Designation: E 1233 – 00

Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Cyclic Air Pressure Differential[1]

This standard is issued under the fixed designation E 1233; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes the determination of the structural performance of exterior windows, curtain walls, and doors under cyclic air pressure differential, using a test chamber. This test method is applicable to all curtain wall assemblies, including, but not limited to, metal, glass, masonry, and stone components.

1.2 This test method is intended only for evaluating the structural performance associated with the specified test specimen, and not the structural performance of adjacent construction.

1.3 Procedure A shall be used for life cycle test loads.

1.4 Procedure B shall be used for wind event test loads.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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. Specific hazard statements are given in Section 7.*

2. Referenced Documents [2]

2.1 *ASTM Standards:*

E 330 Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference[3]

E 631 Terminology of Building Constructions[3]

E 997 Standard Test Method for Structural Performance of Glass in Exterior Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Destructive Method[3]

E 998 Standard Test Method for Structural Performance of Glass in Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Nondestructive Method[3]

E 1886 Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials[3]

E 1996 Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Wind Borne Debris in Hurricanes[3]

2.2 *ASCE Standard:*[4]

ASCE 7 (formerly ANSI A58.1) Minimum Design Loads for Buildings and Other Structures

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology E 631, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *design wind load, n*—the uniform static air pressure difference, inward or outward, for which the specimen would be designed under service load conditions using conventional wind engineering specifications and concepts, expressed in pascals (or pounds-force per square foot). This pressure is determined by either analytical or wind-tunnel procedures (such as are specified in ASCE 7).

3.2.2 *one cycle, n*—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 *permanent deformation, n*—displacement or change in dimension of the specimen after the applied load has been removed and the specimen has relaxed for the specified period of time.

3.2.4 *positive (negative) cyclic test load, n*—the specified differential in static air pressure, creating an inward (outward) loading, for which the specimen is to be tested under repeated conditions, expressed in pascals (or pounds-force per square foot).

3.2.5 *positive (negative) maximum test load, n*—the specified differential in static air pressure, creating an inward

[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 Component Performance of Windows, Curtain Walls, and Doors.

Current edition approved June 10, 2000. Published August 2000. Originally published as E 1233 – 88. Last previous edition E 1233 – 97.

[2] Additional information on curtain wall assemblies can be obtained from the American Architectural Manufacturers' Association, 1827 Walden Office Square, Suite 104, Schaumburg, IL 60173.

[3] *Annual Book of ASTM Standards*, Vol 04.11.

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

(outward) load, for which the specimen is to be tested for required minimum ultimate strength, expressed in pascals (or pounds-force per square foot).

3.2.6 *stick system*, *n*—a curtain wall assembly composed of individually framed continuous members, vertical mullions, and horizontal rails that are installed in a sequential, piece-by-piece process. The completed system is assembled entirely in the field.

3.2.7 *structural distress*, *n*—a change in condition of the specimen indicative of deterioration under repeated load or incipient failure, such as cracking, fastener loosening, local yielding, or loss of adhesive bond.

3.2.8 *test specimen*, *n*—the entire assembled unit submitted for test (as described in Section 8).

3.2.9 *unit/panel system*, *n*—a curtain wall assembly composed of pre-assembled groups of individual framing members. The completed system is designed to be modular, transportable, and installed as a finished assembly.

4. Summary of Test Method

4.1 This test method consists of sealing the test specimen into or against one face of a test chamber, supplying air to or exhausting air from the chamber in accordance with a specific test loading program at the rate required to maintain the test pressure differential across the specimen, and observing, measuring, and recording the deflection, deformations, and nature of any structural distress or failures of the specimen.

4.2 The test loading program calls for the application of a specified spectrum of pressure cycles followed by the application of positive and then negative maximum test loads. The specifier must provide the information required in Section 10.

5. Significance and Use

5.1 This test method is a standard procedure for determining structural performance under cyclic air pressure differential. This typically is intended to represent the long-term effects of repeated applications of wind load on exterior building surface elements or those loads that may be experienced during a hurricane or other extreme wind event. This test method is intended to be used for installations of window, curtain wall, and door assemblies for which the effects of cyclic or repeated loads may be significant factors in the in-service structural performance of the system and for which such effects cannot be determined by testing under a single application of uniform static air pressure. This standard is not intended to account for the effect of windborne debris. This test method is considered appropriate for testing unique constructions or for testing systems that have insufficient in-service records to establish their performance under cyclic loading.

5.1.1 The actual loading on building surfaces is quite complex, varying with wind direction, time, height above ground, building shape, terrain, surrounding structures, and other factors. The resistance of many window, curtain wall, and door assemblies to wind loading is also complex and depends on the complete history of load magnitude, duration, and repetition. These factors are discussed in ASCE 7 and in the literature **(1-12)**[5].

