



*Member of the FM Global Group*

# **Approval Standard for Windstorm Resistant Fenestrations**

**Class Number 4350**

**September 2006**

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# Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

- a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and
- b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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## 1. INTRODUCTION

### 1.1 Purpose

- 1.1.1 This standard states Approval requirements for Windstorm Resistant Fenestrations such as doors, windows, storm shutters and impact resistant film and other materials. Fenestrations are exposed to a number of natural hazards and must reject wind, hail, water infiltration and other deleterious affects caused from everyday exposure to heat, cold, building movement and sunlight. Damage to a building's outer protective layer compromises its ability to provide the functions it has been designed to deliver. Compromised openings can pave the way for serious damage to the building contents and to the building structure itself due to storms and the long term effects of water and air infiltration. Damage to the building envelope during high wind events such as hurricanes, tropical cyclones or typhoons will produce costly undesirable effects and possible business interruptions. Products that receive Approval recognition have been evaluated to provide assurance that they will perform their intended functions and maintain the integrity of the building envelop for the stated design conditions.
- 1.1.2 Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

### 1.2 Scope

- 1.2.1 This standard sets performance requirements for windstorm resistant fenestrations under simulated laboratory conditions when exposed to various natural hazards such as the cyclic nature of wind in high wind events, the impact of simulated hail and where required, the impact of windborne debris during hurricanes, tropical cyclones and typhoons.
- 1.2.2 This standard is intended to qualify all types of fenestrations including, but not limited to doors, windows, storm shutters and impact resistant film and other materials.
- 1.2.3 This standard is not intended to qualify exterior wall panels nor does it address quality of workmanship or ease of or need for maintenance.
- 1.2.4 This standard is not intended to determine the suitability for all end use conditions of a product. Conditions under which fenestration systems are used vary widely. It is the responsibility of the manufacturer and building owner to determine the suitability of the fenestration products for the intended location.

### 1.3 Basis for Requirements

- 1.3.1 The requirements of this standard are based on experience, research and testing and/or the standards of FM Approvals and other organizations. The advice of manufacturers, users, trade associations and loss control specialists was also considered.
- 1.3.2 Meeting these requirements qualifies a product as an FM Approved windstorm resistant fenestration system. Requirements prohibit component substitution without prior authorization by FM Approvals.

1.3.3 The requirements of this standard reflect tests and practices used to examine characteristics of windstorm resistant fenestrations for the purpose of obtaining Approval. These requirements are intended primarily as guides and strict conformity is not always mandatory. Windstorm resistant fenestration systems having characteristics not anticipated by this standard may be FM Approved if performance equal or superior to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, windstorm resistant fenestration systems that meet all the requirements identified in this standard may not be FM Approved if other conditions that adversely affect performance exist or if the intent of this standard is not met.

#### 1.4 Basis for Approval

Approval is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate

- the suitability of the product;
- the performance of the product as specified by the manufacturer and required by FM Approvals; and as far as practical,
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to consistently produce the product which is examined and tested, and the marking procedures used to identify the product. These examinations may be repeated as part of FM Approvals' product follow-up program.

#### 1.5 Basis for Continued Approval

Continued Approval is based upon:

- production or availability of the product as currently FM Approved;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Approval report;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior authorization by FM Approvals.

## 1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products that were FM Approved under a previous edition shall comply with the new version by the effective date or else forfeit Approval.

The effective date of this Standard is *April 1, 2007* for compliance with all requirements.

## 1.7 System of Units

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-02, "Standard for Use of the International System of Units (SI): The Modern Metric System."

## 1.8 Applicable Documents

The following are standards, test methods and practices referenced in this standard:

### American Society for Testing and Materials (ASTM) International

ASTM E 330-02, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

ASTM E 1233-00, Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Differential

ASTM E 1886-05, 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

ASTM E 1996-05, Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Windborne Debris in Hurricanes

### FM Approvals/FM Global

Approval Standard 4470, Class 1 Roof Covers (1986 with addenda)

Approval Standard 4880, "Approval Standard for Class 1 Fire Rating of Insulated Wall or Wall and Roof Ceiling Panels, Interior Finish Materials or Coatings and Exterior Wall Systems (October 2005)

Approval Standard 4881, Class 1 Exterior Wall Panels (June 2005)

Test Standard 4473, Specification Test Protocol for Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls (July 2005)

Structural Test Method for Windstorm Resistant Fenestration Systems Using Static Air Pressure Differentials (Appendix C)

Structural Test Method for Windstorm Resistant Fenestration Using Cyclic Air Pressure Differentials (Appendix D)

Test Method for Windstorm Resistant Fenestration Impacted by Windborne Debris (Appendix E)

Simulated Hail Resistance Test Using Freezer Ice Balls. (Appendix F)

FM Global Property Loss Prevention Data Sheet 1-28, Design Wind Loads (September 2005)

FM Global Property Loss Prevention Data Sheet 1-29, Roof Deck Securement and Above-Deck Roof Components (May 2006)

#### Building Codes

Florida Building Code, 2004 Edition

Testing Application Standard (TAS) 201-94, Impact Test Procedures

Testing Application Standard (TAS) 203-94, Criteria for Testing Products to Cyclic Wind Pressure Loading

### **1.9 Definitions**

For purposes of this standard, the following terms apply:

*Inward Wind Pressure* – a condition created on the windward side of a building. It is caused by wind forces and places forces toward the fenestration system. It is referred to by some entities as positive pressure.

*Outward Wind Pressure* – a condition created on the leeward side of a building. It is caused by wind forces and places forces away from the fenestration system. It is referred to by some entities as negative pressure.

*Pressure Coefficient* – a factor accounting for variations in inward and outward wind pressure on fenestration systems at different locations and elevations of the same building.

*Windborne Debris* – objects and pieces of broken materials that have become airborne projectiles due to the high winds caused by hurricanes, tropical cyclones and typhoons.

## 2. GENERAL INFORMATION

### 2.1 Product Information

- 2.1.1 The selection of a windstorm resistant fenestration system is a critical component in the overall effectiveness of a building's ability to perform the functions for which it has been designed. It is the first line of defense in combating the effects of natural hazards and protecting the contents of the building. The system selected must be durable, cost effective and aesthetically pleasing. It must be able to withstand the design conditions that will be placed on the system from internal sources for which it has been constructed as well as natural external sources such as rain, wind and hail. Selection of a system that has not demonstrated that it can withstand the design conditions over long periods of time can lead to a loss of property as well as a loss of business.
- 2.1.2 Design conditions vary widely throughout the world. The selection of a windstorm resistant fenestration system should be based, in part, on the geographical location where it will be constructed, its surroundings as well as the historical meteorological events that have occurred and are likely to occur in the future.
- 2.1.3 Anticipated design conditions at a particular location vary depending on the intensity of the event, the surrounding terrain and elevation. Components on the windward side of a building are subjected to design wind pressures [ $P^{\text{inward}}$ ] which increase as the elevation of the building increases. Pressures on the leeward side [ $P^{\text{outward}}$ ] of a building can reach twice the wind pressure normally found on the windward face of the building at the same elevation but acting in the opposite direction. Approval ratings will show both inward and outward pressures for which the system has been successfully tested. In an effort to allow for economic building construction, Approval will be granted for two ratios of inward and outward pressure. The ratio of the inward and outward pressures shall be (+)1.0 to (-)1.4 or (+)1.0 to (-)2.0
- 2.1.4 In an effort to allow for economic building construction, in addition to the wind load ratings shown above, Approval categories have been developed for the most common windstorm zones likely to be encountered. These zones, as explained elsewhere, shall be designated as Zones HM, H and NH. The zones have been established to Approve products intended for use in areas that require protection against a) hurricane force winds and missile impacts resulting from windborne debris (HM), b) hurricane force winds only (H) and c) non-hurricane areas (NH) that do not require either a) or b).
- 2.1.5 Windstorm resistant fenestration systems that meet the requirements of this Approval Standard will maintain the integrity of the building envelope for the stated design conditions. While the performance requirements contained in this Approval Standard would indicate that FM Approved windstorm resistant fenestration systems will not suffer permanent deformation or physical damage (except as otherwise noted in Paragraph 2.1.5.1) after windstorms or hail storms, the systems should be examined after each storm for damage that could adversely effect its performance in future storms.
- 2.1.5.1 In the case where a system has been FM Approved for use in areas prone to missile impacts from windborne debris, the system may sustain permanent physical damage. As such, the systems should be examined after each storm for damage that could adversely affect its performance in future storms. Repairs should be made as soon as possible to any damaged areas.
- 2.1.5.2 Because the acceptance criteria for systems impacted by windborne debris vary throughout the country, two (2) levels of both large and small missile Approval have been created. This will assist manufacturers and end users in determining if the system will meet local codes requirements.
- 2.1.6 The requirements of this standard shall be used to measure and describe the performance of windstorm resistant fenestrations to simulated wind loads and hail impact under controlled laboratory conditions.
- 2.1.7 The performance of windstorm resistant fenestration systems can be greatly affected by the quality of the workmanship, exposure to sunlight, heat, building movement and the normal aging process. These items have not been considered in developing the test methods included in this Standard.

