TEXAS TECH UNIVERSITY
National Wind Institute
Debris Impact Testing

Designation: TTU NWI DIF Air Bladder Standard 1.1.2016

Standard Test Method for Structural Performance of Exterior Doors, Windows, Curtain Walls, and Skylights by Uniform Static Air Pressure Difference using Air Bladders

The Debris Impact Facility (DIF) is an A2LA accredited ISO/IEC 17025:2005 test laboratory in the National Wind Institute (NWI) at Texas Tech University (TTU), Lubbock, Texas

1. Scope

1.1 This test method describes the determination of the structural performance of exterior doors, windows, curtain walls, and skylights under uniform static air pressure differences, on a vertically mounted specimen and transverse loaded using air bladders. The performance determined by this test method relates to the ability of elements of the building envelope to remain unbreached during a severe windstorm event, including hurricanes or tornados.

1.2 The static tests are valid for the unit size tested or for smaller units of analogous construction. Extrapolation of test results for units larger than the test specimen are not permitted.

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

1.4 This test method describes the apparatus and the procedure to be used for applying uniformly distributed test loads to a specimen.

1.5 Using this method, specimens may be tested to determine ultimate static capacity or tested to specific static test loads.

1.5.1 *Procedure A* shall be used when a load-deflection curve is not required and a uniform load is applied. Tornado products are pass/fail and do not require deflection curves.

1.5.2 *Procedure B* shall be used when a load-deflection curve is required and a uniform load is applied.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two may result in standard non-conformance.

1.7 *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*. For specific hazard statements, see Section 8.

2. Referenced Documents

2.1 ASTM Standards:[1]

E72 Standard Test Methods of conducting Strength Tests of Panels for Building Construction

E330 Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Differences

E575 Standard Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies

E1886 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

E1996 Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes

F2247 Standard Test Method for Metal Doors Used in Blast Resistant Applications (Equivalent Static Load Method)

2.2 *Other Standards:*

ASCE/SEI 7 American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures

FEMA P320 Taking Shelter from the Storm, Building a Safe Room for your Home or Small Business

FEMA P361 Safe Rooms for Tornadoes and Hurricanes, Guidance for Community and Residential Safe Rooms

ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters

1 For referenced ASTM standards, visit the ASTM website, www.astm.org

3. Terminology

3.1 *Definitions:*

3.1.1 *Air pressure bladder* – vinyl or rubberized cloth capable of sustaining the proof pressure x a factor of 2 and capable of expanding to a depth of 152 mm (6-in.); fitted with an air inlet and outlet for connection to the air source and pressure gauge.

3.1.2 Air *pressure differential* – the specified differential in static air pressure across the specimen, creating an inward (outward) load, expressed in Pa (lbs./ft^2 or lb./in.^{2})

3.1.3 *Basic wind speed* – three-second gust speeds as defined in the latest edition of ASCE 7, or as determined by the Authority having Jurisdiction (AHJ).

3.1.4 *Bladder chamber* – cavity between the pressure wall and the installed test specimen.

3.1.5 *Building envelope components*– windows, doors, curtain walls, wall and roof assemblies.

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

3.1.6.1 *Discussion* – Use design pressure based on allowable stress design.

3.1.6.2 Discussion – The basic wind speed maps in the 2010 edition of ASCE/SEI 7 provide ultimate strength design level wind speeds. For design under service load conditions, either the ultimate design wind speeds in ASCE/SEI 7 need to be converted to nominal design wind speeds, or the resulting design pressures need to be converted to service load levels. The greatest design load, either suction or positive pressure will be used for the tested specimen.

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

3.1.8 *Metal door* – a term used in reference to doors which are built from steel sheets with an internal core composed of honeycomb cardboard, polystyrene, insulation, or cold-rolled or structural steel stiffeners. The materials may be joined together by any fabrication technique including welding, bolting, or structural adhesives.

3.1.9 *Maximum deflection* – greatest deformation of an element or component under the application of an applied force.

3.1.10 Permanent *deformation* -- the permanent displacement from the original position that remains after an applied load has been removed.

3.1.11 Proof *load* – a test load multiplied by a factor of safety

3.1.12 Stick *system* – 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.

3.1.13 S*tructural distress* –a change in condition of the specimen indicative of deterioration or incipient failure, such as cracking, local yielding, fastener loosening, or loss of adhesive.

3.1.14 T*est load* – the specified static pressure differential (positive or negative) for which the specimen is to be tested, expressed in Pa (lbs./ft^2 or lbs./in.^{2}).

3.1.15 T*est specimen* – the entire assembled unit submitted for test.

3.1.16 U*ltimate load* – the pressure (positive or negative) at which failure of the specimen occurs expressed in Pa (lbs./ft.^{2} or lbs./in.^{2}).