5.2 This test method is not intended for use in evaluating the adequacy of glass for a particular application. When the structural performance of glass is to be evaluated, the procedure described in Standard Test Method E 997 or E 998 shall be used.

5.3 The proper use of this test method requires knowledge of the principles of pressure and deflection measurement.

5.4 Two types of cyclic air pressure differentials are defined: (Procedure A) Life cycle load (X1.1) and (Procedure B) Wind event load (X1.2). When testing under uniform static air pressure to establish structural performance, including performance under proof load, Standard Test Method E 330 applies. Consideration of windborne debris in combination with cyclic air pressure differential representing extreme wind events is addressed in Standard Test Method E 1886 and Standard Specification E 1996.

5.5 Typical practice in the United States for the design and testing of exterior windows, curtain walls, and doors has been to consider only a one-time application of design wind load, increased by an appropriate factor of safety. This design wind load is based on wind velocities with actual average probabilities of occurrence of once in the design life of the structure. The actual in-field performance of such assemblies, however, is dependent on many complex factors, and there exists significant classes of applications where the effects of repeated or cyclic wind loading will be the dominating factor in the actual structural performance, even though the magnitudes of such cyclic loads may be substantially lower than the peak load to which the assembly will be subjected during its design life. Examples of assemblies for which the effects of cyclic loading may be significant are included in Appendix X2.

5.5.1 When cyclic load effects are significant, the actual in-field performance of the assembly will depend on the complete load history to which the assembly is subjected. The history includes variable sustained loads as well as gusts, which occur at varying frequencies and durations. Such load histories are not deterministic, requiring the specifier to resort to a probabilistic approach for test parameters. The resistance of an assembly to cyclic loading is similarly complex. When available, endurance curves (stress/number *(S/N)* curves) can be used to estimate the fatigue resistance of a particular material. A major uncertainty in applying these data, however, is that the stress in an element induced by a unit pressure load is usually not known a priori. The problem is further complicated by the fact that the load to which the in situ assembly is subjected is not a repetitive load of given magnitude but one that varies in frequency, duration, and magnitude such as loads associated with a wind event.

[5] The boldface numbers in parentheses refers to the list of references at the end of this test method.

5.5.2 To establish practical test parameters, the considerations in 5.1-5.5.1 must be modeled by a simple loading program that approximates the actual loading with respect to its damage potential. For the case of life cycle loads, the anticipated actual loading may include critical pressures that will occur with greater frequency during the design life of the structure than is practical to use for testing. In such cases, the actual load magnitude and number of repetitions must be represented in the test by an equivalent load of larger magnitude and fewer repetitions. For the case of specific wind event loads, the entire test loading program may be developed from wind tunnel testing or by using methods defined in the literature.

5.5.3 In this test method, the test assembly is first subjected to pressure cycles. The assembly is expected to survive this loading without apparent structural distress. Following this, the assembly is subjected to positive and negative maximum test loads. The maximum test loads may represent sustained loads or gust loads, or both.

5.6 Design wind velocities may be selected for particular geographic locations and probabilities of occurrence based on data from wind velocity maps such as provided in ASCE 7.

5.7 The person specifying the test must translate the anticipated wind velocities and durations into static air pressure differences and durations. Complexities of wind pressures as related to building design, wind intensity versus duration, frequency of occurrence, and other factors must be considered. Superimposed on sustained winds are gusting winds which, for short periods of time, from fractions of seconds to a few seconds, may move at considerably higher velocities than the sustained winds. Wind tunnel studies, computer simulations, and model analyses are helpful in determining the appropriate wind pressures for buildings by showing how a particular building acts under wind velocities established by others. **(1-6)**[5].

5.8 Specification of a test program based on a comprehensive treatment of all of the above considerations is a complex task. The procedures presented in Appendix X1 may be used to establish test parameters when a comprehensive analysis of the problem is not possible. The procedures account for the expected magnitude variation and occurrence frequency in wind velocities; they are not intended to account for turbulent wind load or structural resonance effects **(2)**.

5.9 Some materials have strength or deflection characteristics that are time dependent. Therefore, the duration of the applied test load may have a significant impact on the performance of materials used in the test specimen; the most common examples of materials with time-dependent response characteristics that are used in curtain walls are glass, plastics, and composites that employ plastics. For this reason, the strength of an assembly is tested for the actual time duration to which it would be exposed to a sustained or a gust load, or both, as discussed below. For practical purposes, cyclic load effects are to be considered to be durationin-dependent, and the cyclic test loads need be applied only long enough for the chamber pressure to stabilize. In the past, practice in the United States generally has been to require a minimum test period for maximum test loads of 10 s for specified loads equal to 1.5 times the design pressure, unless otherwise specified. Thus a safety factor was incorporated in the testing. With higher test loads and longer time durations, the designer must also consider what safety factors are essential, particularly with regard to gust wind loads. Gust wind loads are of relatively short duration, so that care shall be exercised not to specify or allow unnecessarily long duration loads for purposes of testing the adequacy of the structure to withstand wind gusts.

