Typical debris in hurricanes consists of missiles including, but not limited to, roof gravel, roof tiles, signage, portions of damaged structures, framing lumber, roofing materials, and sheet metal **(4,7,9)**. Median impact velocities for

[5] The boldface numbers in parentheses refer to the list of references at the end of this standard.

missiles affecting residential structures considered in Ref **(7)** ranged from 9 m/s (30 fps) to 30 m/s (100 fps). The missiles and their associated velocity ranges used in this test method are selected to reasonably represent typical debris produced by windstorms.

5.4 To determine design wind loads, averaged wind speeds are translated into air pressure differences. Superimposed on the averaged winds are gusts whose aggregation, for short periods of time (ranging from fractions of seconds to a few seconds) may move at considerably higher speeds than the averaged winds. Wind pressures related to building design, wind intensity versus duration, frequency of occurrence, and other factors are considered.

5.4.1 Wind speeds are typically selected for particular geographic locations and probabilities of occurrence from wind speed maps such as those prepared by the National Weather Service, from appropriate wind load documents such as ANSI/ASCE 7 or from building codes enforced in a particular geographic region.

5.4.2 Equivalent static pressure differences are calculated using the selected wind speeds **(1)**.

5.5 Cyclic pressure effects on fenestration assemblies after impact by windborne debris are significant **(6-8, 10-12)**. It is appropriate to test the strength of the assembly for a time duration representative of sustained winds and gusts in a windstorm. Gust wind loads are of relatively short duration. Other test methods, such as Test Methods E 330 and E 1233, do not model gust loadings. They are not to be specified for the purpose of testing the adequacy of the assembly to remain unbreached in a windstorm environment following impact by windborne debris.

5.6 Further information on the subjects covered in Section 5 is available in Refs **(1-12)**.

6. Apparatus

6.1 Use any equipment capable of performing the test procedure within the allowable tolerances.

6.2 *Major Components*:

6.2.1 *Mounting Frame*—The fixture which supports the test specimen in a vertical position during testing. The maximum deflection of the longest member of the mounting frame either during impact or the maximum specified static air pressure differential shall not exceed *L*/360, where *L* denotes the longest unsupported length of a member of the mounting frame. Deflection measurements shall be made normal to the plane of the specimen at the point of maximum deflection. The mounting frame shall be either integral with the test chamber or capable of being installed into the test chamber prior to or following missile impact(s). The mounting frame must be anchored so it does not move when the specimen is impacted.

6.2.2 *Air Pressure Cycling Test Chamber*—An enclosure or box with an opening against which the test specimen is installed. It must be capable of withstanding the specified cyclic static pressure differential. Pressure taps shall be provided to facilitate measurement of the cyclic static pressure differential. They shall be located such that the measurements are unaffected by air supplied to or evacuated from the test chamber or by any other air movements.

6.2.3 *Air Pressure System*—A controllable blower, a compressed air supply/vacuum system, or other suitable system capable of providing the required maximum air pressure differential (inward and outward acting) across the test specimen. Specified pressure differentials across the test specimen shall be imposed and controlled through any system that subjects the test specimen to the prescribed test loading program. Examples of suitable control systems include manually operated valves, electrically operated valves, or computer controlled servo-valves.

6.2.4 *Air Pressure Measuring Apparatus*—Pressure differentials across the test specimen shall be measured by an air pressure measuring apparatus with an accuracy of ±2 % of its maximum rated capacity, or ±100 Pa (2 psf), whichever is less, and with a response time less than 50 ms. Examples of acceptable apparatus are: mechanical pressure gages and electronic pressure transducers.

6.2.5 *Missile Propulsion Device(s)*—Any device capable of propelling the missile at a specified speed, orientation, and impact location. The missile shall not be accelerating upon impact due to the force of gravity along a line normal to the specimen. Examples of commonly used missile propulsion devices are found in Appendix X1.

6.2.6 *Speed Measuring System*—A system capable of measuring missile speeds within the tolerances defined in 11.2.1. Typical speed measuring systems are described in Appendix X2.

6.2.7 *Missile*—Missiles shall be one or more of the following:

6.2.7.1 *Small Missile*—A solid steel ball having a mass of 2 g (0.004 lb) ± 5 %, with an 8-mm (5⁄16-in.) nominal diameter, and an impact speed between 0.40 and 0.85 of the basic wind speed (3-s gust in accordance with ANSI/ASCE 7).