## 2.2 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to

Materials - Director  
FM Approvals  
1151 Boston-Providence Turnpike  
PO Box 9102  
Norwood, MA 02062  
U.S.A.

The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, types, sizes, desired Approval ratings, pressure coefficients and options for the products or services being submitted for Approval consideration;
- general assembly drawings, complete set of manufacturing drawings, materials list, anticipated marking format, installation and any maintenance procedures;
- the number and location of manufacturing facilities.
- All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

## 2.3 Requirements for Samples for Examination

2.3.1 Following authorization of an Approval examination, the manufacturer shall submit samples for examination and testing based on the following.

- Maximum size opening (width and height) for which Approval is desired
- Minimum thickness of materials
- Most critical orientation, if applicable

2.3.2 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production. Any decision to use data generated using prototypes is at the discretion of FM Approvals.

## 2.4 Approval Categories and Ratings

### 2.4.1 Wind Load Ratings

2.4.1.1 All FM Approved Windstorm Resistant Fenestration systems shall have a wind load rating. The rating shall be expressed as a pair of inward and outward acting pressures ( $P^{\text{inward}}$  and  $P^{\text{outward}}$ ) using a static pressure test and a cyclic pressure test. The FM Approved rating shall be the lowest pair of pressures (inward and outward) from the static pressure test or the cyclic pressure test. The ratings shall be given in increments of 5 lbs/ft<sup>2</sup> (0.25 kPa) based on the inward pressure. The minimum rating needed for Approval shall be 30 lbs/ft<sup>2</sup> (1.45 kPa) for the inward pressure.

- 2.4.1.2 The magnitude of the pressure on the leeward side is equal or higher than the pressure on the windward side. Because of this, the outward pressure used in the test program shall be of greater magnitude than the inward pressure. The FM Approved outward pressure will be based on pressure coefficients of either (-1.4) or (-2.0) based on an applied pressure (+P) on the windward side. The positive sign is used to signify the fact that  $P^{\text{inward}}$  applies forces toward the fenestration system. The negative sign is used to signify that  $P^{\text{outward}}$  places forces away from the fenestration system (suction). Examples of possible wind load ratings are +30 lbs/ft<sup>2</sup>, -42 lbs/ft<sup>2</sup> (+1.45 kPa, -2.0 kPa) or +40 lbs/ft<sup>2</sup>, -80 lbs/ft<sup>2</sup> (+1.9 kPa, -3.8 kPa). The test sponsor shall determine the pressure coefficient used in the test program. It is recommended that the test sponsor review FM Global Property Loss Prevention Data Sheet 1-28 to determine the anticipated minimum wind load rating(s) needed.
- 2.4.1.3 As an option, the test sponsor may choose to qualify their fenestration system for windborne debris (missile impact) resistance. Two categories of impact resistance are available – large missile or small missile. The large missile test shall consist of a series of impacts using an 8 ft (2.4 m) long nominal wooden 2 x 4 weighing 9 lbs (4 kg) traveling at a speed of 50 ft/sec (15.25 m/s). This speed is approximately 35 miles/hr (56 km/hr). The small missile test shall consist of a series of impacts with each impact consisting of ten (10) steel balls with each steel ball weighing 0.07 oz (2 g) traveling at a speed of 130 ft/sec (39.6 m/s). This speed is approximately 90 miles/hr (145 km/hr).
- 2.4.1.4 The Approval designation for the large or small missile impact resistance rating shall be categorized by the suffix LM (large missile impact resistance) or SM (small impact missile resistance) to denote the level of missile impact resistance.
- 2.4.1.5 Within each category of missile impact resistance, there shall be two (2) levels of Approval. The level of Approval shall be based on the acceptance criteria used. The first level of Approval is based on the International Building Code (IBC). The second level of Approval is based on the acceptance criteria of the Florida Building Code (FBC). This distinction is being made as the acceptance criteria for the FBC is more stringent than the acceptance criteria for other parts of the country. The main difference is that the IBC acceptance criteria allows for the development of small through openings which may be acceptable in some cases whereas the FBC does not allow the missile to penetrate the building component being tested. When the second level of Approval is obtained, the connotation (FL) shall be shown after the category of missile impact resistance. For example, a windstorm resistant fenestration system that meets the large missile impact resistance using the first level (IBC) of Approval criteria would be shown as Wind Zone HM – LM (see paragraph 2.4.1.6 for Wind Zone Designations). A windstorm resistant fenestration system that meets the small missile impact resistance using the second level (FBC) of Approval criteria would be shown as Wind Zone HM – SM (FL).
- 2.4.1.6 FM Approvals recognizes three (3) different wind zone categories. These Approval categories shall be referred to as Zone HM, Zone H and Zone NH. The FM Global Property Loss Prevention Data Sheets shall be used to determine which zone applies for a particular location.
- 2.4.1.7 Zone HM shall be used to denote those fenestration systems that have been qualified for locations that are subject to both hurricane force winds and missile impact from windborne debris. The ratings shall be determined from static and cyclic pressure tests and the missile impact test(s). Such assemblies may meet the requirements of either the large missile or the small missile impact test.
- 2.4.1.8 Zone H shall be used to denote those fenestration systems that have been qualified for locations that are subject to hurricane force winds but not subject to missile impacts from windborne debris. The ratings shall be determined from static and cyclic pressure tests.
- 2.4.1.9 Zone NH shall be used to denote those fenestration systems in non-hurricane zones that are not subjected to either hurricane force winds or missile impacts from windborne debris. The ratings shall be determined from static and cyclic pressure tests.

## 2.5 Hail Resistance Ratings

- 2.5.1 All FM Approved Windstorm Resistant Fenestration systems shall have a Hail Resistance Rating. This rating simulates the expected impact of hail. The ratings available are Severe and Moderate. These values are consistent with corresponding ratings and impact energies used in Approval Standard 4470, Class 1 Roof Covers and 4881, Class 1 Exterior Wall Systems. FM Global Loss Prevention Data Sheet 1-29 shall be used to determine the impact (hail) rating needed for a particular location.
- 2.5.2 As an option, Windstorm Resistant Fenestration systems shall be permitted to be tested to simulate hail impacts resulting in a greater impact energy in order to meet other jurisdictional requirements.