NOTE 1—In applying the results of tests by this test method, note that the performance of a wall or its components, or both, may be a function of fabrication, installation, and adjustment. The specimen may or may not truly represent every aspect of the actual structure. In service, the performance will also depend on the rigidity of the supporting construction and on the resistance of components to deterioration by various other causes, including vibration, thermal expansion, contraction, etc.

6. Apparatus

6.1 The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

6.2 *Major Components (see* Fig. 1*)*:

6.2.1 *Test Chamber*—A test chamber or box with an opening, a removable mounting panel, or one open side in which or against which the specimen is installed. Static pressure taps shall be provided to measure the pressure difference across the test specimen and shall be so located that the reading is unaffected by the velocity of air supplied to or from the chamber or from any other air movements. A means shall be provided to facilitate test specimen adjustments and observations. Neither the test chamber nor the specimen mounting frame shall deflect under the test load in such a manner that the performance of the specimen will be affected.

6.2.2 *Air System*—A controllable blower, a compressed-air supply, an exhaust system, or reversible controllable blower designed to provide the required maximum air-pressure difference across the specimen. The system shall provide an essentially constant air-pressure difference for the required test period.

NOTE 2—For Procedure A, Life cycle load, it is convenient to use a reversible blower or a separate pressure and exhaust system to provide the required air-pressure difference so that the test specimen can be tested for

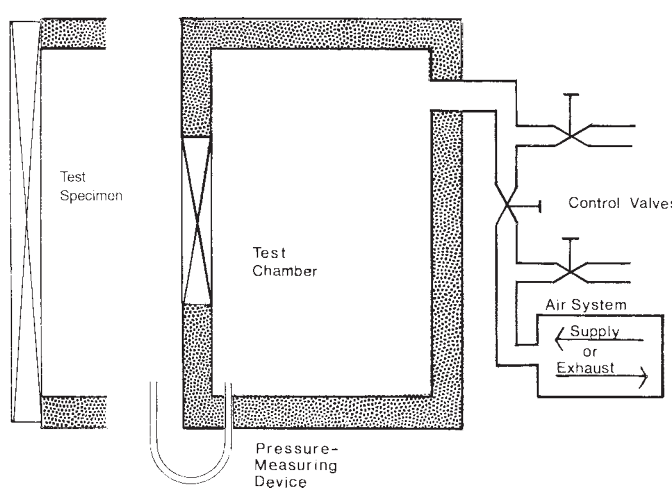


FIG. 1 General Arrangement of Testing Apparatus

the effect of wind blowing against the wall (positive pressure) or for the effect of suction on the lee side of the building (negative pressure) without removing, reversing, and reinstalling the test specimen. For Procedure B, Wind event load, it is not necessary to use a reversible blower. In this case, it is permitted for the test specimen to be removed, reversed and reinstalled in the test chamber between the positive and negative pressure cycles. If an adequate air supply is available, a completely airtight seal need not be provided around the perimeter of the test specimen and the mounting panel, although it is preferable. However, substantial air leakage will require an air supply of much greater capacity to maintain the required pressure differences.

6.2.3 *Pressure-Measuring Apparatus*—A device to measure the test pressure difference within a tolerance of ±2 %, or ±2.5 Pa (±0.01 in. of water column), whichever is greater.

6.2.4 *Deflection-Measuring System*—A means of measuring deflections within a tolerance of ±0.25 mm (±0.01 in.).

6.2.4.1 Any locations at which deflections are to be measured shall be stated by the specifier.

6.2.4.2 When deflections are to be measured, the deflection gages shall be installed so that the deflections of the components can be measured without being influenced by possible movements of, or movements within, the specimen or member supports.

6.2.4.3 For tests to determine the ultimate performance of a specimen, deflection-measuring devices with lesser accuracy may be used. Permanent deformation of unsymmetrical or unsymmetrically loaded members, or both, can be determined by the use of a straightedge gage applied to the members after preloading and again after the test load has been removed.