3.1.17 U*nit/panel system* – a curtain wall assembly composed of pre-assembled groups of individual framing members. The completed system is designed to modular, transportable, and installed as a finished assembly.

3.1.18 U*nseating pressure* – (for an out-swinging door) an applied pressure that causes the door panel to unseat from the frame so that the door reactions must be resisted by the restraining hardware that is expressed in Pa (lbs./ft.2 or lbs./in.2).

4. Test Specimen

4.1 One specimen of a type of exterior door, window, curtain wall, or skylight is required for the test.

4.1.1 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.

4.1.1.1 *Discussion* – It is recommended that the largest size or most heavily or critically loaded of a particular design, type, construction, or configuration be tested. It is also recommended that the largest lite or panel in a system or building be used at each side of a horizontal or vertical framing member. The glass in a specimen should be of the same thickness, type, and heat-treatment condition as to be used in the system or building.

4.2 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 component and framing member.

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

4.2.3 Conditions of structural support shall simulate, as accurately as possible, the structural conditions of the actual building.

4.3 A door, window, or other wall or roof component test specimen shall consist of the entire assembled unit, including frame and anchorage as supplied by the manufacturer for installation in a building.

5. Summary of Test Method

5.1 This test method consists of installing the test specimen vertically transverse in a steel test fixture and mounted as intended for normal construction. A predesigned pressure wall is inserted inside the specimen assembly.

5.2 A door specimen will have the door opened and the air bladder installed to the pressure wall using tape loosely applied or Velcro fasteners. The bladder can be folded to fit the cavity and loosely taped.

5.3 Windows, curtain walls, or skylights, specimens will be similarly installed in a steel test fixture and mounted as intended for normal construction. A pressure wall designed and constructed unique to the specimen to be tested is fitted with the appropriate size bladder and that pressure wall with bladder attached slipped into the test fixture containing the specimen.

5.4 The steel fixture with specimen and pressure wall installed is then clamped to a rigid reaction frame with two rails thereby providing a structure simply supported at the top and bottom

6. Significance and Use

6.1 This test method is an alternative method for determining structural performance under uniform static air pressure difference. This typically is intended to represent the effects of a wind load on exterior building surface elements. 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 doors, windows, curtain walls, and skylights to wind loading is also complex and depends on the complete history of load, magnitude, duration, and repetition. These factors are discussed in ASCE/SEI 7. Extreme loading from severe storms, hurricanes and tornadoes, is further discussed in FEMA P320, FEMA 361, and ICC-500.

6.2 Design wind velocities are selected for particular geographic locations and probabilities of occurrence based on data from wind velocity maps such as are provided in ASCE/SEI 7. Severe storm velocities are recorded in maps in FEMA 361 and ICC-500. These wind velocities are translated into uniform static air pressure differences and durations acting inward and outward. Complexities of wind pressures, as related to building design, wind intensity versus duration, frequency of occurrence, and winds are gusting winds which, for short periods of time from a fraction of a second to a few seconds, are capable of moving at considerably higher velocities then the sustained winds. Generally, U.S. practice for wind load testing has been to require a minimum test period of 10 seconds for design loads equal to the design wind load and proof loads equal to 1.5 times the design wind load. Thus, a safety factor is incorporated in the testing. The ICC-500 requires a safety factor of 1.5 for doors subjected to hurricanes and tested with static pressure vs cyclic pressure testing. Doors intended for tornado applications are required to have a 1.2 safety factor times the design pressure for this severe storm.