## 3. GENERAL REQUIREMENTS

### 3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The Approval investigation shall define the limits of the Approval.

### 3.2 Physical or Structural Features

During the test program, fenestration systems shall be installed within a test frame that is representative of the construction for which it will be Approved.

### 3.3 Markings

- 3.3.1 The packaging for windstorm resistant fenestrations shall bear the manufacturer's name, product trade name and the Approval mark of FM Approvals (see Appendix A).
- 3.3.2 Upon completion of an installation, the manufacturer shall attach a permanent, corrosion resistant label to the product. At a minimum, the labels shall bear the manufacturer's name, product trade name, the Approval mark of FM Approvals and the applicable FM Approval ratings for wind zone, wind pressure and hail.
- 3.3.3 With the exception of the labels described above, labels or markings denoting Approval shall be applied by the manufacturer only within and on the premises of manufacturing locations that are under the FM Approvals Facilities and Procedures Audit Program.

3.3.4 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as FM Approved. The manufacturer shall not place this model or type identification on any other product unless covered by a separate agreement.

3.3.5 The Approval Mark (see Appendix B) shall be displayed visibly and permanently on the product and/or packaging as appropriate. The manufacturer shall not use this Mark on any other product unless such product is covered by a separate report.

3.3.6 All markings shall be legible and durable.

### 3.4 Manufacturer's Installation Instructions

The manufacturer shall provide the user with

- instructions for the installation, maintenance and operation of the product;
- facilities for repair of the product and supply replacement parts; and
- services to ensure proper installation, inspection, or maintenance for products of such nature that it would not be reasonable to expect the average user to be able to provide such installation, inspection, or maintenance.

### 3.5 Calibration

All examinations and tests performed in evaluation to this Standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

## 4. PERFORMANCE REQUIREMENTS

### 4.1 Simulated Wind Load Rating

#### 4.1.1 Structural Test Method for Fenestration Systems Using Static Air Pressure Differentials

##### A. Requirement

In order to qualify as an FM Approved Windstorm Resistant Fenestration System, all systems shall be tested in accordance with the Structural Test Method for Windstorm Resistant Fenestration Systems Using Static Air Pressure Differentials (Appendix C). 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 according to a specific test loading program at the rate required to maintain the test pressure difference across the specimen, and observing, measuring and recording the nature of any distress or failure of the specimen. The inward pressure level,  $P^{\text{inward}}$ , that is used during the test, shall be at the discretion of the test sponsor. The tests shall be conducted such that the ratio of the outward pressure to the inward pressure ( $P^{\text{outward}}/P^{\text{inward}}$ ) shall be either (-1.4) or (-2.0).

#### B. Test/Verification

One (1) sample shall be tested per the Structural Test Method for Windstorm Resistant Fenestration Systems Using Static Air Pressure Differentials (Appendix C). This sample is not required to be subjected to any other tests as part of a test program. Upon completion of the test, the sample shall show no signs of cracking or any other signs of failure. At the discretion of the test sponsor, the sample shall be permitted to be reused for other tests in this program or to be retested at higher pressures in order to obtain a higher wind rating.

#### 4.1.2 Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials (Procedure A)

##### A. Requirement

In order to qualify as an FM Approved Windstorm Resistant Fenestration System, all systems shall be tested in accordance with the Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials (Appendix D). Systems that are intended for use in areas subject to hurricane force winds (Zones HM and H) shall be examined in accordance with Procedure A of this test method. Systems that are intended for use in areas that are not subject to hurricane force winds (Zone NH) shall be examined in accordance with Procedure B as shown on Paragraph 4.1.3.

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 according to a specific test loading program (a total of 9000 cycles) at various pressure levels across the specimen, and observing, measuring and recording the nature of any distress or failure of the specimen. The inward pressure level,  $P^{\text{inward}}$  that is used during the test shall be at the discretion of the test sponsor. The tests shall be conducted such that the ratio of the outward pressure to the inward pressure ( $P^{\text{outward}}/P^{\text{inward}}$ ) shall be either (-1.4) or (-2.0).

##### B. Test/Verification

The fenestration system shall be tested per the Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials (Appendix D). Samples intended for use in Zone H are not required to be subjected to any other tests prior to or subsequent to this test. Samples intended for use in Zone HM shall be impacted by either the large missiles or small missiles (windborne debris) in accordance with the Test Method for Fenestration Systems Impacted by Windborne Debris (Appendix E) prior to being subjected to this test.

For systems intended for use in Zone H, one (1) sample shall be tested in accordance with Procedure A. Upon completion of the test, the sample shall show no signs of cracking or any other signs of failure.

For systems intended for use in Zone HM, see the acceptance criteria for the Test Method for Fenestration Systems Impacted by Windborne Debris (Paragraph 4.2.1). All three (3) samples that are impacted for windborne debris shall be subjected to the Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials, Procedure A. Upon completion of the Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials test, each sample shall continue to meet the acceptance criteria for the Test Method for Fenestration Systems Impacted by Windborne Debris.

FM Approved systems for use in Zone HM shall also have one (1) additional sample examined in accordance with the Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials, Procedure A. This sample shall not be impacted by simulated windborne debris. Upon completion of the test, the sample shall show no signs of cracking or any other signs of failure.

Systems intended for use in Zone NH shall be tested in accordance with the Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials, Procedure B.

#### 4.1.3 Structural Test Method for Fenestration Systems Exposed to Cyclic Air Pressure Differentials (Procedure B)

##### A. Requirement

In order to qualify as an FM Approved Windstorm Resistant Fenestration Systems, all systems shall be tested in accordance with the Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials. This test method (Procedure B) is intended only for use in areas not prone to hurricane force winds (Zone NH). Systems that are intended for use in areas that are prone to hurricane force winds (Zone HM and H) shall be examined in accordance with Procedure A as shown in Paragraph 4.1.2.

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 according to a specific test loading program (a total of 1056 cycles) at various pressure levels across the specimen, and observing, measuring and recording the nature of any distress or failure of the specimen. The inward pressure level,  $P^{\text{inward}}$ , that is used during the test shall be at the discretion of the test sponsor. The tests shall be conducted such that the ratio of the outward pressure to the inward pressure ( $P^{\text{outward}} / P^{\text{inward}}$ ) shall be either (-1.4) or (-2.0).

##### B. Test/Verification

The fenestration system shall be tested per the Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials, Procedure B (Appendix D). Samples intended for use in Zone NH are not required to be subjected to any other tests prior to or subsequent to this test.

For systems intended for use in Zone NH, one (1) sample shall be tested. Upon completion of the test, the sample shall show no signs of cracking or any other signs of failure.

## 4.2 Windborne Debris Ratings

#### 4.2.1 Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris

##### A. Requirement

In order to qualify as an FM Approved Windstorm Resistant Fenestration Systems for use in Zone HM, the system shall be tested for either Large Missile or Small Missile Impact Resistance in accordance with the Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris (Appendix E). These systems are intended for use in areas prone to hurricane force winds and where windborne debris resistance is required.

The large missile impact test consists of impacting a test specimen with a series of impacts. The large missile is an 8 ft (2.4 m) long nominal wooden 2 x 4 weighing 9 lbs (4 kg) traveling at a speed of 50 ft/sec (15.25 m/s). Each sample shall be subjected to two (2) impacts at predetermined locations.