7. Hazards

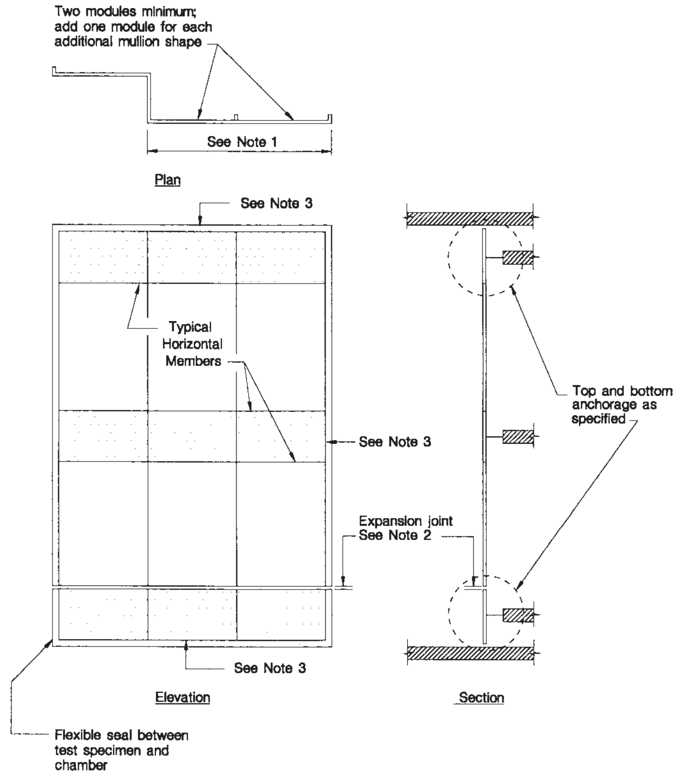
7.1 Take proper precautions to protect the observers in the event of any failure. At the pressures used in this test method, considerable energy and hazard are involved.

NOTE 3—**Warning:** Do not permit personnel in pressure chambers during tests.

8. Test Specimen

8.1 Curtain wall test specimens shall be of sufficient size and configuration to determine the performance of all typical parts of the system and to provide full loading on each typical vertical and horizontal framing member, including building comer details and end joints, if applicable. For multi-story systems, the specimen height shall not be less than two full building stories plus the height necessary to include at least one full horizontal joint accommodating vertical expansion. If water testing is to be performed on the test specimens, at least one full horizontal joint accommodating vertical expansion shall be included and located in the bottom third of the specimen. The specimen shall include all typical expansion joints, connections, anchorages, and supporting elements including those at the top, bottom, and both sides of the specimen. Where the largest system or building wall is smaller than that required herein, the largest system or full size building wall shall be tested. (See Figs. 2 and 3 for optional specimen configurations.)

8.1.1 All parts of the wall test specimen shall be full size, using the same materials, details and methods of construction, and anchorage as used on the actual building.



NOTE 1—Width of typical specimen if no comers are included in system or project.

NOTE 2—Include vertical expansion joint comers and end (jamb) conditions in test specimen if such items are part of system or project wall. If water testing is to be performed, place one expansion joint in lower third of specimen.

NOTE 3—See 8.1.2 for structural support requirements at specimen perimeter.

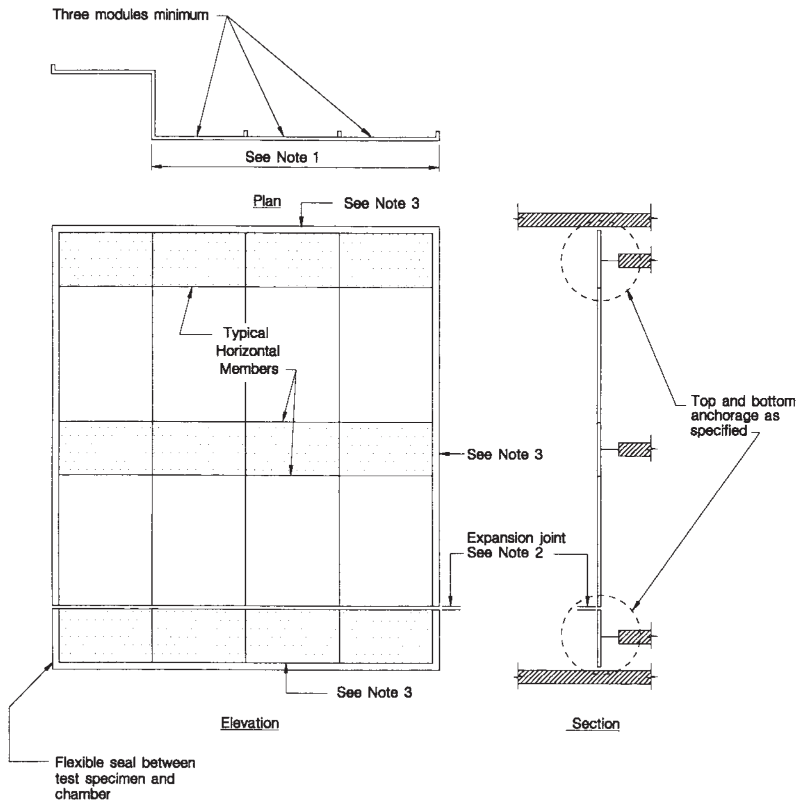
FIG. 2 Typical Stick-System Test Specimen Concept

8.1.2 Conditions of the structural support by the test chamber shall simulate, as accurately as possible, the structural conditions of the actual building. Separate tests of anchorage systems using the actual anchors and anchor substrates shall be conducted when specified.