6.2.7.2 *Large Missile*—A No. 2 or better Southern Yellow Pine or Douglas Fir 2 × 4 in. lumber having an American Lumber Standard Committee accredited agency mark having a mass of between 2050 g ± 100 g (4.5 ± 0.25 lb) and 6800 g ± 100 g (15.0 ± 0.25 lb) and having a length between 1.2 m ± 100 mm (4 ft ± 4 in.) and 4.0 m ± 100 mm (13.2 ft ± 4 in.) and an impact speed between 0.10 and 0.55 of the basic wind speed (3-s gust in accordance with ANSI/ASCE 7). The missile shall have no defects, including knots, splits, checks, shakes, or wane within 30 cm (12 in.) of the impact end. The impact end shall be trimmed square in accordance with the rules certified by the American Lumber Standard Committee. If required for propulsion, a circular sabot having a mass of no more than 200 g (0.5 lb) may be applied to the trailing edge of the large missile. The mass and length of the large missile includes the mass and length of the sabot.

6.2.7.3 *Other Missile*—Any other representative missile with mass, size, shape, and impact speed as a function of basic wind speed determined by engineering analysis such as Ref **(9)**.

7. Hazards

7.1 This test method involves potentially hazardous situations. Proper precautions shall be taken to protect all personnel.

7.2 All observers shall be isolated from the path of the missile during the missile impact portion of the test.

7.3 Keep observers at a safe distance from the test specimen during the entire procedure.

8. Test Specimens

8.1 The test specimen shall consist of the entire fenestration or impact protective system assembly and contain all devices used to resist wind and windborne debris. Test specimens for large fenestration and curtain wall assemblies shall be one panel unless otherwise specified.

8.2 All parts of the test specimen shall be full size, as specified for actual use, using the identical materials, details, and methods of construction.

9. Calibration

9.1 The speed measuring system shall be calibrated to an accuracy of ±2 % of the elapsed time required to measure the speed of the specified missile. Calibration shall be performed at the manufacturers specified interval, but in any event, not more than six months prior to the test date. The speed measuring system shall be calibrated by at least one of the following methods:

9.1.1 Photographically, using a stroboscope and a still camera,

9.1.2 Photographically, using a high speed motion picture or video camera with a frame rate exceeding 500 frames per second and capable of producing a clear image and a device that allows single frame viewing,

9.1.3 Using gravity to accelerate a free-falling object having negligible air drag through the timing system and comparing measured and theoretical elapsed times, or

9.1.4 Using any independently calibrated speed measuring system with an accuracy of ±1 %.

9.2 Electronic pressure transducers shall be calibrated at 6 month intervals using a NIST traceable calibrating system or a manometer readable to 2.5 Pa.

9.3 Calibration of manometers is normally not required provided the instruments are used at a temperature near their design temperature.

10. Required Information

10.1 The specifying authority shall supply the following information and requirements:

10.1.1 Number of test specimens,

10.1.1.1 Conditioning temperature of specimens,

10.1.2 Pass/fail criteria,

10.1.3 Basic wind speed,

10.1.4 Missile,

10.1.4.1 Description of the missile, including dimensions, mass, and tolerances,

10.1.4.2 Missile speed at impact, or the equation relating missile speed to basic wind speed,

10.1.4.3 Missile orientation at impact,

10.1.4.4 Number of impacts, and

10.1.4.5 Location of impacts on the test specimens and tolerances.

10.1.5 Test loading program, and

10.1.5.1 The maximum air pressure differential and its relationship to the design pressure,

10.1.5.2 The positive and negative cyclic test loads,

10.1.5.3 The number of cycles of cyclic test load sequence to be applied, and

10.1.5.4 The minimum and maximum duration for each cycle.

10.1.6 Whether or not certification of the calibration is required.

11. Test Procedure

11.1 *Preparation*—Remove from the test specimen any sealing or construction material that is not intended to be used when the unit is installed in or on a building. Support and secure the test specimen into the mounting frame in a vertical position using the same number and type of anchors normally used for product installation as defined by the manufacturer or as required for a specific project. If this is impractical, install the test specimen with the same number of equivalent fasteners located in the same manner as the intended installation. This test shall not be used to evaluate anchorage of curtain wall and heavy commercial assemblies. In those cases, the specimen shall be securely anchored to facilitate testing. The test specimen shall not be removed from the mounting frame at any time during the test sequence.