The small missile impact test consists of impacting a test specimen with a series of impacts. Each impact of the small missile consists of ten (10) steel balls with each steel ball weighing 0.07 oz (2 g) traveling at a speed of 130 ft/sec (39.6 m/s).

Subsequent to the missile impact test, either large or small missile, the specimen shall be subjected to Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials (Procedure A). The inward pressure level,  $P^{\text{inward}}$ , that is used during the test shall be at the discretion of the test sponsor. The tests shall be conducted such that the ratio of the outward pressure to the inward pressure ( $P^{\text{outward}} / P^{\text{inward}}$ ) shall be either (-1.4) or (-2.0).

#### B. Test/Verification

Three (3) separate samples shall be tested per the Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris (Appendix E) for either Large Missile or Small Missile Impact Resistance. Following the Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris, each sample shall also be subjected to the Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials (Procedure A).

To obtain Approval for either Large Missile Impact Resistance [Wind Zone HM-LM] or Small Missile Impact Resistance [Wind Zone HM-SM], upon completion of the cyclic pressure test (which follows the impact test), all three (3) samples shall not develop any openings more than 5 in. (125 mm) in length or any through openings through which a 3 in. (75 mm) diameter solid sphere can freely pass.

To obtain Approval for either Large Missile Impact Resistance [Wind Zone HM-LM (FL)] or Small Missile Impact Resistance [Wind Zone HM-SM (FL)], upon completion of the cyclic pressure test (which follows the impact test), all three (3) samples shall have no penetration of the impact protective system by the missile (for the impact test) and during the cyclic test, shall not develop any openings more than 5 in. (125 mm) in length or  $\frac{1}{16}$  in. (1.6 mm) in width through which air can pass.

### 4.3 Hail Resistance Rating

#### 4.3.1 Simulated Hail Resistance Test Using Freezer Ice Balls

##### A. Requirement

All FM Approved Windstorm Resistant Fenestration Systems shall be subjected to a simulated hail impact test in accordance with the Simulated Hail Resistance Test Using Freezer Ice Balls (Appendix F). Two (2) ratings are available: Severe (S) and Moderate (M). The test is based on FM Approvals Test Standard 4473, Specification Test Protocol for Impact Resistance Testing of Rigid Roofing Materials Impacted with Freezer Ice Balls with some variations. The Severe Hail rating will consist of a nominal 1.75 in. (44 mm) diameter ice ball having a kinetic energy of 14.9 ft-lbs (20.3 J). The Moderate Hail rating shall consist of a nominal 1.5 in. (38 mm) diameter ice ball having a kinetic energy of 7.8 ft-lbs (10.4 J). Other impact energies that result in a greater impact energy in order to meet other jurisdictional requirements shall be permitted.

##### B. Test/Verification

One (1) test specimen shall be subjected to either the Severe or Moderate impact energy in accordance with the Simulated Hail Resistance Test Using Freezer Ice Balls (Appendix F). Each sample shall be impacted ten (10) times with six (6) of the impacts occurring within six 6 in. (150 mm) of the edges of the sample. The specimen shall be considered to meet the test criteria if there is no sign of cracking or splitting.

## 5. OPERATIONS REQUIREMENTS

A Quality Control Program is required to assure that subsequent Windstorm Resistant Fenestration Systems produced by the manufacturer shall present the same quality and reliability as the specific sample(s) examined. Design quality, conformance to design and performance are the areas of primary concern.

- Design quality is determined during the examination and tests, and is documented in the Approval Report.
- Continued conformance to this Standard is verified by the Facilities and Procedures Audit (F&PA).
- Quality of performance is determined by field performance and by periodic re-examination and testing.

### 5.1 Demonstrated Quality Control Program

5.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

#### 5.1.2 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

#### 5.1.3 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

#### 5.1.4 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents must be reported to, and authorized by, FM Approvals prior to implementation for production.
- The manufacturer shall assign an appropriate person or group to be responsible for, and require that, proposed changes to FM Approved or Listed products be reported to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals' Form 797, FM Approved Product/ Specification-Tested Revision Report or Address/Main Contact Change Report.
- Records of all revisions to all FM Approved products shall be maintained.

## **5.2 Facilities and Procedures Audit (F&PA)**

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a uniform product consistent with that which was tested and FM Approved.

5.2.2 These audits shall be conducted periodically but at least annually by FM Approvals or its representatives.

5.2.3 FM Approved products or services shall be produced or provided at or from the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the Approval Mark is not permitted at any other location without prior written authorization by FM Approvals.

## **5.3 Installation Inspections**

Field inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the discretion of FM Approvals.

## **5.4 Manufacturer's Responsibilities**

The manufacturer shall notify FM Approvals of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

## APPENDIX A

### Units of Measurement

<b>AREA</b>	$\text{in}^2$ - “square inches”; ( $\text{mm}^2$ - “square millimeters”) $\text{mm}^2 = \text{in}^2 \times 6.4516 \times 10^2$  $\text{ft}^2$ - “square feet”; ( $\text{m}^2$ - “square meters”) $\text{m}^2 = \text{ft}^2 \times 0.0929$
<b>ENERGY</b>	$\text{ft-lbs}$ - “foot pounds” - (J - “joules”) $\text{J} = \text{ft-lbs} \times 1.36$
<b>FORCE</b>	$\text{lb}_f$ - “pound-force”; (N - “Newtons”) $\text{N} = \text{lb}_f \times 4.448$
<b>LENGTH:</b>	$\text{in}$ - “inches”; ( $\text{mm}$ - “millimeters”) $\text{mm} = \text{in.} \times 25.4$  $\text{ft}$ - “feet”; ( $\text{m}$ - “meters”) $\text{m} = \text{ft} \times 0.3048$
<b>MASS</b>	$\text{lb}$ - “pounds”; ( $\text{kg}$ - “kilograms”) $\text{kg} = \text{lb} \times 0.454$
<b>PRESSURE</b>	$\text{lbs/in}^2$ - pounds per square inch”; ( $\text{kPa}$ - “kilopascals”) $\text{kPa} = \text{lbs/in}^2 \times 6.895$  $\text{bar}$ - “bar”; ( $\text{kPa}$ - “kilopascals”) $\text{bar} = \text{kPa} \times 0.01$ $\text{bar} = \text{lbs/in}^2 \times 0.06895$
<b>TEMPERATURE</b>	$^{\circ}\text{F}$ - “degrees Fahrenheit”; ( $^{\circ}\text{C}$ - “degrees Celsius”) $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.556$
<b>VELOCITY</b>	$\text{ft/sec}$ - “feet per second”; ( $\text{m/sec}$ - “meters per second”) $\text{m/sec} = \text{ft/sec} \times 0.3048$  $\text{miles/hr}$ - “miles per hour”; ( $\text{km/hr}$ - kilometers per hour”) $\text{km/hr} = \text{miles/hr} \times 1.61$
<b>VOLUME</b>	$\text{ft}^3$ - “cubic feet”; ( $\text{m}^3$ - “cubic meters”) $\text{m}^3 = \text{ft}^3 \times 0.028$

## APPENDIX B

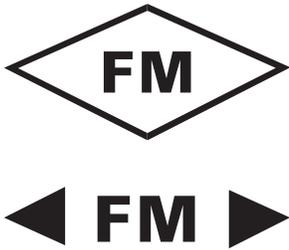
### FM Approvals Certification Marks

FM Approvals certifications marks are to be used only in conjunction with products or services that have been Approved by FM Approvals and in adherence with usage guidelines.



#### **FM APPROVED mark:**

Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



#### **Cast-On FM Approvals marks:**

Where reproduction of the FM Approved mark described above is impossible because of production restrictions, use these modified versions of the FM Approved mark. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.