8.2 A window, door, or other wall component test specimen shall consist of the entire assembled unit, including frame and anchorage as supplied by the manufacturer for installation in the building, or as set forth in a referenced specification, if applicable.

8.2.1 If only one specimen is to be tested, the specifying authority shall determine the selection.

NOTE 4—Since performance is likely to be a function of size and geometry, select specimens covering the range of sizes to be used in a building. In general, the largest size or most heavily or critically loaded of a particular design, type, construction, or configuration to be used should be tested. In general, the largest lite or panel to be used in a system or building should be used at each side of a horizontal or vertical framing member. The glass in a specimen should be of the same thickness and heat-treatment condition as to be used in the system or building. Glass stronger than that to be used in a system or building should not be used in a test specimen. ASTM E 1300 should be used to verify that the selected glass will meet the specified design wind load. Fully sealed roof coping details do not have to be included in a specimen unless specified.



NOTE 1—Width of typical specimen if no comers are included in system or project.
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NOTE 3—See 8.1.2 for structural support requirements at specimen perimeter.

FIG. 3 Typical Unit/Panel System Test Specimen Concept

9. Calibration

9.1 All pressure and deflection measuring devices, except manometers and mechanical deflection measuring devices, shall be calibrated in accordance with the manufacturer's specification in accordance with the tolerances provided in Section 6 but in any event no more than six months prior to testing. Calibration of manometers and mechanical deflection measuring devices are normally not required, provided the instruments are used at a temperature near their design temperature.

10. Information Required

10.1 In specifying this test method, the specifying authority shall supply the following information: (See Appendix X1 for suggested test criteria)

10.1.1 *Procedure A*, Life cycle load or *Procedure B*, Wind event load procedure,

10.1.1.1 The positive and negative cyclic test loads (see 3.2.4) or design wind load (see 3.2.1),

10.1.1.2 The number and duration of cycles to be applied,

10.1.1.3 Those points in the test loading sequence at which deflections and qualitative observations shall be recorded,

10.1.1.4 The positive and negative maximum test loads,

10.1.1.5 The duration of the maximum test loads, and

10.1.1.6 The number and location of deflection measurements required, if any.

11. Procedure

11.1 *Preparation*—Remove from the test specimen any sealing or construction material that is not to be used when the assembly is installed in or on a building. Fit the specimen into or against the chamber opening. The outdoor side of the specimen shall face the higher pressure side for positive loads; the indoor side shall face the higher pressure side for negative loads. Support and secure the specimen by the same number and type of anchors used in installing the unit in a building or, if this cannot be accomplished, by the same number of other comparable fasteners, located in the same way as in the intended installations.

11.1.1 If air flow through the test specimen is such that the specified pressure cannot be maintained (for example, flow in excess of blower equipment capacity), then the cracks and joints through which air leakage is occurring shall be sealed using tape or other means that will effectively stop the leakage of air. The means to stop air leakage shall not restrict any relative movement between specimen components. As an alternative, cover both sides of the entire specimen and mounting panel with a single thickness of polyethylene film no thicker than 0.050 mm (0.002 in.). The technique of application is important to ensure that the maximum load is transferred to the specimen and that the membrane does not prevent movement or failure of the specimen. Apply the film loosely with extra folds of material at each comer and at all offsets and recesses. When the load is applied, there shall be no fillet caused by tightness of plastic film.

11.2 *General Loading Sequence*—The loading procedure consists of applying the cyclic test load or the design wind load, the specified pressure cycles and then applying the maximum test load.

11.3 *Procedure A, Life cycle load*:

11.3.1 Check the specimen for proper adjustment. Open, close, and lock each ventilator, sash, or door five times after adjustments and prior to testing.

11.3.2 Install any required deflection-measuring devices at their specified locations.

11.3.3 Apply one half of the positive cyclic test load for 3 s. Release the pressure difference across the specimen and, after a recovery period to allow stabilization of the test specimen, record initial readings. The recovery period for stabilization shall not be less than 1 min nor more than 5 min at zero load.

11.3.4 Apply the full positive cyclic test load for 3 s, and record pertinent readings.

11.3.5 Reduce the pressure difference to zero and, after a recovery period to allow stabilization of the test specimen, record permanent deformation. The recovery period for stabilization shall not be less than 1 min nor more than 5 min at zero load.

11.3.6 Repeat for negative cyclic test loads.

11.3.7 Continue to apply cyclic test loading for Cycles 2, 3, 4, and so forth, until the specified number of cycles are applied, recording deflections and making qualitative observations in accordance with the procedures in 11.3.1-11.3.6 at the specified cycles. If no deflection readings are to be taken after a cycle then, for that cycle, the preload in 11.3.3 and the 1 to 5 min waiting period in 11.3.5 are not required.