11.1.1 Unless otherwise specified, separate and condition the specimens for at least 4 h within a temperature range of 15°C to 35°C (59°F to 95°F).

11.1.2 *Missile Impact*—Secure the specimen and mounting frame such that the missile will impact the exterior side of the specimen as installed.

11.1.3 Locate the end of the propulsion device from which the missile will exit at a minimum distance from the specimen equal to 1.5 times the length of the missile. This distance shall be no less than 1.80 m.

11.1.4 Set up appropriate signal/warning devices to prevent test or other personnel, or both, from coming between the propulsion device and the test specimen during testing.

11.1.5 Weigh each missile within 15 min prior to impact.

11.1.6 Load the missile into propulsion device.

11.1.7 Reset the speed measuring system.

11.1.8 Align the missile propulsion device such that the specified missile will impact the test specimen at the specified location.

11.2 Propel the missile at the specified impact speed and location.

11.2.1 The measured missile speed will be within the following respective tolerances at any point after the missile acceleration caused by the propulsion device equals zero:

±2 % specified speed when speed ≤23 m/s
±1 % specified speed when speed >23 m/s

11.2.2 For missiles having a longitudinal axis, on impact the longitudinal axis of the missile shall be within ±5° of a line normal to the specimen at the specified impact point.

NOTE 1—From a horizontal datum, measure the vertical height to the center of the exit end of the propulsion device (if it is horizontal), h_B, and the vertical height to the center of the missile impact point on the specimen, h_I. To ensure the missile rotates less than 5° prior to impact:

$$5° \leq \tan^{-1}\left|\frac{h_B - h_I}{d}\right| \quad (1)$$

where d denotes horizontal distance from the exit end of the propulsion device to the specimen.

11.3 If required, repeat steps 11.1.4-11.2 at all additional impact locations specified for the specimen.

11.4 *Air Pressure Cycling*—If the mounting frame is not integral within the test chamber, attach the mounting frame to the test chamber such that the exterior side of the test specimen faces outward from the chamber.

11.4.1 If at any time during testing the specified maximum pressure differential cannot be achieved in either direction due to excessive air leakage, cover all cracks and joints through which leakage occurs with tape or film in such manner as to stop the leakage. Tape shall not be used when there is a probability that it will restrict significantly differential movement between adjoining segments of the specimen, in which case cover both sides of the test specimen with a single thickness of polyethylene or other plastic film no thicker than 0.050 mm (0.002 in.). The technique of application is important in order that the full load is permitted to be transferred to the test specimen and that the film does not prevent movement or failure of the test specimen. Apply the film loosely with extra folds of material at each corner and at all offsets and recesses. When the load is applied there shall be no fillet caused by tightness of the plastic film.

11.4.2 Unless otherwise specified, apply the cyclic static pressure differential loading in accordance with Table 1 in which P denotes the maximum inward (positive) and outward (negative) air pressure differentials as defined in 3.2.3.

11.4.2.1 Unless otherwise specified, the duration of each air pressure cycle shall not be less than 1 s and not more than 5 s. Dwell time between successive cycles shall be no more than 1 s.

11.4.2.2 Interruptions for equipment maintenance and repair shall be permitted.

11.4.2.3 It is permitted for the test specimen to be removed, reversed and reinstalled in the test chamber between the positive and negative pressure cycles.

11.4.2.4 The test specimen shall not contact any portion of the test chamber at any time during the application of the cyclic static pressure differential loading.

12. Report

12.1 Report the following information:

12.1.1 Date of test and report,

12.1.2 Names and addresses of the testing agency that conducted the tests and the requester of the tests,

12.1.3 Manufacturer's model number or any other method of identification,

TABLE 1 Cyclic Static Pressure Differential Loading

Loading Sequence	Loading Direction	Air Pressure Cycles	Number of Air Pressure Cycles
1	Positive	0.2P–0.5P	3500
2	Positive	0.0P–0.6P	300
3	Positive	0.5P–0.8P	600
4	Positive	0.3P–1.0P	100
5	Negative	0.3P–1.0P	50
6	Negative	0.5P–0.8P	1050
7	Negative	0.0P–0.6P	50
8	Negative	0.2P–0.5P	3350

12.1.4 A description of the test specimen, including all parts and components, glazing thickness and construction, and the number of specimens tested,

12.1.5 Detailed drawings of the test specimen, showing dimensioned section profiles, sash or door dimensions and arrangement, framing location, panel arrangement, installation and spacing of anchorage, weather-stripping, locking arrangement, hardware, sealants, glazing details, test specimen sealing methods, and any other pertinent construction details,

12.1.5.1 Any deviation from the drawings or any modifications made to the test specimen to obtain the reported values shall be noted on the drawings and in the report.