#### **FM Approved Mark with “C” only:**

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



#### **FM Approved mark with “C” and “US”:**

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with US and Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.

## FM Approvals Certification Marks Usage Guidelines

All FM Approvals certification marks are the sole property of FM Approvals LLC (“FM Approvals”) and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.

FM Approvals certification marks may be used only on FM Approved products and related product packaging, in advertising material, catalogs and news releases. Use of FM Approvals certification marks on such material is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.

No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals “diamond,” etc.) and word aspects (“FM,” “Approved,” etc.). The use of any FM Approvals certification mark as a trademark is strictly prohibited.

The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say “ABC Company’s 4100 Fire Door is FM Approved”; the proper terminology is, “ABC Company’s Fire Door is FM Approved per Approval Standard 4100.”

FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.

Products or services may not be marketed under any mark or name similar to “FM Global,” “FM Approvals” or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.

When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.

A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, “Approval by FM Approvals pending” or “Approval by FM Approvals applied for.”

FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, “exceeds,” “first” or “only” may not be used to qualify any FM Approvals certification mark.

Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.

The text of the FM Approvals certification marks may not be translated into any language other than English.

FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.

## APPENDIX C

### Test Procedures

#### Structural Test Method for Windstorm Resistant Fenestration Systems Using Static Air Pressure Differentials

##### C-1 Introduction

- C-1.1 This test method is intended to evaluate the structural performance of windstorm resistant fenestration systems. It is based on ASTM E330-02 with several modifications incorporated into the procedure. The method consists of sealing a test specimen into or against one face of a test chamber and supplying air to or exhausting air from the chamber according to a specific test loading program.
- C-1.2 The inward pressure level,  $P^{\text{inward}}$ , that is used during the test shall be at the discretion of the test sponsor. The tests shall be conducted such that the ratio of the outward pressure to the inward pressure ( $P^{\text{outward}} / P^{\text{inward}}$ ) shall be either (-1.4) or (-2.0). The minimum pressure levels used in the test program shall be [ $P^{\text{outward}}$ ;  $P^{\text{inward}}$ ] -42 lbs/ft<sup>2</sup> and +30 lbs/ft<sup>2</sup> (-2.0 kPa and +1.45 kPa) when the pressure coefficient of (-1.4) is used and -60 lbs/ft<sup>2</sup> and +30 lbs/ft<sup>2</sup> (-2.9 kPa and +1.45 kPa) when the pressure coefficient of (-2.0) is used.

##### C-2 Test Apparatus and Arrangement

- C-2.1 The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted. Only the major components are described.
- C-2.2 Test Chamber – the test chamber consists of a box shaped device with one side open onto which the specimen is installed. It shall incorporate a static pressure tap to measure the pressure difference across the specimen. The tap shall be located such that it is not affected by the velocity of the air supplied to or exhausted from the chamber. The air supply opening into the chamber shall be arranged so that the air does not impinge directly on the test specimen with any significant velocity. The test specimen mounting frame shall be of sufficient size so as not to deflect under the test load in a manner that will affect the performance of the test specimen.
- C-2.3 Air System – the air system shall consist of a controllable blower, a compressed air supply, an exhaust system or a reversible controllable blower designed to provide the maximum air pressure differential across the specimen. The system shall provide an essentially constant air pressure difference for the required test period.
- C-2.4 Pressure Measuring Apparatus – the pressure measuring apparatus used to measure the test pressure difference shall be capable of having a tolerance of  $\pm 2\%$  or  $\pm 0.01$  in. ( $\pm 2.5$  kPa) of water column, whichever is greater.
- C-2.5 Deflection Measuring System – an optional deflection measuring system may be provided to measure deflections during the test. If used, such a device shall have a tolerance of  $\pm 0.01$  in. ( $\pm 0.25$  mm).

### C-3 Test Specimen

- C-3.1 The test specimen shall be of sufficient size and configuration to determine the performance of all components of the system. The conditions of structural support shall simulate, as accurately as possible, the actual structural conditions of a building.
- C-3.2 The test specimen shall be subjected to both inward and outward acting static pressures. The specimen shall incorporate the same number and type of fasteners and anchors normally used when installing the system on a building.

### C-4 Test Procedure

- C-4.1 The test specimen shall be fitted onto or against the test chamber. Air shall be supplied to or exhausted from the system until the test pressure has been achieved. The rate of air supplied or exhausted shall be such that the design pressure is reached in not less than 5 seconds and not more than 15 seconds.
- C-4.2 If the test specimen is such that the specified air pressure can not be maintained, then any cracks or joints through which air leakage is occurring shall be sealed with tape or other effective means. As an alternate, the entire specimen can be covered with a single thickness of polyethylene film no thicker than 0.002 in. (0.05 mm). The application of the film shall be such that the maximum load is transferred to the test specimen and that the membrane does not prevent movement or failure of the specimen. The film should be applied loosely with extra folds of material at the corners and all offsets or recesses.
- C-4.3 Procedure A (+1.0P, -1.4P) [where + denotes  $P^{\text{inward}}$  and - denotes  $P^{\text{outward}}$ ]
- C-4.3.1 Air shall be supplied until the loading reaches +0.5P. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at +0.5P for 60 seconds, the pressure difference shall be released. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes.
- C-4.3.2 After the recovery period, air shall be supplied until the loading reaches +1.0P. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at +1.0P for 60 seconds, the pressure difference shall be released. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes.
- C-4.3.3 After the recovery period, air shall be supplied until the loading reaches -0.7P [0.5P x (-1.4)]. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at -0.7P for 60 seconds, the pressure difference shall be released. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes.
- C-4.3.4 After the recovery period, air shall be supplied until the loading reaches -1.4P [1.0P x (-1.4)]. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at -1.4P for 60 seconds, the pressure difference shall be released and examined.
- C-4.4 Procedure B (+1.0P, -2.0P) [where + denotes  $P^{\text{inward}}$  and - denotes  $P^{\text{outward}}$ ]
- C-4.4.1 Air shall be supplied until the loading reaches +0.5P. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at +0.5P for 60 seconds, the pressure difference shall be released. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes
- C-4.4.2 After the recovery period, air shall be supplied until the loading reaches +1.0P. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at +1.0P for 60 seconds, the pressure difference shall be released. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes.

- C-4.4.3 After the recovery period, air shall be supplied until the loading reaches  $-1.0P$  [ $0.5P \times (-2.0)$ ]. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at  $-1.0P$  for 60 seconds, the pressure difference shall be released. The sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes.
- C-4.4.4 After the recovery period, air shall be supplied until the loading reaches  $-2.0P$  [ $1.0P \times (-2.0)$ ]. The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at  $-2.0P$  for 60 seconds, the pressure difference shall be released and examined.
- C-4.5 As an alternative to Procedure B, upon completion of maintaining the  $-1.4P$  pressure level shown in Paragraph C-4.3.4 (Procedure A), the sample shall be allowed a recovery period of not less than one (1) minute or more than two (2) minutes. After the recovery period, air shall be supplied until the loading reaches  $-2.0P$ . The pressure shall be held at this level for a period of 60 seconds. Upon holding the pressure at  $-2.0P$  for 60 seconds, the pressure difference shall be released and examined.
- C-4.5.1 If the specimen meets the performance requirements shown in Paragraph C-5, it shall be deemed to have qualified for a rating based on  $+1.0P$  and  $-2.0P$  provided that the sample also meets the criteria of the Standard Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials using  $-2.0P$  as the outward pressure.