11.3.8 If glass breakage occurs at any cycle, carefully examine the test specimen to determine the cause of the breakage. If the breakage was caused by deformation or failure of the supporting frame of the glass, by loosening or failure of any fasteners, or by damage to the glass caused by interaction between the glass and its supporting elements, record the findings and discontinue the test. If the breakage was not caused by any of these structural problems, replace the glass, reusing the original fasteners, and continue the test to completion, resuming at the cycle at which the test was stopped. If new structural elements or fasteners are used instead of the original ones, repeat the entire test.

11.4 *Procedure B, Wind event load*:

11.4.1 Check the specimen for proper adjustment. Open, close, and lock each ventilator, sash, or door five times after adjustments and prior to testing.

11.4.2 Install any required deflection-measuring devices at their specified locations.

11.4.3 Apply one half of the design wind load for 10 s. Release the pressure difference across the specimen and, after a recovery period to allow stabilization of the test specimen, record initial readings. The recovery period for stabilization shall not be less than I min nor more than 5 min at zero load.

11.4.4 Apply the full positive design wind load for 10 s, and record pertinent readings.

11.4.5 Reduce the pressure difference to zero and, after a recovery period to allow stabilization of the test specimen, record permanent deformation. The recovery period for stabilization shall not be less than 1 min nor more than 5 min at zero load.

11.4.6 Repeat for negative design wind loads.

11.4.7 Begin with first positive pressure cycle and continue cycling until loading sequence is complete. Unless otherwise specified, the duration of each air pressure cycle shall not be less than 1 s and not more than 5 s and the dwell time between successive cycles shall be no more than 1 s.

11.4.8 If glass breakage occurs at any cycle, carefully examine the test specimen to determine the cause of the breakage. If the breakage was caused by deformation or failure of the supporting frame of the glass, by loosening or failure of any fasteners, or by damage to the glass caused by interaction between the glass and its supporting elements, record the findings and discontinue the test. If the breakage was not caused by any of these structural problems, and the glass has no post-breakage strength, replace the glass, reusing the original fasteners, and continue the test to completion, resuming at the cycle at which the test was stopped. If new structural elements or fasteners are used instead of the original ones, repeat the entire test.

11.4.9 If the specifier allows glass breakage during loading, and the glass has post-breakage strength, continue the test until the cycles are complete, or until the test specimen cannot carry the applied loads.

11.5 *Maximum Test Load*:

11.5.1 Apply one half of the positive maximum test load and hold for 10 s. Release the pressure difference across the specimen and, after a recovery period to allow stabilization of the test specimen, record initial readings. The recovery period for stabilization shall not be less than 1 min nor more than 5 min at zero load.

11.5.2 Apply the full maximum test load and maintain this load for a period of 10 s, unless otherwise specified. Record pertinent readings.

11.5.3 Reduce the pressure difference to zero and, after a recovery period to allow stabilization of the test specimen, record permanent deformation. The recovery period for stabilization shall not be less than 1 min nor more than 5 min at zero load.

11.5.4 If glass breakage occurs before the maximum test load is reached, carefully examine the test specimen to determine the cause of the breakage. If the breakage was caused by deformation or failure of the supporting frame of the glass, by loosening or failure of any fasteners, or by damage to the glass caused by interaction between the glass and its supporting elements, record the findings and discontinue the test. If the breakage was not caused by any of these structural problems, replace the glass with the same type and treatment, using the original fasteners and repeat the maximum test load portion of the test. If new structural elements or fasteners are used instead of the original ones, repeat the entire test.

11.5.5 Repeat the procedure for negative maximum test load.

12. Report

12.1 Report the following information:

12.1.1 Date of the test and the report.

12.1.2 Identification of the specimen (manufacturer, source of supply, dimensions, model types, materials, specimen selection, and other pertinent information).

12.1.3 Detailed drawings of the specimen showing dimensioned section profiles, sash or door dimensions and arrangement, framing location, panel arrangement, installation and spacing of anchorage, weatherstripping, locking arrangement, hardware, sealants, glazing details, test specimen sealing methods, and any other pertinent construction details. Any deviation from the drawings or any modifications made to the specimen to obtain the reported values shall be noted on the drawings and in the report.

12.1.4 For window and door components, a description of the type, quantity, and locations of the locking and operating hardware.

12.1.5 Glass thickness and type, and method of glazing. Include the statement, "No conclusions of any kind regarding the adequacy or inadequacy of the glass in the test specimen are to be drawn from the test."