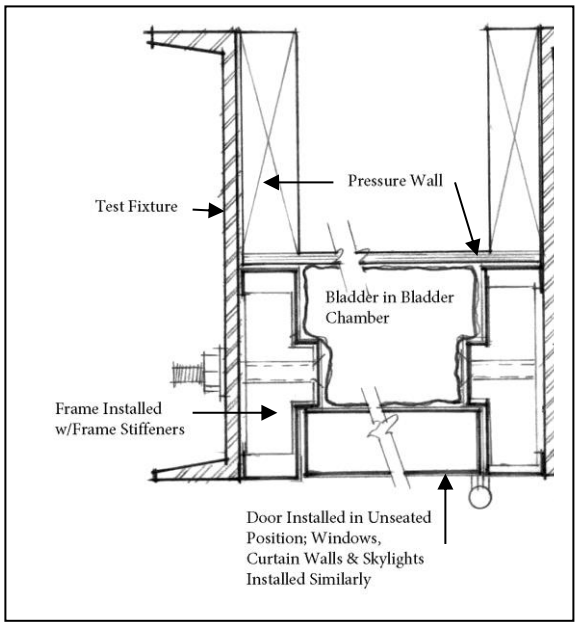

Figure 1. Horizontal Section thru Mounted Test Specimen & Bladder Chamber

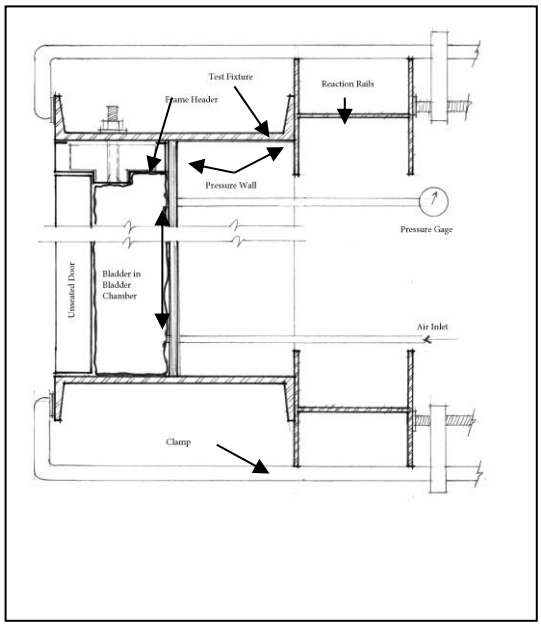

Figure 2. Vertical Section thru Mounted Specimen & Bladder Chamber

7. Apparatus

7.1 The description of the apparatus is general in nature; any equipment capable of performing the test procedure within the allowable tolerances is permitted.

7.2 *Major Components* (see Figures 1 & 2)

7.2.1 *Test Fixture* is a heavy steel channel structure that is manufactured or adjusted to the rough opening of the specimen to be tested.

7.2.2 *Pressure Wall* built of wood or steel, structural element attached to a pressure plate of wood or steel. Pressure wall constructed to fit the specimen rough opening and of sufficient depth to fit between the specimen frame and reaction frame rails. The pressure wall must be structurally engineered to withstand the specimen pressure without deflection exceeding L/480.

7.2.3 *Air Bladder* of sufficient size and depth to fill the cavity between the pressure wall and allow at least 2-in. of movement of the specimen. Air bladder shall have inlet and outlet ports for measurements of air-pressure difference inside the bladder and across the specimen.

7.2.4 *Air System*, a compressed-air supply capable of providing an essentially constant air-pressure difference for the require test period.

7.2.5 *Pressure-Measuring Apparatus*, calibrated pressure gages to measure the test pressure difference with a tolerance of +/-2.0%, Pa, (lbs./in.$^{2)}$.

7.2.6 *Deflection Measuring System*, to measure deflections within a tolerance of +/-0.25 mm (+/-0.01 in.).

7.2.6.1 For *Procedure A*, does not require any locations at which deflections are to be measured. Any devices required shall be at locations requested by the specifier or Test Director.

7.2.6.2 For *Procedure B*, maximum and end deflections of at least one of each type of principal member not directly and continuously supported by surrounding construction shall be measured. Additional locations for deflection measurements, if required, shall be stated by the specifier or Test Director.

7.2.6.3 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 within the specimen or member supports.

7.2.6.4 When product failure appears imminent, gages can be removed to prevent their damage.

7.2.6.5 When performing unseated door assemblies, a chain or other restraining device should be loosely installed to allow for door failure, but also to prevent catastrophic failure of the assembly and damage to test apparatus.

7.2.6.6 For proof load tests of unseated products, permanent deformation can be determined by the use of a straightedge-type

gage applied to the members prior to testing and again after the test load has been removed.

8. Hazards

8.1 Take proper precautions to protect the observers in the event of any failure. Considerable energy and hazard are involved at the pressures used in this test method.

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 and in accordance with the tolerance provided in Section 7, but in any event, not more than twelve months prior to testing.

10. Required Information

10.1 When specifying this test method, the following information shall be supplied by the specifying authority:
10.1.1 *Procedure A:*
10.1.1.1 The positive or negative proof loads,
10.1.1.2 The duration of test and proof loads, and
10.1.1.3 The number and location of deflection measurements required, if any.
10.1.2 Procedure *B:*
10.1.2.1 The number of incremental test loads at which deflection measurements are required,
10.1.2.2 The duration of incremental and maximum test loads, and
10.1.2.3 The number and location of required deflection measurements.