12.1.6 When the tests are made to check conformity of the test specimen to a particular specification or pass/fail criteria, an identification or description of that specification or criteria,

12.1.7 Results for each test specimen,

12.1.8 Impact test,

12.1.8.1 The location of impact(s) on each test specimen,

12.1.8.2 The exact description of the missile including dimensions and mass (weight),

12.1.8.3 The missile speed and orientation at impact, and

12.1.8.4 The conditioning temperature of the specimens.

12.1.9 Cyclic pressure test,

12.1.9.1 The cyclic static pressure loading differential and sequence,

12.1.9.2 The maximum air pressure differential (P) and its relationship to the design pressure, and

12.1.9.3 A statement as to whether or not tape or film, or both, were used to seal against air leakage and whether in the judgment of the test engineer the tape or film influenced the results of the test.

12.1.10 A description of the condition of the test specimens after completion of each portion of testing, including details of damage and any other pertinent observations,

12.1.11 A statement that the tests were conducted in accordance with this test method,

12.1.12 A statement of whether, upon completion of testing, the test specimens pass or fail in accordance with any specified criteria,

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

12.1.14 Signatures of persons responsible for supervision of the tests and a list of all observers, and

12.1.15 Any additional data or information considered to be useful to a better understanding of the test results, conclusions, or recommendations. (Append to report.)

13. Precision and Bias

13.1 Due to the lack of sufficient test data, the precision and bias of this test method cannot be determined at this time. Similar test methods have been performed by several laboratories, however, there are differences between tests currently being performed and this test method.

14. Keywords

14.1 cyclic pressure loading; fenestration; hurricanes; impact protective systems; missile impact; windborne debris; windstorms

APPENDIXES

(Nonmandatory Information)

X1. MISSILE PROPULSION DEVICES

X1.1 For those wishing to use missile propulsion devices which have already been developed to launch certain types of missiles, the following apparatus are recommended:

X1.2 *Large Missile Air Cannon*—The large missile air cannon shall use compressed air to propel the large missile. The cannon shall be capable of producing missile impact at the speeds defined in 6.2.7.2. The large missile cannon shall consist of four major components: a compressed air supply, a pressure release valve, a barrel and support frame, and a speed measuring system for determining the missile speed.

X1.2.1 The barrel of the large missile cannon shall consist of a 100-mm (4-in.) nominal inside diameter pipe and shall have a length at least as long as the missile. The total length of the barrel shall be the distance from the pressure valve to the vent holes in advance of the timing system or to the mouth of the barrel. The barrel of the large missile cannon shall be mounted on a support frame in a manner to facilitate aiming the missile so that it impacts the specimen at the desired location.

X1.2.2 The large missile is defined in 6.2.7.2. The end of the missile that impacts the target is denoted as the missile's impact end. The end of the missile opposite to the impact end is denoted as the missile's trailing edge. A sabot shall be used at the trailing edge of the missile to facilitate launching.

X1.2.3 The speed of the missile shall be measured on the trailing edge of the missile after it exits the barrel. The photoelectric sensors can be mounted on an extension of the barrel or supported independently of the cannon. In either case the missile shall not be accelerating as its trailing edge passes between the photoelectric sensors.

X1.3 *Bungee Test Apparatus*

X1.3.1 *Suggested Components*:

X1.3.1.1 A rigid PVC (or other suitable) pipe having a 100-mm (4-in.) nominal inside diameter and a minimum length of 2.75 m.

X1.3.1.2 Three to five 7.62-m lengths of 10-mm outside diameter × 5-mm inside diameter latex rubber surgical tubing banded together.

X1.3.1.3 One 50 × 100 × 150-mm wood block with threaded eye hook mounted to and projecting from either 100 × 150-mm face.

X1.3.1.4 Two through-beam photoelectric sensors of the same make and model with accuracy tolerances no greater than ±2 %.

X1.3.1.5 Mounting frame of general construction capable of supporting pipe and timing and timing system without movement during test.

X1.3.1.6 One 3-m steel cable with a quick release snap hook attached to one end.