## C-5 Performance Requirements

- C-5.1 Upon completion of the test and upon examination, the test specimen shall show no signs of cracking or any other signs of failure.
- C-5.2 Both an inward acting (positive) and an outward acting (negative) wind load rating shall be assigned based on the maximum pressure levels successfully maintained. The ratings shall be based on the positive pressure rating in increments of  $5 \text{ lbs/ft}^2$  ( $0.25 \text{ kPa}$ ). The pressure ratings shall be stated in multiples of  $+P$ ,  $-1.4P$  or  $+P$ ,  $-2P$  as applicable.

## APPENDIX D

### Test Procedures

#### Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials

##### D-1 Introduction

- D-1.1 This test method is intended to evaluate the structural performance of windstorm resistant fenestration systems. It is consistent with several well known test methods. The method consists of sealing a test specimen into or against one face of a test chamber and supplying air to or exhausting air from the chamber according to a specific test loading program.
- D-1.2 This test method offers two (2) different loading sequences. They shall be referred to as Procedure A and Procedure B. In each case, the test specimen size, apparatus, arrangement, pressure coefficients and basic procedure are identical. The number of cycles, pressure levels used and sequence of pressure applications varies depending on the exterior wall system's intended use.
- D-1.3 Procedure A shall be used to qualify fenestration systems that are intended to be used in areas that are prone to hurricane force winds (Zones HM and H). The test method consists of a total of 9000 pressure cycles. It is conducted in accordance with several well known test methods such as ASTM E1886-02, SBCCI STD 12-99 and FBC TAS 203-94.
- D-1.3.1 When a fenestration system is being qualified for use in areas that are also prone to the impact of windborne debris (Zone HM), the test specimen shall be subjected to the Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris (Appendix E) prior to being subjected to this procedure.
- D-1.4 Procedure B shall be used to qualify fenestration systems that are intended to be used in areas that are not prone to hurricane force winds (Zone NH). The test method consists of 1056 pressure cycles. It is conducted in accordance with ASTM E1233-00, Table X1.2.
- D-1.5 The inward pressure level,  $P^{\text{inward}}$ , that is used during the test shall be at the discretion of the test sponsor. The tests shall be conducted such that the ratio of the outward pressure to the inward pressure ( $P^{\text{outward}} / P^{\text{inward}}$ ) shall be either (-1.4) or (-2.0). The minimum pressure levels used in the test program shall be [ $P^{\text{outward}}$ ;  $P^{\text{inward}}$ ] -42 lbs/ft<sup>2</sup> and +30 lbs/ft<sup>2</sup> (-2.0 kPa and +1.45 kPa) when the pressure coefficient of (-1.4) is used and -60 lbs/ft<sup>2</sup> and +30 lbs/ft<sup>2</sup> (-2.9 kPa and +1.45 kPa) when the pressure coefficient of (-2.0) is used.

##### D-2 Test Apparatus and Arrangement

- D-2.1 The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted. Only the major components are described.
- D-2.2 Test Chamber – the test chamber consists of a box shaped device with one side open onto which the specimen is installed. It shall incorporate a pressure tap to measure the pressure difference across the specimen. The tap shall be located such that it is not affected by the velocity of the air supplied to or exhausted from the chamber. The air supply opening into the chamber shall be arranged so that the air does not impinge directly on the test specimen with any significant velocity. The test specimen mounting frame shall be of sufficient size so as not to deflect under the test load in a manner that will affect the performance of the test specimen.

- D-2.3 Air System – the air system shall consist of a controllable blower, a compressed air supply, an exhaust system or a reversible controllable blower designed to provide the maximum air pressure differential across the specimen. The system shall provide an essentially constant air pressure difference for the required test period.
- D-2.4 Pressure Measuring Apparatus – the pressure measuring apparatus used to measure the test pressure difference shall be capable of having a tolerance of  $\pm 2\%$  of its maximum rated capacity or  $\pm 2$  lbs/ft<sup>2</sup> ( $\pm 100$  kPa), whichever is less and a response time less than 50 ms. Examples of acceptable apparatus are mechanical pressure gauges and electronic pressure transducers..
- D-2.5 Pressure Recording Device – a pressure recording device shall be interconnected with the air pressure system and pressure measuring device such that the number of cycles, pressure levels and cycle times are recorded.

### D-3 Test Specimen

- D-3.1 Each test specimen shall be of sufficient size and configuration to determine the performance of all components of the system. The conditions of structural support shall simulate, as accurately as possible, the actual structural conditions of a building. The distance between structural supports incorporated into the test specimen shall be the maximum support spacing granted in the Approval.
- D-3.2 The test specimen shall be subjected to both inward and outward acting cyclic pressures as shown in Table D-1 or Table D-2. The specimen shall incorporate the same number and type of fasteners and anchors normally used when installing the system on a building.
- D-3.3 When a fenestration system is being qualified for use in areas that are also subject to the impact of windborne debris (Zone HM), three (3) test specimens shall be examined. Each test specimen shall be subjected to the Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris prior to being subjected to this procedure.
- D-3.4 When a fenestration system is being qualified for use in areas that are not subject to the impact of windborne debris, (Zone H and NH), only a single test specimen needs to be examined.

### D-4 Test Procedure

- D-4.1 Each test specimen shall be fitted onto or against the test chamber. The air pressure used shall be in accordance with either Procedure A (Zones HM and H) or Procedure B (Zone NH). Air shall be supplied to or exhausted from the system until the test pressure has been achieved. The duration of each air pressure cycle shall not be less than one (1) second or more than five (5) seconds. The dwell time between successive cycles shall be no more than one (1) second.
- D-4.2 If the test specimen is such that the specified air pressure can not be maintained, then any cracks or joints through which air leakage is occurring shall be sealed with tape or other effective means. As an alternate, the entire specimen can be covered with a single thickness of polyethylene film no thicker than 0.002 in. (0.05 mm). The application of the film shall be such that the maximum load is transferred to the test specimen and that the membrane does not prevent movement or failure of the specimen. The film should be applied loosely with extra folds of material at the corners and all offsets or recesses.
- D-4.3 Interruptions for equipment maintenance and repair shall be permitted.
- D-4.4 The test specimen shall be permitted to be removed, reversed and reinstalled in the chamber between the inward acting and outward acting pressure cycles.

## D-4.5 Procedure A

Apply the cyclic loads in accordance with Table D-1. P denotes the inward acting (positive) pressure and -P denoted the outward acting (negative) pressure. The outward pressure shall be a ratio (-1.4 or -2.0) of the inward pressure as described in D-1.5.

Table D-1

<i>Loading Sequence</i>	<i>Loading Direction</i>	<i>Air Pressure Cycles</i>	<i>No. of Air Pressure Cycles</i>	<i>Outward Pressure Values Multiplied by a Ratio of -1.4</i>	<i>Outward Pressure Values Multiplied by a Ratio of -2.0</i>
1	Inward	$0.2P^{\text{Inward}} - 0.5P^{\text{Inward}}$	3500	NA	NA
2	Inward	$0.0P^{\text{Inward}} - 0.6P^{\text{Inward}}$	300	NA	NA
3	Inward	$0.5P^{\text{Inward}} - 0.8P^{\text{Inward}}$	600	NA	NA
4	Inward	$0.3P^{\text{Inward}} - 1.0P^{\text{Inward}}$	100	NA	NA
5	Outward	$0.3P^{\text{Outward}} - 1.0P^{\text{Outward}}$	50	-0.4P/-1.4P	-0.6P/-2.0P
6	Outward	$0.5P^{\text{Outward}} - 0.8P^{\text{Outward}}$	1050	-0.7P/-1.1P	-1.0P/-1.6P
7	Outward	$0.0P^{\text{Outward}} - 0.6P^{\text{Outward}}$	50	0.0P/-0.8P	0.0P/-1.2P
8	Outward	$0.2P^{\text{Outward}} - 0.5P^{\text{Outward}}$	3350	-0.3P/-0.7P	-0.4P/-1.0P

## D-4.6 Procedure B

Apply the cyclic loads in accordance with Table D-2. P denotes the inward acting (positive) pressure and -P denoted the outward acting (negative) pressure. The outward pressure shall be a ratio (-1.4 or -2.0) of the inward pressure as described in D-1.5.