12.1.6 *Test Loads*—A statement of the positive and negative cyclic test loads, Procedure A (Life cycle load) or design loads, Procedure B (Wind event load), a statement of those cycles at which deflections and qualitative observations were recorded, and the number of cycles applied. For each cycle at which information was recorded, a tabulation of the deflections at each load increment and qualitative observations regarding structural distress, permanent deformation, or other pertinent data.

12.1.7 *Maximum Test Load*—A tabulation of pressure differences exerted across the specimen and their durations during all tests and the deflections and permanent deformations at locations specified for each specimen tested.

12.1.8 Record whether or not glass breakage occurred during testing.

12.1.9 Duration of maximum test loads.

12.1.10 Record of visual observations of performance.

12.1.11 When the tests are made to check conformity of the specimen to a particular specification, an identification or description of that specification.

12.1.12 Statement that the tests were conducted in accordance with this test method, or a full description of any deviations from this test method.

12.1.13 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.

12.1.14 Author of the report.

12.1.15 Testing agency that conducted the tests and specifying authority that requested the tests, including addresses.

12.1.16 Ambient conditions, including temperature, before and during tests.

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

12.1.18 Other data, useful to the understanding of the test report, as determined by the laboratory or specifier, shall either be included within the report or appended to the report.

12.2 If several essentially identical specimens of a component are tested, report results for all specimens, properly identifying each specimen, particularly with respect to distinguishing features or differing adjustments. A separate drawing for each specimen will not be required if all differences between them are noted on the drawings provided.

13. Precision and Bias

13.1 No statement is made either on the precision or bias of this test method for measuring structural performance, since the method merely states whether or not the test specimen sustained the loads applied and otherwise conformed to the criteria specified for success.

14. Keywords

14.1 curtain wall; deflection; deformation; distress; door; load; pressure chamber; specimen; support; window

APPENDIXES

(Nonmandatory Information)

X1. TEST PROCEDURES

Until current and future research produces a method that comprehensively treats the necessary considerations in a rational manner, these test procedures will provide a test that is reasonable for most applications.

X1.1 *Life Cycle Load Procedure*—The long-term structural performance of a window, door or curtain wall assembly may be assessed by applying a uniform set of pressure cycles that varies between positive (inward acting) and negative (outward acting) pressure differentials. The magnitude(s) of the positive and negative pressure differential(s) and the number of cycles are specified by the user based upon analysis of expected loads during the life of the assembly. When a comprehensive study of the projected load history of the assembly is not possible, the following procedures may be use to establish test parameters.

X1.1.1 *Simplified Life Cycle Test*

X1.1.1.1 Adopt as the positive and negative cyclic test loads 75% of the design wind loads normally used to test the structural performance of the assembly under a one-time application of load. These design wind loads, such as those specified in ASCE 7, must include consideration of building exposure, height above ground level, internal and external pressure coefficients, gusting, and probability of occurrence. Conduct the test per Procedure A defined in 11.3.

X1.1.1.2 Unless otherwise specified, apply 100 cycles of this positive and negative cyclic test load. Deflection measurements and qualitative observations, in accordance with the applicable instructions, are to be made at Cycles 1, 10, 50, and 100.

X1.1.1.3 Test the assembly for minimum required ultimate strength using one-time applications of positive and negative maximum test loads based on design wind loads increased by a factor of safety. Unless a theoretical analysis justifies otherwise, use a factor of safety of 1.5. The maximum test loads may employ sustained or short-term loads, or both.

X1.1.2 The simplified method in X1.1.1 may not cause gross failure of the assembly under cyclic loading, but distress or damage (for example, crack onset and progression or fastener loosening) may become apparent.

X1.1.3 One hundred cycles are specified so that enough cycles are applied to initiate some potential problems resulting from cyclic loading; this number is small enough to be applied in a reasonable amount of time.

X1.1.4 By testing under cyclic conditions at 0.75 times the design load, the specifier can establish a criterion based on familiar methods. Because a safety factor is omitted, the test load will be equivalent to a load-with-safety-factor of lower intensity; one that would be expected to repeat many times during the design life of the structure. The effects of cumulative damage and repeated gusts of short duration are approximately accounted for in this simplified test method.

X1.1.5 By checking deflections and making qualitative observations at specified cycles during this phase of testing, the onset or progression of most forms of structural distress can be detected, and the observer can determine whether any degrading effects of cyclic loading would stabilize after a few cycles or continue. The probability of glass breakage is directly related to the duration of the load on the glass. To reduce the probability of glass breakage during the testing, the load application time (time to apply, maintain, and release the load) should be minimized.