X1.3.1.7 Hand operated cable winch with ratchet lock.

X1.3.2 *Assembly*:

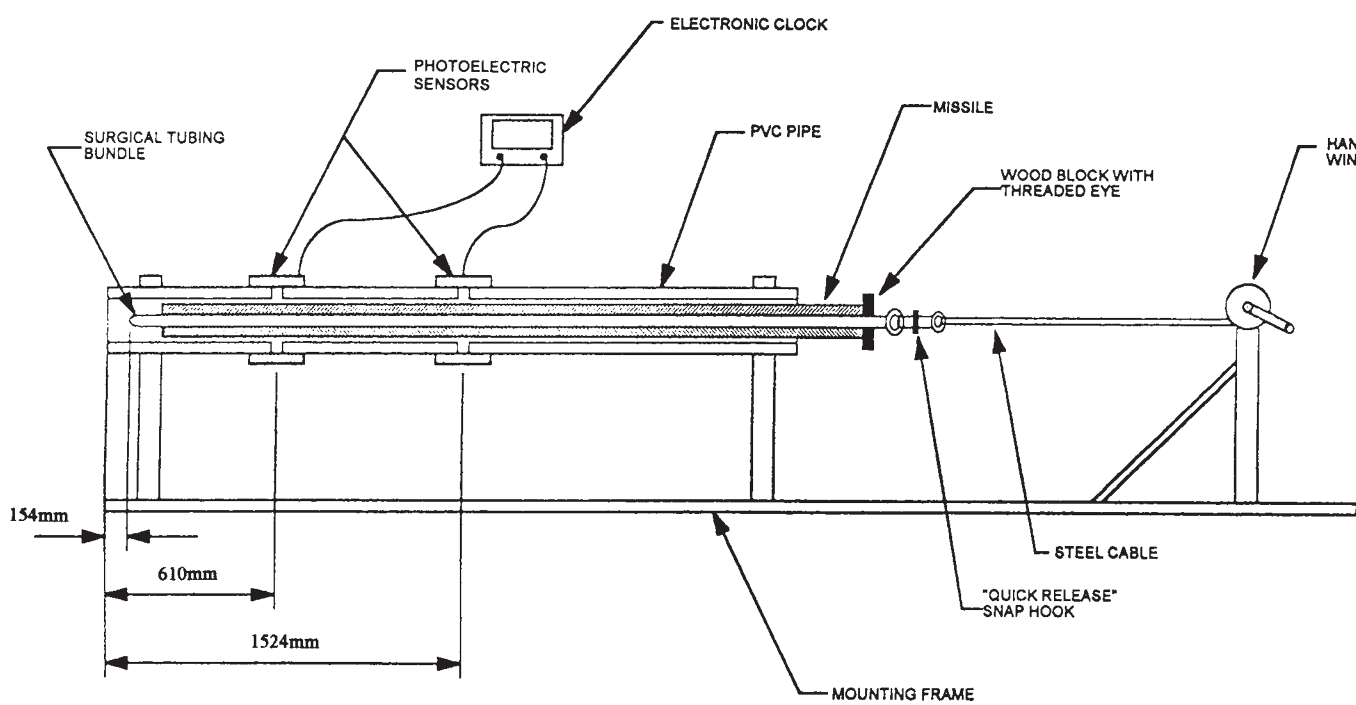

FIG. X1.1 Bungee Test Apparatus

X1.3.2.1 Assembly described is illustrated in Fig. X1.1.

X1.3.2.2 Drill two holes through each side of the PVC pipe 610 mm and 1520 mm from one end of the pipe, respectively. Holes should be of sufficient size to allow the light beams from the photoelectric sensors to pass through the holes unobstructed across the diameter of the pipe.

X1.3.2.3 Mount the photoelectric sensors on the pipe such that the light beams pass through the respective holes from one side of the pipe to the other across the pipe's diameter.

X1.3.2.4 Drill one hole through each side of the PVC pipe approximately 150 mm from the end of the pipe upon which the sensors are mounted. These holes should be located 90° around the pipe circumference from the holes described in X1.3.2.2.

X1.3.2.5 Thread each end of the surgical tubing bundle through one of the respective holes described in X1.3.2.4 and fix the ends such that they cannot pull out. Pull the center of the bundle through the pipe such that it exits the pipe at the opposite end.