11. Installation Procedure

11.1 Transverse uniform loading of exterior doors, windows, curtain walls, and skylights using air bladders is best accomplished in a vertical orientation. The procedure for vertical transverse testing with bladders is as follows:
11.1.1 The door test subject is mounted in an appropriately sized test fixture for unseated testing.
11.1.2 An appropriately sized and engineered pressure wall is slipped into the test fixture and snugged against the subject frame.
11.1.3 The test fixture with installed door specimen and pressure wall is clamped to rails on the reaction frame, such that the wall is simply supported between the rails.
11.1.4 The door is opened and the bladder is installed without pinches or air restricting fillets.
11.1.5 Supply air lines are connected to the bladder inlet port and the pressure differential gage connected to the outlet port.
11.2 Transverse uniform loading of windows, curtain walls, and skylights using air bladders is best accomplished in a vertical orientation. The procedure for vertical transverse testing with bladders is as follows:
11.2.1 The test subject is mounted in an appropriately sized test fixture for unseated testing.
11.2.2 The air bladder is installed against the specimen with tape without pinches or air restricting fillets.
11.2.3 An appropriately sized and engineered pressure wall is slipped into the test fixture and snugged against the subject frame.
11.2.4 The test fixture with installed specimen and pressure wall is clamped to rails on the reaction frame, such that the wall is simply supported between the rails.
11.2.5 Supply air lines are connected to the bladder inlet port and the pressure differential gage connected to the outlet port.

12. Test Procedure

12.1 *Procedure A* - Use the following procedure when a load-deflection curve is not required:
12.1.1 Check the specimen for proper adjustment. For operable specimens, assure that the locks and latches are thrown and the specimen is properly installed.
12.1.2 Install any required deflection-measuring devices at their specified locations.
12.1.3 Apply a pre-load of one half of the 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, zero-out deflection-measuring devices. The recovery period for stabilization shall not be less than 1 min nor more than 5 min at zero load.
12.1.4 Unless otherwise specified, apply and maintain the test load for not less than 10 s. Record deflection readings.
12.1.5 Reduce the pressure difference to zero and, after a recovery period and 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.
12.1.6 If glass breakage occurs at any test load, 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 frame elements, record the findings and discontinue the test. If the breakage was not caused by any of the above named structural problems, replace the glass using the original fasteners and continue the test at the load where glass breakage occurred. If new structural elements or fasteners are used instead of the original ones, repeat the entire test.

12.2 *Procedure B* – Use the following procedure when the determination of a load-deflection curve is required

12.2.1 Follow 12.1.1 and 12.1.2.

12.2.2 Apply a load of one half of the specified maximum test load and hold for 10 s, unless otherwise specified. Release the pressure difference across the specimen and, after a recovery period to allow stabilization of the test specimen, zero-out deflection-measuring devices. The recovery period for stabilization shall not be less that 1 min nor more than 5 min at zero load.

12.2.3 Apply the load in the number of increments specified up to the specified maximum test load. The specifier shall determine the number of increments to be used in the test, not to be less than four approximately equal increments to maximum test load. At each increment, unless otherwise specified, apply and maintain the full test load for 10 s, unless otherwise specified, and record pertinent deflection readings.

12.2.4 Release the pressure difference 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.

12.2.5 When the behavior of the specimen under load indicates that sudden failure may occur and damage the measuring devices, the deflection measuring devices may be removed and the load continuously increased until maximum test load or the maximum load that can be sustained is reached. At this point, release the load 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.

12.2.6 If glass breakage occurs, follow the procedure described in 12.2.6.

13. Report

13.1 Report the following information:

13.1.1 Date of the test and the report.

13.1.2 Identification of the specimen (manufacturer, source of supply, dimensions, model types, material, specimen selection procedure, and other pertinent information).

13.1.3 Detailed drawings of 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.

13.1.4 For window and door components, a description of the type, quantity, and locations(s) of the locking and operating hardware.

13.1.5 Glass thickness and type, and method of glazing.

13.1.6 *Procedure A* – A tabulation of pressure differences exerted across the specimen, their durations during all tests, and the deflections and permanent deformations at locations specified for each specimen tested.

13.1.7 *Procedure B* – A tabulation of the number of test load increments, the pressure differences exerted across the specimen at these increments, their durations, the pertinent deflections at these pressure differences, and permanent deformations at locations specified for each specimen tested.

13.1.8 The duration of maximum test loads, including incremental loads for Procedure B.

13.1.9 A record of visual observations of performance.

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

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

13.1.12 A statement as to whether or not tape or any other temporary attachment methods influenced the results of the test.

13.1.13 The name of the author of the report.

13.1.14 The names and addresses of both the testing agency that conducted the tests and the requester of the tests.

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

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

13.1.17 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.

13.2 If several essentially identical specimens of a component are tested, results for all specimens shall be reported, each specimen being properly identified, 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.

14. Precision and Bias

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

15. Keywords

15.1 air pressure bladder; bladder chamber, curtain wall; deflection; deformation; door; reaction frame; skylight; specimen; test fixture; vertical transverse loading; window