Table D-2

<i>Loading Sequence</i>	<i>Loading Direction</i>	<i>Air Pressure Cycles</i>	<i>No. of Air Pressure Cycles</i>	<i>Negative Pressure Values Multiplied by a Ratio of -1.4</i>	<i>Negative Pressure Values Multiplied by a Ratio of -2.0</i>
1	Inward	$0.0P^{\text{Inward}} - 0.6P^{\text{Inward}}$	12	NA	NA
2	Inward	$0.0P^{\text{Inward}} - 0.8P^{\text{Inward}}$	1	NA	NA
Repeat positive loading sequence 1 and 2 an additional four (4) times prior to loading sequence 3					
3	Inward	$0.0P^{\text{Inward}} - 1.0P^{\text{Inward}}$	1	NA	NA
4	Outward	$0.0P^{\text{Outward}} - 0.6P^{\text{Outward}}$	12	0.0/-0.8P	0.0P/-1.2P
5	Outward	$0.0P^{\text{Outward}} - 0.8P^{\text{Outward}}$	1	0.0P/-1.1P	0.0P/-1.6P
Repeat negative loading sequence 4 and 5 an additional four (4) times prior to loading sequence 6					
6	Outward	$0.0P^{\text{Outward}} - 1.0P^{\text{Outward}}$	1	0.0P/-1.4P	0.0P/-2.0P
Repeat the loading sequence 1 through 6, in the order designated an additional seven (7) times.					

**D-5 Performance Requirements**

- D-5.1 Both an inward acting (positive) and outward acting (negative) wind load rating shall be assigned based on the maximum pressure levels successfully maintained. The ratings shall be based on the inward acting pressure rating in increments of 5 lbs/ft<sup>2</sup> (0.25 kPa). The pressure ratings shall be stated in multiples of +P, -1.4P or +P, -2P as applicable.
- D-5.2 For windstorm resistant fenestration systems that are being qualified for use in areas that are not subject to the impact of wind debris (Wind Zones H and NH), the test specimen shall show no signs of cracking or any other signs of failure.
- D-5.3 For windstorm resistant fenestration systems that are being qualified for use in areas that are subject to the impact of wind debris (Wind Zone HM), see the Performance Requirements for the Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris.
- D-5.3.1 In addition to meeting the Performance Requirements stated in Paragraph D-5.3, a separate sample, not impacted by windborne debris, shall meet the criteria for a Wind Zone H Approval. This is to ensure that windstorm resistant fenestrations systems that are FM Approved for use in Wind Zone HM meet the cyclic wind criteria when not impacted by windborne debris.

## APPENDIX E

### Test Procedures

#### Test Method for Windstorm Resistant Fenestration Systems Impacted by Windborne Debris

##### E-1 Introduction

- E-1.1 This test method is intended to evaluate the performance of windstorm resistant fenestration systems located in geographical areas that are subject to the impact of windborne debris (Zone HM). The test method is based on several known test methods such as ASTM E1996-05, SBCCI STD 12-99 and FBC TAS 201-94 with several modifications incorporated. The modifications are basically a compilation of the existing test methods such that the resulting test method incorporates the most critical item from each test method. This should allow a manufacturer to meet all the major building codes by conducting a single set of tests.
- E-1.2 Two (2) levels of performance requirements have been provided. This is done to assist the manufacturer in gaining acceptance of the product(s) by local jurisdictions that utilize a building code that exceeds the minimum acceptance criteria of FM Approvals (most notably the Florida Building Code).
- E-1.3 Two (2) different levels of missile impact are offered.
- The large missile impact test consists of impacting a test specimen with an 8 ft (2.4 m) long wooden 2 × 4 weighing 9 lbs (4 kg) traveling at a speed of 50 ft/sec (15.25 m/s). Each sample shall be subjected to two (2) impacts at predetermined locations.
- The small missile impact test consists of impacting a test specimen with ten (10) steel balls with each steel ball weighing 0.07 oz (2 g) traveling at a speed of 130 ft/sec (39.6 m/s). Each sample shall be subjected to three (3) impacts at predetermined locations.
- E-1.4 Following the impact test, each sample shall be subjected to Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials, Procedure A (Appendix D).

##### E-2 Test Apparatus and Arrangement

- E-2.1 Large Missile Impact Device - The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted. Only the major components are described.
- E-2.1.1 The Large Missile Cannon shall be used to deliver the large missile. The cannon consists of a 4 in. (100 mm) internal diameter pipe that is approximately 12 ft (3.7) in length mounted onto a support frame. Compressed air is supplied to the cannon and monitored by a pressure gauge. A remote firing device and valve shall be used to fire the missile.
- E-2.1.2 The large missile shall consist of an 8 ft ±4 in. (2.4 m ± 100 mm) long wooden 2 × 4, (Southern Yellow Pine or Douglas Fir) weighing 9 ±0.25 lbs (4100 ± 100g). The 2 × 4 shall be free of knots and splits within 12 in. (300 mm) of the impact end. A shabot shall be permitted on the trailing edge to facilitate launching. If used, the shabot's weight shall be considered in determining the missile's total weight.
- E-2.1.3 A timing system shall be provided. It shall be capable of measuring the speed of the missile within a tolerance of 1 ft/sec (0.3 m/s).

- E-2.1.4 The test sample shall be mounted vertically within or onto a test frame. The test frame shall be of sufficient size, strength and be adequately anchored to withstand the anticipated forces of the impacting missile without resulting in noticeable damage or excessive deflection. The mounting frame shall either be integral with the cyclic air test chamber or capable of being installed on the test chamber used in the Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials.
- E-2.2 Small Missile Impact Device - The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted. Only the major components are described.
- E-2.2.1 The Small Missile Cannon shall be used to deliver the small missile. The cannon consists of a 1 in. (25 mm) internal diameter pipe that is approximately 4 ft (1.2 m) in length mounted onto a support frame. Compressed air is supplied to the cannon and monitored by a pressure gauge. A remote firing device and valve shall be used to fire the missile.
- E-2.2.2 The small missile shall consist of ten (10) steel balls fired simultaneously with each steel ball weighing 0.07 oz (2 g).
- E-2.2.3 A timing system shall be provided. It shall be capable of measuring the speed of the missile within a tolerance of 1 ft/sec (0.3 m/s). Only the speed of one (1) steel ball needs to be monitored in order to determine the projectile speed.
- E-2.2.4 The test sample shall be mounted vertically within or onto a test frame. The test frame shall be of sufficient size, strength and be adequately anchored to withstand the anticipated forces of the impacting missile without resulting in noticeable damage or excessive deflection. The mounting frame shall either be integral with the test chamber or capable of being installed on the test chamber used in the Structural Test Method for Windstorm Resistant Fenestration Systems Exposed to Cyclic Air Pressure Differentials.

### E-3 Test Specimen

The test specimen shall be of sufficient size and configuration to determine the performance of all components of the system. The conditions of structural support shall simulate, as accurately as possible, the actual structural conditions of a building. The distance between structural supports incorporated into the test specimen shall be the maximum support spacing granted in the Approval.