X1.3.2.6 Attach the wood block to the surgical tubing bundle such that the center of the block is aligned with the center of the bundle. The 100 × 150-mm face of the block with the eye hook protruding from it should face away from the end of the tube from which the tubing bundle exits.

X1.3.2.7 Mount the tube/surgical tubing assembly to the frame as illustrated in Fig. X1.1.

X1.3.2.8 Mount the hand winch to the frame in the illustrated location. Fix the end of the steel cable that does not have the quick release snap hook to the winch and wrap the cable around the drum of the winch. The end of the cable with the snap hook should hang free.

X1.3.2.9 Connect the quick release snap hook to the eye hook of the wood block and draw enough cable on the winch drum to place a slight tension in the surgical tubing bundle.

X1.3.3 *Operation*:

X1.3.3.1 Place the large missile in the pipe such that the non-impacting end of the missile rests on the wood block of the surgical tubing bundle.

X1.3.3.2 Crank the hand winch to draw wood block back to place tension in the surgical tubing bundle. The amount of tension placed in the bundle is based on the number of tubes in the bundle and the required missile propulsion speed.

X1.3.3.3 Reposition the missile such that the end is centered on the wood block.

X1.3.3.4 Setup and zero timing system for speed measurement.

X1.3.3.5 Align pipe such that the projected missile will impact the test specimen at the specified location.

X1.3.3.6 Release retaining pin of the quick release snap hook to release wood block and propel missile.

X1.4 *Small Missile Cannon*—A compressed air cannon shall be used that is capable of propelling missiles of the speed and size defined in 6.2.7.1. The cannon assembly shall be comprised of a compressed air supply, a remote firing device and valve, a barrel, and a timing system. The small missile cannon shall be mounted on a frame designed to permit movement of the cannon so that it can propel missiles to impact the test specimen at specified locations. The photoelectric sensors shall be positioned to measure missile speed within 150 cm of the impact point on the test specimen.

X2. SPEED MEASURING SYSTEMS

X2.1 For those wishing to use speed measuring devices that have already been developed, the following three systems are recommended.

NOTE X2.1—These do not require special design; other systems are possible.

X2.2 *Photoelectric Sensors*—Two photoelectric sensors shall be used. Both photoelectric sensors shall be the same model. An electronic timing device shall be activated when the reference point of the missile passes the first sensor. The electronic timing device shall be stopped when the reference point of the missile passes the second sensor. The electronic timing device shall have an operating frequency of no less than 10 kHz with a response time not to exceed 0.15 ms. The speed of the missile shall be determined by dividing the distance between the two through-beam photoelectric sensors by the time interval counted by the electronic timing device.

X2.3 *High Speed Video Camera*—A high speed video camera and a single frame viewing device as specified in 9.1.2 may be used as the speed measuring system in lieu of the speed measuring system described in X2.2. The high speed video camera shall be used in conjunction with an appropriate grid that may be fixed background or on the missile, and a reference line that may be the trailing edge of the missile or a fixed background, respectively. The video camera shall be used to record the relative distance traveled between the line and the grid. The speed of the missile is computed as the product of the distance traveled in two consecutive frames and the frame rate of the high speed video camera. For example, if the frame rate of the high speed video camera is 500 frames per second and the recorded change in position is 27 mm, then the missile speed is 500 × 0.027 = 13.5 m/s.

X2.4 *Standard Video Camera*—A standard video camera and a four head videotape playback device with stop action capabilities may be used. The time between consecutive images is $1/30$ s.

X3. TESTING GLAZING PANELS

X3.1 For those wishing to use the apparatus and procedures specified in this test method to test glazing materials, the following procedure is recommended.

X3.2 *Terminology:*

X3.2.1 *Glazing panel*—The transparent or translucent portion of the fenestration assembly which shall be comprised of glass, wired glass, laminated glass, glass/plastic laminates, plastic sheet, or insulating glass.

X3.2.2 *Glazing material*—The material used to make a glazing panel.

X3.3 *Procedure:*

X3.3.1 This test procedure shall be conducted on glazing panel specimens that are used in windows, doors, curtain walls, or other fenestration products.

X3.3.2 *Standard Test Frame*—The standard test frame shall be capable of supporting a rectangular glazing panel in a vertical plane. The standard test frame shall conform to Test Method E 997.

X3.3.3 Glazing panels shall be mounted in the test frame in accordance with Test Method E 997.

X3.3.4 Glazing panels mounted in the standard test frame shall be tested using the procedures outlined in this test method.

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