X1.2 *Wind Event Load Procedure*—The structural performance of a window, door or curtain wall assembly that may be subjected to an extreme wind event may be assessed by applying a test load spectrum. The specified load spectrum should contain a series of varying positive and negative pressure cycles that represent the wind event likely to affect the building. The user may develop load spectra from wind tunnel analysis or by using methods defined in the literature. When a comprehensive study of load spectra associated with extreme wind events is not possible, the simplified methods in X1.2.1 (Hurricane Test Spectrum) or X1.2.2 (Other Extreme Wind Test Spectrum) may be used.

X1.2.1 *Hurricane Test Spectrum*

X1.2.1.1 Adopt as the positive and negative load, the design wind load normally used to test the structural performance of the assembly under a one-time application of load. These design wind loads, such as those specified in ASCE 7, must include consideration of building exposure, height above ground level, internal and external pressure coefficients, gusting, and probability of occurrence. Conduct the test per Procedure B defined in 11.4.

X1.2.1.2 Unless otherwise specified, apply the positive and negative pressure cycles as defined in Table X1.1 **(10, 11)**.

X1.2.1.3 Test the assembly for minimum required ultimate strength using one-time applications of positive and negative maximum test loads based on design wind loads increased by a factor of safety. Unless a theoretical analysis justifies otherwise, use a factor of safety of 1.5. The maximum test loads may employ sustained or short-term loads, or both.

X1.2.2 *Other Extreme Wind Test Spectrum*

X1.2.2.1 Adopt as the positive and negative load, the design wind load normally used to test the structural performance of the assembly under a one-time application of load. These design wind loads, such as those specified in ASCE 7, must include consideration of building exposure, height above ground level, internal and external pressure coefficients, gusting, and probability of occurrence. Conduct the test per Procedure B defined in 11.4.

X1.2.2.2 Unless otherwise specified, apply the positive and negative pressure cycles as defined in Table X1.2 **(12)**.

X1.2.2.3 Test the assembly for minimum required ultimate strength using one-time applications of positive and negative maximum test loads based on design wind loads increased by a factor of safety. Unless a theoretical analysis justifies otherwise, use a factor of safety of 1.5. The maximum test loads may employ sustained or short-term loads, or both.

TABLE X1.1 Hurricane Test Spectrum

Loading Sequence	Loading Direction	Air Pressure Cycles[A,B]	Number of Air Pressure Cycles
1	Positive	0.2–0.5P_{pos}	3500
2	Positive	0.0–0.6P_{pos}	300
3	Positive	0.5–0.8P_{pos}	600
4	Positive	0.3–1.0P_{pos}	100
5	Negative	0.3–1.0P_{neg}	50
6	Negative	0.5–0.8P_{neg}	1050
7	Negative	0.0–0.6P_{neg}	50
8	Negative	0.2–0.5P_{neg}	3350

[A] P_{pos} and P_{neg} are the maximum inward (positive) and maximum outward (negative) design wind loads respectively. Positive and negative design wind loads may be different in magnitude.

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

TABLE X1.2 Other Extreme Wind Test Spectrum

Loading Sequence	Loading Direction	Air Pressure Cycles[A,B]	Number of Air Pressure Cycles
1	Positive	0.0–0.6P_{pos}	12
2	Positive	0.0–0.8P_{pos}	1
Repeat positive loading sequence 1 and 2 an additional four times prior to loading sequence 3			
3	Positive	0.0–1.0P_{pos}	1
4	Negative	0.0–0.6P_{neg}	12
5	Negative	0.0–0.8P_{neg}	1
Repeat negative loading sequence 4 and 5 an additional four times prior to loading sequence 6			
6	Negative	0.0–1.0P_{neg}	1
Repeat the loading sequence 1 through 6, in the order designated, an additional seven times			

[A] P_{pos} and P_{neg} are the maximum inward (positive) and maximum outward (negative) design wind loads respectively. Positive and negative design wind loads may be different in magnitude.

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

X2. SPECIFIC APPLICATIONS

X2.1 Not all assemblies are susceptible to degradation due to the application of cyclic loads. The following are specific examples of applications for which this test method may be appropriate:

X2.1.1 Assemblies with threaded fasteners that are not self-locking and that may loosen under cyclic load. (Connections with locknuts or lock washers may be considered to be selflocking for this purpose.)

X2.1.2 Assemblies with fastenings or attachments of the type that may be prone to ratcheting action for which their performance under cyclic conditions has not been tested previously. (Examples include innovative locking devices for window wall assemblies.)

X2.1.3 Welded assemblies or assemblies with notch effects in which hairline cracks may develop under low levels of loading and propagate under repeated loads.

X2.1.4 Masonry veneers on flexible backup systems, in which cracks may develop under low levels of loading and cause deterioration under further cycling.

X2.1.5 Innovative metallic assemblies in which local yielding may occur at unusual connection details that may lead to low-cycle fatigue.

X2.1.6 New materials, such as composites, that are previously untested for cyclic conditions.

X2.1.7 Assemblies with glass products designed to remain integral following breakage.

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