### E-4 Test Procedure

#### E-4.1 Large Missile Impact

- E-4.1.1 When ready for testing, the Large Missile Cannon shall be positioned such that each test specimen receives a series of two (2) impacts of the large missile. The end of the cannon shall be located approximately 14 ft (4.3 m) away from the face of the test specimen. The first missile shall impact the test specimen within a 5 in. (125 mm) radius circle located at the center of the test specimen. The second missile shall impact a corner of the test specimen within a 5 in. (125 mm) radius circle centered no more than 6 in. (150 mm) away from any supporting members.
- E-4.1.2 The large missile shall impact the surface of the test specimen with a speed of 50-52 ft/sec (15.2-15.8 m/s) which is approximately 34 miles/hour (55 km/hr).

#### E-4.2 Small Missile Impact

- E-4.2.1 When ready for testing, the Small Missile Cannon shall be positioned such that each test specimen receives a series of three (3) impacts of the small missile. The end of the cannon shall be located at an appropriate distance from the test panel such that the missiles are distributed over a maximum spread of 2 ft<sup>2</sup> (0.2 m<sup>2</sup>). The series of impacts shall be located at the center of the test specimen, along the edge of the center of the long dimension of the test specimen and at one corner of the test specimen.
- E-4.2.2 The small missile shall impact the surface of the test specimen with a speed of 130-132 ft/sec (39.6-40.2 m/s) which is approximately 90 miles/hour (146 km/hr).

### E-5 Performance Requirements

#### E-5.1 Wind Zones HM-LM and HM-SM

- E-5.1.1 To obtain Approval for either Large Missile Impact Resistance [Wind Zone HM-LM] or Small Missile Impact Resistance [Wind Zone HM-SM], upon completion of the cyclic pressure test (which follows the impact test), all three (3) samples shall not develop any openings more than 5 in. (125 mm) in length or any through openings through which a 3 in. (75 mm) diameter solid sphere can freely pass.

#### E-5.2 Wind Zones HM-LM(FL) and HM-SM(FL)

- E-5.2.1 To obtain Approval for either Large Missile Impact Resistance [Wind Zone HM-LM (FL)] or Small Missile Impact Resistance [Wind Zone HM-SM (FL)], upon completion of the cyclic pressure test (which follows the impact test), all three (3) samples shall have no penetration of the impact protective system by the missile (for the impact test) and during the cyclic test, shall not develop any openings more than 5 in. (125 mm) in length or 1/16 in. (1.6 mm) in width through which air can pass.

## APPENDIX F

### Test Procedures

#### Simulated Hail Resistance Test Using Freezer Ice Balls

##### F-1 Introduction

- F-1.1 This test method is intended to evaluate the performance of windstorm resistant fenestration systems when subjected to the impact of simulated hail. It is based on FM Approvals Approval Standard 4470, Class 1 Roof Covers, Appendix F and Test Standard 4473, Specification Test Protocol for Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls. This test is consistent with Standard 4470 in that equivalent impact energies are used but different in that it utilizes ice balls instead of steel balls.
- F-1.2 Two ratings are available – Severe (S) and Moderate (M). The Severe Hail rating will consist of a nominal 1.75 in. (44 mm) diameter ice ball having a kinetic energy of 14.9 ft-lbs (20.3 J). The Moderate Hail rating shall consist of a nominal 1.5 in. (38 mm) diameter ice ball having a kinetic energy of 7.8 ft-lbs (10.4 J). The impact speeds are 101.8 ft/sec (31.0 m/sec) and 92.5 ft/sec (28.2 m/sec), respectively.
- F-1.3 As an option, systems shall be permitted to be tested using simulated hail impacts resulting in a greater impact energy in order to meet other jurisdictional requirements.

##### F-2 Test Apparatus and Arrangement

- F-2.1 The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted. Only the major components are described.
- F-2.2 Launcher – the launcher shall be a device capable of propelling ice balls at the speeds necessary to develop the intended kinetic energy. Aiming accuracy of the launcher must be sufficient to assure that the ice balls strike the test specimen at the specified impact areas.
- F-2.3 Velocity Measuring Device – a velocity measuring device shall be used to monitor the speed of the ice balls. It shall be accurate within  $\pm 1$  ft/sec ( $\pm 0.3$  m/sec).
- F-2.4 Conditioning Box or Freezer – a conditioning box or freezer shall be capable of maintaining the conditioning requirements stated below.

##### F-3 Test Specimen

- F-3.1 The test specimen shall be the maximum size for which Approval is desired and shall be representative of the samples being considered for Approval. The test specimen shall be placed over  $\frac{1}{2}$  in. (13 mm) thick plywood if necessary.
- F-3.2 The test specimen shall be conditioned at  $40^{\circ}\text{F} \pm 5^{\circ}\text{F}$  ( $4^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ) for a period of not less than 48 hours immediately prior to the test. It shall be tested within five (5) minutes of being removed from the conditioning box.
- F-3.3 The ice balls shall be molded using distilled water by placing them in a freezer for a minimum of 48 hours at a controlled temperature of  $-7^{\circ}\text{F} \pm 7^{\circ}\text{F}$  ( $-22^{\circ}\text{C} \pm 4^{\circ}\text{C}$ ) until they are frozen solid. Acceptable ice balls shall be free of cracks and air bubbles. They shall meet the criteria listed in Table F-1 within 0 and +10% of the values shown. The ice balls shall be propelled at the sample within two (2) minutes of being removed from the freezer.

Table F-1

<i>Nominal Ice Ball Diameter in. (mm)</i>	<i>Mass in Pounds (g)</i>
1.5 (38)	0.0584 (26.5)
1.75 (45)	0.0928 (42.1)

#### F-4 Test Procedure

- F-4.1 Calibrate the ice ball launcher to meet the minimum missile speeds shown in Table F-2. These speeds are designed to impart the kinetic energies shown. The calibrated speed used during the tests shall not exceed the values shown by more than 5 ft/sec (1.5 m/sec).
- F-4.2 Maintain the temperature of the test area between 60°F and 90°F (16°C and 32°C).
- F-4.3 Remove the test specimen from its conditioning box and position it vertically to assure that the trajectory of the ice ball is perpendicular ( $90^\circ \pm 5^\circ$ ) to the test specimen and to determine the impact locations. Once the impact locations have been determined, remove a sufficient number of ice balls from the freezer.
- F-4.3.1 In order to obtain a Severe Hail rating, the test specimen shall be impacted with the 1.75 in. (45 mm) diameter ice balls as shown in Table F-2. In order to obtain a Moderate Hail rating, the test specimen shall be impacted with the 1.5 in. (38 mm) diameter ice balls as shown in Table F-2.
- F-4.4 The test specimen shall be impacted a total of ten (10) times with the appropriate ice balls in three (3) general areas. The test specimen shall be impacted four (4) times within a 12 in. (300 mm) diameter circle located at the center of the specimen. The specimen shall be impacted three (3) times along the top edge of the specimen within six (6) in. (150 mm) of the edge of the specimen. The specimen shall be impacted three (3) times along one (1) side edge of the specimen within six (6) in. (150 mm) of the edge of the specimen. Each missile shall be fired separately.

#### F-5 Performance Requirements

The specimen shall be considered to meet the test criteria if there is no sign of cracking or splitting after being impacted as described above.

Table F-2

<i>Nominal Ice Ball Diameter, in (mm)</i>	<i>Missile Impact Speed, ft/sec (m/sec)</i>	<i>Kinetic Energy, ft-lbs (J)</i>
1½	92.5 (28.2)	7.8 (10.4)
1¾	101.8 (31.0)	14.9 (20.3)

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